HYDROGEOCHEMISTRY OF SPRINGS NEAR THE EUSTIS MINE, P.Q.

HYDROGEOCHEMISTRY OF SPRINGS NEAR THE EUSTIS MINE, QUEBEC

by

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ABSTRACT

Spring and drill hole waters near the Eustis Mine in Quebec were sampled areally and periodically and analyzed for Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, SO_4^{2-}, HCO_3^{-}, Cl^{-}, H_4SiO_4, Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}. The ground waters have a $Ca\text{-}Mg\text{-}HCO_3\text{-}SO_4$ character which is due to the dissolution of carbonate and sulfide minerals. Saturation indices for 24 mineral-water reactions indicate that the water composition is controlled by carbonate and clay minerals. Buffering of the dissolved constituents in infiltrating water by the soil zone regulates the effects of precipitation composition, precipitation volume and organic contributions of constituents.

Acid mine dump waters are effectively neutralized and stripped of their Cu, Zn and Fe content by percolation through the bedrock which contains abundant carbonate minerals.

Techniques were developed which use chemical and hydrologic theory to estimate travel distance, extent of contact with oxidizing sulfides and approximate source area of a water.

RÉSUMÉ

Les eaux de sources et de trous de forage à proximité de la Eustis Mine au Québec furent échantillonnées en divers points périodiquement, et analysées pour Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, SO_4^{2-}, HCO_3^{-}, Cl^{-}, H_4SiO_4, Fe^{2+}, Mn^{2+}, Zn^{2+} et Cu^{2+}. Les eaux sous-terraines ont un charactère $Ca\text{-}Mg\text{-}HCO_3\text{-}SO_4$ qui est dû à la dissolution de mineraux carbonates et sulfurés. Les indices de saturation de 24 réactions minéral-eau indiquent que la composition de l'eau est contrôlée par les mineraux carbonates et argileux. Le tamponnâge des constituants dissouts dans des eaux infiltrantes par le zone de terre règle les effets de la composition précipitée, le volume precipité, et les contributions organique des constituants.

Les eaux acides de décharge de mine sont neutralisées effectivement et dépouillées de leur contenu de Cu, Zn et Fe par le filtrage à travers le roc qui contient d'abondants mineraux carbonates.

Des techniques furent developpées utilisant la théorie chimique et hydrologique pour évaluer la distance de parcours, l'étendue du contact avec des sulfures oxydants et le lieu d'origine approximatif d'une eau.

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CHAPTER I INTRODUCTION

GENERAL STATEMENT

Hydrogeochemical exploration is the technique of using water composition to locate ore deposits. The main advantage of this type of mineral exploration is that water has easy access to exposed and blind ore bodies, thus detectable amounts of ore, gangue or indicator elements can be dissolved. This technique is most effective in highly dissected terrain which has moderate rainfall. The technique has been used little in North America due to lack of research and to the excellent success of stream sediment and soil sampling methods. The method has great potential in Canada since Canada contains over 20% of the world's fresh water.

The objective of this thesis was to conduct an in-depth study of the chemical reactions which control the major and trace elements in natural waters near the Eustis Mine, Quebec. This study is specifically aimed at improving the probability of locating mineralized zones by developing methods of determining the source area of anomalous waters and to account for changes in metal concentrations due to seasonal effects.

The thesis is divided into three parts; comparing the water composition to underlying lithology, studying the periodical variations of major and trace elements, and relating areal anomalies of Zn^{++} and Cu^{++} to probable sources of these ions.

PREVIOUS WORK

Previous work is divided into two general categories; hydrogeochemical exploration and rock-water interaction. These two separate axes of thought are reviewed so that a comprehensive understanding of the relationship of both major and trace elements to one another in ground waters can be developed.

Hydrogeochemical exploration

The successful use of hydrogeochemical exploration depends upon the mobility of elements which are indicative of mineralization. The use of this method has been hampered by the technical difficulties in detecting extremely low concentrations of elements in solution, frequently in the parts per billion range. One of the first uses of hydrogeochemistry for exploration was by Fersman (1939), but it was not until after World War II that extensive studies were made on the application of hydrogeochemistry in prospecting for ore deposits. This increased interest is largely due to the sensitive field test method of detecting heavy metals in water described by Huff (1948). The use of this method has had varying success, depending upon the environment. The decrease of interest in recent years has been due to the successful use of other methods, which appear to be more predictable.

Hydrogeochemical exploration has been used successfully in the U.S.S.R. in many different environments. A good summary of this work is given by Goleva (1968). Boyle et al. (1971) summarize the usefulness of this technique in the Canadian

Shield. The main types of waters which have been studied are stream water, spring water and drill hole water. Recently lake water and snow have been successfully used as sampling media. This investigation is concerned with stream, spring and drill hole water, thus only these will be discussed.

Stream water

Sergeev (1946) in a stream sampling study near polymetalic deposits in the U.S.S.R. concluded what many people since him have emphasized, that the most favorable conditions for the creation of a dispersion train in stream water are active oxidation and dissected topography with a well developed drainage pattern.

Webb and Millman (1950) studied in detail the migration of heavy metals in an area of lead-zinc mineralization in Nigeria, West Africa. They found that springs with high heavy metal content flowing into a stream markedly elevated the trace metal concentration of this stream. They concluded from the results of their preliminary work that hydrogeochemical prospecting should be given a thorough trial. Kennedy (1956) studied the heavy metal content of springs and streams in the southwestern Wisconsin zinc-lead area and concluded that analysis of stream water is not as promising as analysis of springs, due to precipitation of zinc in stream water, but that stream water analysis may be helpful when spring sampling is not feasible.

Boyle et al. (1956) studied the heavy metal content in natural waters near lead-zinc-silver mineralization in the Galena Hill-Mount Haldane area in the Yukon Territory. They determined that stream water sampling was useful when zinc was the metal to

be analyzed, but that copper and lead were not detected. Boyle et al. (1966) found that most of the known lead-zinc-copper sulfide bodies in the Bathurst-Jacquet River District, New Brunswick, are indicated by higher than average amounts of heavy metals in the nearby streams. The heavy metals in the waters were primarily zinc, with very low copper and almost no lead. They also noted that further investigation was necessary to determine the source of numerous other anomalies in the area. Williams (1967) studied the copper variation over an 18 month period in New Zealand and found that the copper content of the water and sediments tends to be higher in the summer. Appreciable amounts of copper were detectable because the water was acid (pH 4.9-6.5).

Dall'Aglio and Tonani (1973) took 949 samples of stream waters in a 20,000 square kilometer area in Tuscany, Italy and analyzed them for major constituents. By use of simple and multiple correlation and regression analysis, it was possible to discriminate between sulfate from oxidizing sulfides and sulfate of marine origin. It should be emphasized that this type of study is only for reconnaissance and positive results depend upon massive amounts of sulfate being introduced into the drainage system.

The effectiveness of stream water sampling depends upon the release of fairly large amounts of heavy metals into the drainage system. More important for the persistence of an anomaly is that the water has to be fairly acid (pH less than 5) so that oxides and carbonates are prevented from precipitating

and that sorption is not effective. In order for these two prerequisites to be met, mineralization has to be rapidly oxidizing, thus it must be near the surface. In summary, stream water sampling can be an effective sampling medium only under special conditions and would not likely direct one's attention to subtle anomalies.

Spring water

Springs can be divided into two types (Boyle et al., 1956). (1) Water from runoff and near surface sources and (2) water from deep underground sources. Generally springs of type 1 contain a lower concentration of dissolved solids than springs of type 2. Boyle et al. (1955) found in the spring waters sampled in the lead-zinc-silver deposits of Galena and Keno Hill District, Yukon Territory, that zinc is the principal metal found in the waters, with practically no lead. Kennedy (1956) in his study in the Wisconsin lead-zinc district found varying amounts of zinc in spring waters and quite often the high values were associated with mineralization. He concludes that spring water is a much more effective sampling medium than stream sampling, because the metals have not yet precipitated.

DeGeoffroy et al. (1967) sampled springs in the southwest Wisconsin zinc area. They found an excellent relationship between zinc concentration in the ground water and known mineralization. They found many anomalies and in several cases these were drilled with excellent success. They also found that seasonal variation was well within their range of analytical error and concluded that seasonal variation does not affect this

spring sampling technique.

Boyle et al. (1969) studied various geochemical prospecting techniques near the silver veins of Cobalt, Ontario. They found that lead and copper were very low in the waters, whereas there were often appreciable amounts of zinc detected. The contents of the three metals in the ores were roughly similar at approximately .1 percent. Concentrations of lead, copper, as well as zinc in precipitates collected at springs and drill holes were found primarily near known mineralization. The mineralization was not, however, pinpointed by this method.

Goleva (1968) reviewed studies done by Russian scientists and found that ratios of zinc, lead and copper to one another can be a useful technique for determining the relative distance a water is from oxidizing sulfides. Zinc is more mobile than either copper or lead thus it is detected at greater distances from mineralization. Detection of copper or lead in ground waters indicates proximity to mineralization. The usefulness of these elements and ratios depends upon their relative abundance in the deposits.

In summary, the following points should be considered:

(1) An assessment of the type of springs should be made.

(2) Under ideal conditions spring sampling might pinpoint mineralization, but more commonly only a general location would be indicated.

(3) In base metal deposits and other deposits where zinc is present, even in minor quantities, it should be used as an indicator element.

(4) The presence of copper and lead will indicate the mineralized source is relatively close. Copper and lead are good indicators on a very local scale but poor on a regional scale.

Drill hole waters

Drill hole water sampling gives one a three dimensional picture of metal dispersion. In order to interpret this data one must have a thorough knowledge of the geologic structure and hydrology.

One of the first studies using drill hole waters for hydrogeochemical prospecting was done by Kennedy (1956) in the southwestern Wisconsin zinc-lead area. He devised a sampler with which he was able to sample drill holes at depth. Although he found some variation with depth, he could not differentiate a drill hole with sporadic mineralization from one cutting solid ore. He noted that zinc was largely prevented from going into solution at depths greater than 100 feet, and that this was probably due to the lack of oxygen at this depth. Boyle et al. (1969) sampled drill hole waters in the Cobalt, Ontario area and noted that mineralized areas have higher than normal contents of trace metals. He also noted that water analysis was not specific for locating mineralization. Goleva and Lushnikov (1967) studied the distribution of selenium in drill hole waters, but concluded that a detailed study needed to be made on the modes of migration of selenium and of the structure of the deposit before meaningful results could be made.

In summary, these few examples indicate that for appreciable amounts of trace metals to go into solution oxygenated waters must come in contact with the ore deposit. The structure and hydrology of the area should be well known for success in locating the source of these metals.

Range of trace metal concentrations expected in ground waters

Table 1-1 shows the ranges of trace constituents given by various authors. This table is not meant to be a complete compilation, but only an indication of the ranges expected in nature. In acid solutions the upper limit of copper and zinc can be hundreds of ppm, but under neutral conditions not nearly this amount can be retained in solution. There is quite a bit of variability between analyses taken from different sources. This is to be expected considering the variety of different deposits studied. In the areas which were analyzed for total heavy metals, zinc is considered to be the predominant metal in solution since it has much greater mobility. From Table 1-1 one sees that 80 ppm zinc is the upper limit in near neutral waters. This figure is unusual and a value of 3 ppm is more realistic as the upper limit of zinc concentration found in natural waters. The background concentrations of copper and zinc in near neutral waters near mineralization vary from 1-10 ppb for copper and 2-100 ppb for zinc (Goleva, 1968). Most of the high values are from ground waters which have not been exposed to atmospheric conditions, but once these waters emerge and travel any distance their heavy metal content rapidly decreases (Kennedy, 1956).

TABLE 1-1.

Range of zinc and copper concentrations found in ground waters.

Element	Range (ppm)	pH	Reference
Heavy Metals	8-.02	Neutral	Webb and Millman (1950)
Heavy Metals	1.3-.02	Neutral	Sergeev (1946)
Heavy Metals	130	3.1	Huff (1948)
Heavy Metals	6-.01	Neutral	Huff (1948)
Zinc	70% ≤ 3		Davletgalieva (1969)
Copper	94% ≤ .5		Davletgalieva (1969)
Zinc	2.5-.05	Neutral	DeGeoffroy et al. (1967)
Copper	21-.0001		Udolov and Parilov (1961)
Zinc	5.8-.0001		Udolov and Parilov (1961)
Zinc	1.5-.02	Neutral	Kennedy (1956)
Copper	.185-0		Vogt and Rosenqvist (1943)
Heavy Metals	.1-.001	Neutral	Atkinson (1957)
Zinc	80-.006	6.4-7.8	Boyle et al. (1956)
Zinc	7.9-.005	6.3-7.9	Boyle et al. (1969)
Copper	.354-.002	Neutral	Boyle et al. (1969)

Seasonal variation

Seasonal variation of heavy metal content in waters depends upon the climatic conditions of the area. There are three basic climatic zones which have different effects on seasonal variations. (1) Tropical-subtropical, (2) Arctic-subarctic, and (3) Temperate.

Webb and Millman (1950) and Atkinson (1957) describe the following characteristics in tropical areas. (1) Fairly low metal content during the dry season, (2) a high erratic metal content at the onset of the rainy season, and (3) decreasing metal content as the rainy season progresses, but commonly higher metal content than during the dry season. These variations are caused by the interplay between the flushing of metals which accumulated in the soil zone during the dry season and dilution by runoff water.

The seasonal variations found in permafrost areas are similar in many respects to those in tropical areas. Kravtsov (1971) and Oleinikov and Shvartsev (1968) found an accumulation of sulfate minerals developed in the oxidation zone of sulfide areas during the winter months. Shvartsev (1965) found that there was element migration up into the ice layers, and during the initial thaw period these metals were rapidly released and a large increase in metal content was observed. When the snows rapidly melt dilution plays a large part and can disguise these anomalies. After the surface runoff has ceased, the active layers continue to thaw and contribute waters to the ground water system. Boyle et al. (1955) conclude that the best period of sampling waters

is when the active layer of permafrost has thawed sufficiently to allow spring and stream waters access to veins and mineralized areas.

Temperate climates tend to show similarities to both the permafrost and tropical climates. Williams (1967) in a study done in New Zealand finds higher contents of metals in waters during the dry season when surface runoff is at a minimum. Lillich (1971) found predominantly increased zinc content in ground water and spring waters after heavy precipitation and with high ground water levels. He noted that dilution through surface runoff might blur this effect. From the foregoing observations, it is apparent that anomalies in temperate climates can have a very complex nature, and must be scrutinized very closely.

Rock-water interaction

Descriptive studies

Descriptive studies of water chemistry entail the representation of chemical data by graphical means. These diagrams are then interpreted by comparing them with waters of well known character. Graphical methods are a very effective way of initially presenting one's data, since the major characteristics of the water stand out. Most of the literature on ground water studies is of a descriptive nature. It has not been until the last fifteen years that extensive efforts have been made in describing rock-water interaction in equilibrium and kinetic terms. The best reference for a review of the various descriptive and graphical methods in use is Hem (1970). Of particular interest are Hem's

graphical methods for comparing water chemistry to bedrock lithology. Two of the most useful diagrams, which will be used in this study, are bar graphs and trilinear diagrams.

Equilibrium studies

The first extensive text to treat the matter of rock-water interaction was the text by Garrels (1960) entitled, Mineral Equilibria. The research in this field has moved so fast that it was necessary for a new publication to be presented just five years later entitled, Solutions, Minerals and Equilibria by Garrels and Christ (1965). This publication is already partially out of date and a new book by Stumm and Morgan (1970), Aquatic Chemistry, has become an important reference to low temperature geochemistry.

Feth et al. (1964) did an extensive study on the equilibria controlling the water composition in a granitic terrain. Their work was so thorough that subsequently many people have used their data in expanding the understanding of rock-water interaction. One such publication was that of Garrels and Mackenzie (1967) who back-reacted the waters to determine the proportions of the various minerals destroyed. They concluded from their study that an ideal water produced from the attack of CO_2 on granitic rock containing quartz, plagioclase, K-feldspar, biotite and minor hornblende should have the following characteristics:

(a) HCO_3^- should be the chief anion.

(b) Na^+ and Ca^+ should be the chief cations and the Na/Ca ratio should be the same as that in the plagioclase of the rock.

(c) The sum of Mg^{2+} and K^{+} should be less than 20% of the sum of the Na^{+} and Ca^{2+}, and the Mg/K ratio should be 1. Higher values of this ratio are related to higher percentages of mafic minerals and lower values to greater amounts of K-feldspar.

(d) The H_4SiO_4/Na^{+} should be approximately 2.

(e) The Na/K ratio should be 5 because of the high weathering rate of albite versus K-feldspar.

Bricker et al. (1968) in a study of a small watershed located in the Maryland Piedmont underlain by a pelitic schist found the following:

(a) The major portion of the dissolved load in the stream is derived from rock weathering.

(b) The CO_2-charged rain water reacts rapidly with the silicate minerals in the fresh rock and the soil, and produces aluminum-rich phases while the water is enriched in cations, silica and bicarbonate.

(c) Aluminum and iron are conserved in the solid phases.

(d) The reaction of water with silicates is so fast that the water remains in near equilibrium with one or more of the solid phases at all times.

(e) Most of the dissolved silica is from plagioclase, with quartz contributing practically none.

(f) The rate of removal of material as dissolved load is about five times greater than the rate of removal by mechanical means.

Paces (1969) studied the rock-water interaction in a mining district in Czechoslovakia which was composed largely of a metamorphic rock, biotite-muscovite schist, and an igneous rock, biotite granite. He found a $Ca\text{-}SO_4$-rich water from the metamorphic rock affected by mining activity and an $Na\text{-}HCO_3$ water from the granitic rocks. The longer the water is in contact with the rock, the closer it gets to saturation with respect to calcite. Paces (1972) found slow oxidation of pyrite and faster dissolution of secondary sulfate minerals. He also found a rapid adsorption of H^+ on the surface of aluminum silicates, and incongruent hydrolysis of primary aluminum silicates to solution in exchange for hydrogen ion. This results in reversible exchange of silica and probably alumina between solution and amorphous surface layers of the aluminum silicate.

Kennedy (1971) studied the silica variation in stream and soil water in the Mattole River basin of northern California which is underlain by folded graywacke, shale and conglomerate. He found that silica increased rapidly in solution, but quickly leveled off, both after a storm and in his soil leaching experiments. He found that the electrolytes (measured by specific conductance) did not increase as rapidly and did not tend to level off in concentration over time. He concluded this was due to a state of equilibrium between silica and a solid phase, whereas the electrolytes have not reached equilibrium with respect to a solid phase.

Garrels (1967) used published analyses to help explain the genesis of ground waters in contact with igneous rocks. He concluded that ground waters react with granitic rocks in a manner that would be expected theoretically for a CO_2-rich water in a closed system. The CO_2 reacts with the silicate minerals producing dissolved constituents and secondary silicates. At an HCO_3^- concentration of about 100 ppm Ca-montmorillonite starts to precipitate. Further reaction causes the precipitation of calcite at about 200 ppm HCO_3^-.

Helgeson and his colleagues have presented a series of papers which present the thermodynamic and mathematical relations necessary for the calculation and application of mass transfer to the natural rock-water system. (Helgeson, 1967, 1968, 1969, 1971 and Helgeson et al., 1969, 1970).

In a recent paper by Paces (1973) the steady state kinetics between ground water and granitic rock were discussed. He reviews the literature and supports the hypotheses advocated by others that the dissolution of albite is brought about by the surface exchange of sodium for hydrogen and then the residual anionic lattice layer collapses. He notes that this residual surface layer reaches a steady state thickness which depends upon the CO_2 pressure and the temperature. The essential points are: (1) sodium ions at the interface between fresh albite and solution are exchanged for hydrogen ions due to the difference in chemical potential between the feldspar and the solution; (2) since the hydrogen ion is negligibly small, sodium ions can diffuse from the interior of the albite crystal down the chemical potential

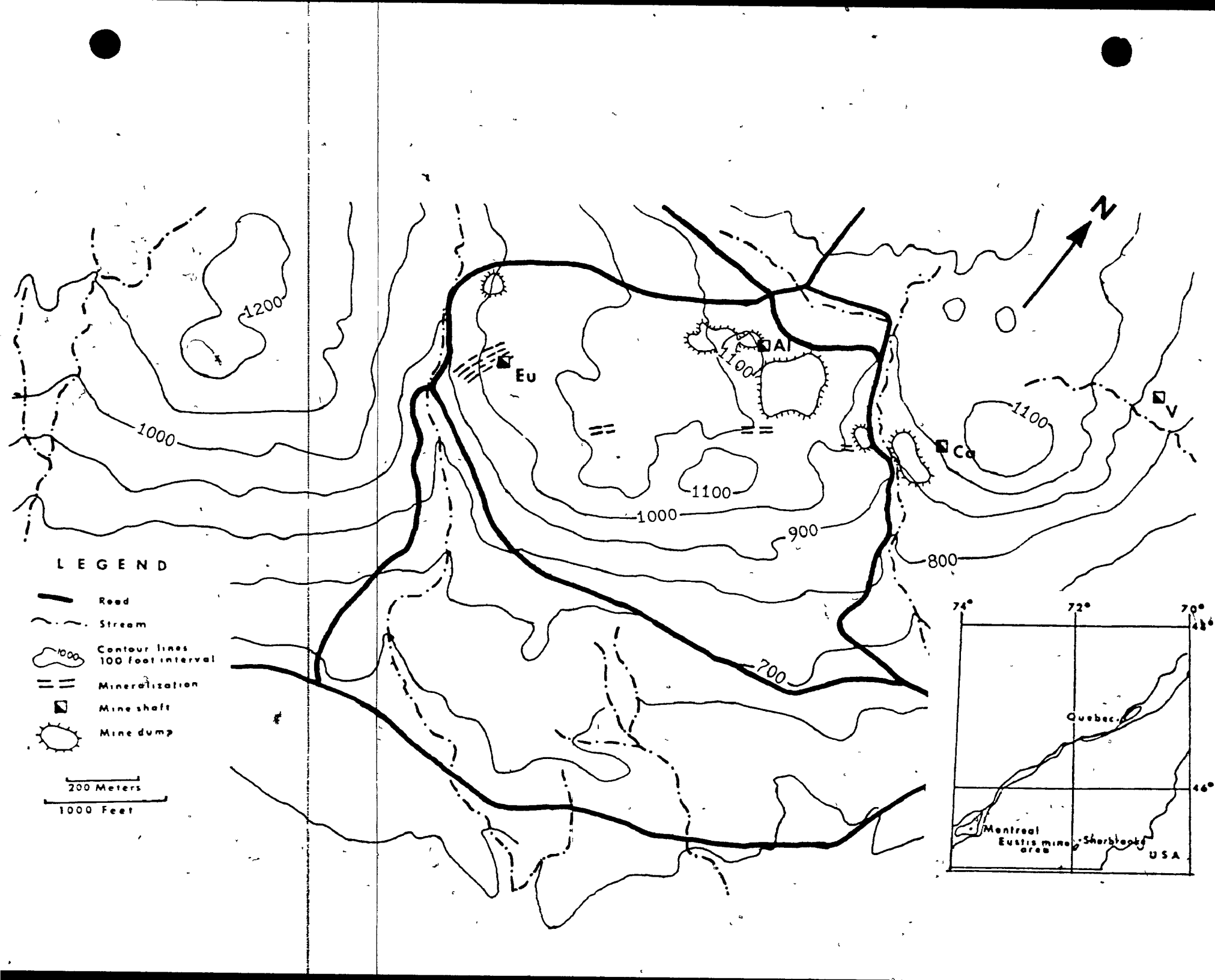
gradient and ultimately into solution; and (3) the residual structure of alumina and silica remain until the strain due to the vacancies occupied only by the small hydrogen ion or due to collision between silicon and aluminum in the residual structure and ions in the solution becomes too great. The tetrahedra are then released and readily dissolved. Rades (1973) then goes on to discuss the kinetics of dissolution and concludes that a steady state is reached and the release of sodium is constant where the concentration of alumina, silica and hydrogen ion are maintained constant by other mechanisms. This state is attained when a buffered aqueous solution is in equilibrium with a secondary aluminosilicate.

DESCRIPTION OF THESIS AREA

Location and physical features

The area described in this thesis is located in Ascot Township, ten miles southwest of the city of Sherbrooke in the Eastern Townships of Quebec. The principal reasons for this selection were the abundance of drill holes (75 or more), many of which are cased and flowing, the availability of background information on the area, and proximity to our laboratories which facilitated repeated visits to the area for periodic sampling. Figure 1-1 shows the primary area of study. Shown on this map are some of the old mines, the Eustis, Albert, Capel and Victoria mines which are designated on the map as Eu, Al, Ca and V respectively. The Eustis Mine is located by the universal transverse mercator grid system at coordinates 271240

Figure 1-1. Location map showing the primary area of study. Also shown on this map is the location of areas of old mining activity and known mineralization.
Eu = Eustis Mine Al = Albert Mine Ca = Capel Mine
V = Victoria Mine


N
1200
1000
1100
1100
1000
900
800
700
1100
Eu
Al
Co
V
LEGEND
Road
Stream
Contour lines
100 foot interval
Mineralization
Mine shaft
Mine dump
200 Meters
1000 Feet
74°
72°
70°
46°
Quebec
Montreal
Eustis mine
area
Sherbrooke
USA

meters East and 5022230 meters North. This location will serve as a reference point, to locate all other places of interest. In the following manuscript the area in general will be referred to as the Eustis Mine area.

The Eustis Mine area is located on top of a ridge known locally as the Ascot Ridge. This ridge is part of the Stoke Mountain range of the Appalachian Highlands. The Ascot Ridge extends southwest to Lake Memphremagog and northeast through the city of Sherbrooke to Lake St. Francis. The hills in the immediate area of study rise about 500 feet above the surrounding lowlands. A fairly thick overburden of glacial moraine and fluvioglacial material have been deposited in the lowlands.

The area is widely settled with most of the cleared land devoted to agriculture and cattle raising. The chief agricultural crops are hay, potatoes and corn.

General geology

The bedrock geology of the Sherbrooke area was remapped in 1962 and 1963 by P. St-Julien and R.-Y. Lamarche (1965). The following description is based on their report.

The bedrock can be categorized into two separate time units: one volcanic and one sedimentary with associated intrusive rocks. The volcanic rocks, which are called the Ascot Formation, are entirely Cambrian or partly Cambrian and partly Lower Ordovician. This formation is made up of metamorphosed intermediate and acidic lavas, minor phyllites, pyroclastic rocks and psammites, all of which are represented now as quartzofelds-

pathic schists containing chlorite or sericite or both chlorite and sericite.

The sedimentary rocks, the St. Francis Group, are of Silurian-Devonian age and rest with angular unconformity above the Ascot Formation. The rocks consist of slates interbedded with brownish sandstones, and calcareous rocks interbedded with conglomerate. Intrusive rocks of this group are represented by small masses of meta-ultramafic rocks, masses of granite and albite porphyry, dikes of diorite and dikes of lamprophyre which cut all the other rocks. There are many carbonatized zones especially in the diorite dikes and in some of the other rocks in the area.

The Ascot Formation forms two anticlinal structures; a major one, the "Sherbrooke Anticline" and a minor one to the east, the "Eustis Anticline". These anticlines are overturned to the northwest and separated from each other by a thrust fault. The St. Francis Group face to the southwest and dip steeply in the same direction. Of the above-mentioned formations only the Ascot Formation and intrusive rocks of the St. Francis Group occur within the area of water sampling in this study.

Sulfide mineralization

The sulfide mineralization in the Eustis Mine is typical of all mineralization in this area. Stevenson (1934) found that the mineralization consisted of massive base metal sulfides which were largely conformable to the enclosing schists. The primary sulfides were pyrite and up to 20% chalcopyrite. Sphalerite and galena never amount to over 1% of the ore. The strike of the

schists and ore is northeast and the dip averages 45° southeast but varies from horizontal to 80° southeast. The wall rock alteration consists of extensive carbonatization, quartz veining and formation of chlorite. Stevenson (1934) determined that there were several stages of carbonatization and carbonate minerals are pervasive throughout the country rock as well as near the mineralization. Stevenson considered the ore to have been formed by replacement of the schistose rocks by mineralization solutions from depth. However the nature of the mineralization is probably also compatible with an origin related to more recent theories of ore deposits formed by submarine volcanism. There was probably remobilization of the sulfides due to metamorphism since some of the mineralization appears to be structurally controlled.

FIELD METHODS OF SAMPLING AND ANALYSIS

Fifty-four surface and twenty drill hole waters were sampled during the summer of 1972. These were analyzed for Zn^{2+} and Cu^{2+}. Complete chemical analyses were performed on nine surface and eleven drill hole waters. The phrase "complete chemical analyses" in this manuscript will refer to

the analysis for the following constituents; Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-}, pH and the trace constituents Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}. Five additional sample sites were selected for sampling over a period of 14 months (22 samples from each site). These samples consisted of three flowing drill holes, one spring and one cement cased well. The samples are numbered in sequence with sample numbers 1 to 52 being spring or surface waters and numbers 53 to 73 being drill hole waters. The descriptions of the sampling sites are given in Appendix III. In all, 178 water samples were taken and over 1600 separate chemical analyses were performed. The raw data for these analyses are given in Appendix III.

Sampling techniques

The surface waters were sampled either by immersing a polyethelene bottle into the source or, in the case of very low flow, using a 50 ml polypropylene syringe to collect the water, then transferring it to a polyethelene bottle. In either case, both the bottles and the syringe were washed out three times with water from the sample site.

The drill holes which were sampled were either cased and flowing, cased and not flowing, or not cased and flowing. These were sampled by a variety of methods. The cased and flowing drill holes were sampled directly from the casing if there was a fair flow. The cased and not flowing holes were sampled with a pump-bottle setup. The bottle was set up

between the pump and the drill hole so that the water did not come in contact with the pump. The water was pumped long enough so that the equivalent of three volumes of water flowed through the bottle before the sample was taken. The pump, a Little Giant manufactured by Peters and Russell, Springfield, Ohio has a maximum lift of approximately 8.5 meters, thus no drill hole with the water level below this level could be sampled by this method. Where a drill hole was cased and flowing slowly a large stopper was fitted onto the casing with a length of plastic tubing inserted into the sample bottle. The water was allowed to flow through at least three times before it was sampled. The uncased and flowing holes were sampled with either a plastic syringe or with a hand pump and bottle setup.

In drill holes which had iron hydroxides precipitated around the hole, two samples were taken; a 500 ml unfiltered sample and a 100 ml sample which was filtered through a .22 micron, Millipore filter (GSWP 02500) contained in a Millipore Swinnex-25 filter holder (SX 02500) and attached to a 50 ml Millipore plastic syringe (XX1105005). This was done to remove any suspended iron hydroxides.

Initially the springs which were sampled periodically had filtered and unfiltered samples taken, but no difference was found between the two samples, and it was felt that only contamination could result from this procedure. Thus the bulk of the surface water samples were unfiltered.

Field analytical techniques

Field conductivity was measured with a Beckman RB3-SoluBridge conductivity meter, using one of two probes. The precision is estimated at less than 5%. Temperature was measured with a Fisher #15-173-24B 90C thermometer, which is graduated in .1°C intervals. In many instances pH and Eh were measured in the field using a Beckman model N pH meter and Fisher glass (Cat. #13-639-3), calomel (Cat. #13-639-51) and a Beckman thimble type platinum electrode (Cat. #39271). Buffers for pH were Fisher #B-78 and B-80. An Eh buffer, Zobel solution, was prepared according to the following formula described by Zobel (1946):

1/300 Molar $K_3Fe(CN)_6$

1/300 Molar $K_4Fe(CN)_6$

.1 Molar KCl

This solution has an Eh with reference to the standard hydrogen half cell of .429 at 25°C. At other temperatures near 25° the Eh follows this equation: .429 + .0024 (25-t); where t is temperature in degrees Celsius (Langmuir, 1971a).

Where Eh and pH were measured in the field, the electrodes were either immersed in the source with a plastic shield for protection, or the water flowed through a sealed plastic cup with the electrodes in it. Whenever the Eh was measured, the Eh buffer was checked first. If the reading was different than it was supposed to be, the platinum electrode was cleaned with a mixture of sea sand and laboratory detergent. After this was completed the correct Eh of the buffer solution was realized.

The last set of periodical samples taken, August 2, 1973, were tested in the field for alkalinity, sulfide and dissolved oxygen with a Hach dr/2 model 2506-00 water testing kit. The Hach method for alkalinity was also performed after the samples were returned to the lab, 24 hours later under refrigeration, to see if there had been a change. At this time the samples also had the usual alkalinity test performed. Table 1-2 compares the results obtained. There is an extremely close agreement among the three methods of analysis for alkalinity and the results are well within the precision of the method. It appears that the bicarbonate content has not changed during transportation and storage. This criteria is critical for the study of mineral equilibria, which involve the carbonate equilibria and/or pH, since if there is a change in the partial pressure of CO_2, then there will be a subsequent change in pH. This fact is supported by the controlling reaction; $H^+ + HCO_3^- \rightleftharpoons H_2O + CO_2$. If CO_2 is lost the pH will become more alkaline.

Samples 71V, 72V and 73V were tested for dissolved oxygen. Sample 73V was the only sample which had any detectable oxygen, 1.75 ppm, where the detection limit for this test is .25 ppm. Apparently the other two waters had used up any detectable oxygen which might have been available. None of the samples had any free sulfide within the detection limit of this field test, i.e., .1 ppm.

TABLE 1-2.

Comparison of methods for analysis of alkalinity. Samples were refrigerated from the field to the lab.

Sample	Hach Test Field (ppm)	Hach Test Lab (ppm)	Lab Method (ppm)
71	299.	305.	304.
72	378.	390.	381.
73	140.	137.	139.
51	88.	85.	86.
52	41.	39.	40.

LABORATORY ANALYTICAL TECHNIQUES

After collection the samples were taken back to the lab under refrigeration and immediately analyzed for HCO_3^- by the method given in Table 1-3. The samples were then acidified with concentrated nitric acid at the rate of 1 ml acid per 100 ml of sample (≈ pH 1).

The springs and drill holes which were sampled in June and July were analyzed for zinc and copper by an extraction technique described by Sachdev and West (1969). This method uses dithizone as the complexing agent in a solvent of ethyl propionate with subsequent analysis by atomic absorption spectroscopy. Since atomic absorption is extremely sensitive for zinc, zinc was also analyzed by direct aspiration without preconcentration. The two methods are compared for zinc in Figure 1-2. As can be seen there is considerable scatter between the two methods. The reason for this scatter lies in the fact that for the extraction analysis of zinc there was considerable machine noise and a very high blank. For copper there was very little noise and a low blank. It appears that this method is excellent for copper but less than satisfactory for zinc. The zinc analyses used were those obtained by direct aspiration of the samples except where the concentration of zinc was below or near the detection limit of 5 parts per billion. The results of the extraction method were used if they were not markedly above 5 ppb. Unfortunately only 100 ml of most of the waters were collected, thus the extraction method

TABLE 1-3.

Summary of analytical techniques.

Constituent	Technique	Working Range[a]	Sensitivity (ppm)[b]	Reference	Comments
Ca	AA[c]	0- 7.	.07	AMAAS[h]	.25%La solution to suppress interference.
Mg	AA	0- 0.5	.007	AMAAS	" "
Na	AA	0- 1.	.015	AMAAS	--
K	FE[d]	0- 2.	.02	AMAAS	High Na interferes. Corrected by standard additions.
Fe	AA	0- 5.	.1	AMAAS	Water filtered on site.
Mn	AA	0- 3.	.05	AMAAS	" "
Cu	AA	0- 5.	.10	AMAAS	" "
Zn	AA	0- 1.	.015	AMAAS	" "
H_4SiO_4	C[e]	0- 10.	.05	SMEWW[i]	Reduced silicate molybdate blue method.
Cl^-	C	0- 10.	.05	Iwasaki et al. (1952)	Complexation with mercuric thiocyanate.
SO_4^{2-}	T[c]	0- 50.	.1	SMEWW	Precipitation of SO_4^{2-} as $BaSO_4$.
HCO_3^-	P[g]	0-500.	1.0	SMEWW	Titration to pH 4.5 with standardized H_2SO_4.

[a]Range in which a linear calibration curve is obtained. Water samples with concentrations greater than this range had to be diluted.

[b]Based on 1% absorption for atomic absorption and colorimetry, on 1% transmittance for turbidimetry and a .05 ml burette reading for HCO_3^-.

[c]Atomic absorption spectrometry with a Perkin-Elmer model 403 unit.

[d]Flame emission spectrometry with a Perkin-Elmer model 403 unit.

[e]Colorimetric with a Bausch and Lomb Spectronic 88 Spectrophotometer.

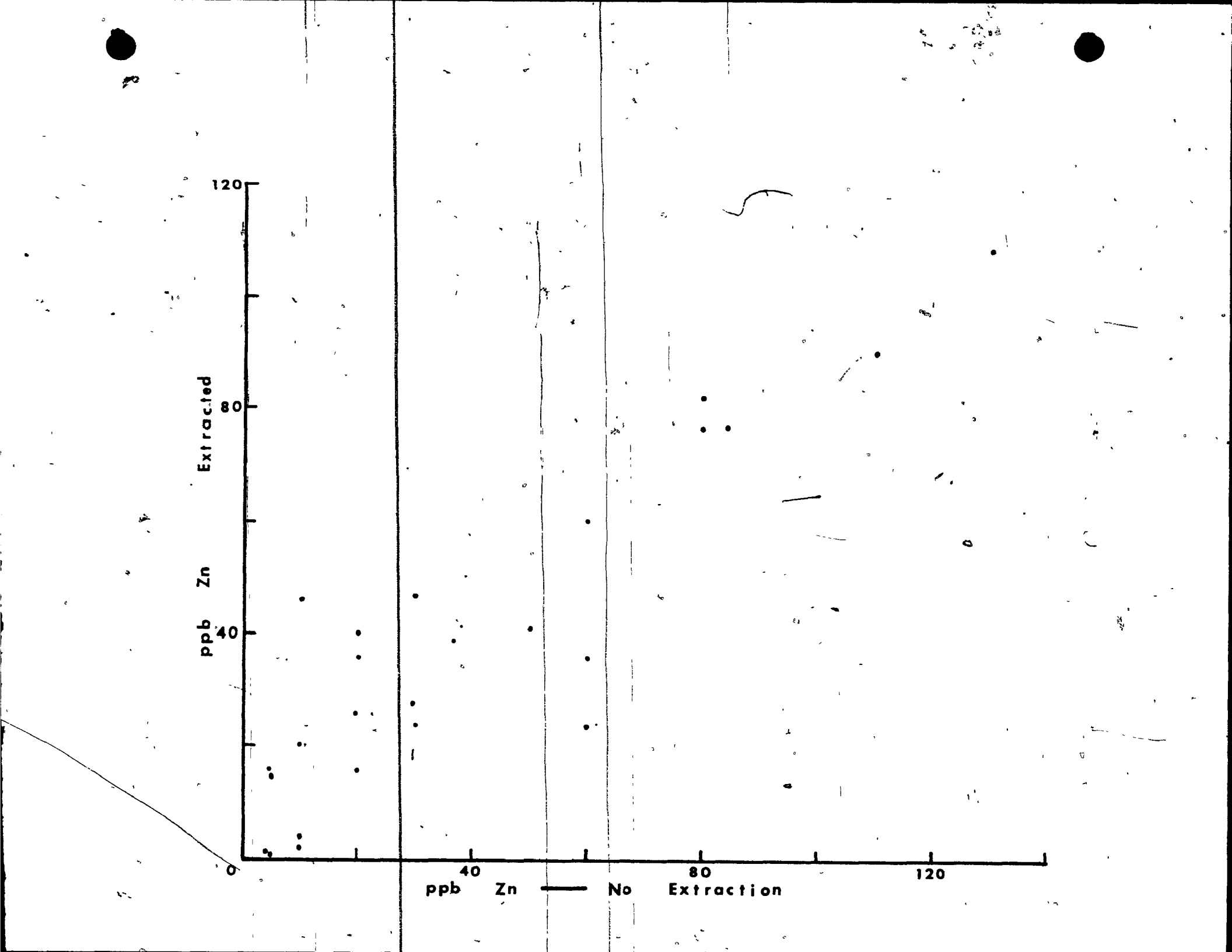
[f]Turbidimetric with a Bausch and Lomb Spectronic 88 Spectrophotometer.

[g]Potentiometric with a Beckman Zeromatic II potentiometer.

[h]Analytical Methods for Atomic Absorption Spectrophotometry (1971).

[i]Standard Methods for the Examination of Water and Wastewater (1965).

Figure 1-2. Diagram showing the relationship between atomic absorption analysis of waters for zinc by two methods: concentration of zinc by complexing with dithizone in a solvent of ethyl propionate and by direct aspiration.


120
80
40
0
ppb Zn Extracted
40
80
120
ppb Zn — No Extraction

could only be performed once. Zinc and copper in the periodical samples were analyzed by atomic absorption spectrometry without preconcentration. The other constituents were analyzed by various methods which are summarized in Table 1-3.

COMPUTER TECHNIQUES

Saturation indices

The degree of saturation with respect to 24 mineral reactions was calculated by comparing the activity product with the equilibrium constant at the temperature of the water. The activities of the constituents have been found using Debye-Huckel theory, assuming ion pairing and using a method of successive approximations to calculate ionic strength and activities (Garrels and Thompson, 1962). The calculations include provisions for accurate calculations at temperatures up to 200°C.

A computer program using Fortran was written to perform these calculations. The description and listing of this program are given in Appendix II.

Change of equilibrium constant with temperature

The equilibrium constant for the 24 mineral reactions was calculated at 25°, 60°, 100°, 150° and 200°C by the method described by Helgeson (1969) and is given in Appendix I. These values were then used to calculate the coefficients of an equation which accurately describes the equilibrium and dissociation con-

stants from 0°C to 200°C. The method of calculation that was developed to find these coefficients is an original technique which gives precise estimates which are based on known values of heat capacity for the ions and solids. The program was developed with the flexibility of determining the equilibrium constant up to 200°C in order that studies could be made on the distribution of complex ions and change in saturation indices of the various mineral-water reactions with respect to temperature changes. This would give some insight into the possibility of forming ore deposits by surface leaching of metals and reprecipitation at depth. Unfortunately there was too much other information to be processed and studies of this nature were not performed. As the temperature range in the Eustis Mine waters is only 1.8°C to 17.7°C the calculation method was only used in this range. The complete description of procedures and calculations is given in Appendix I.

Statistical calculations

All statistical calculations, such as correlation coefficients, means and standard deviations were performed with standard programs available at the McGill University computing center.

ORIGINAL CONTRIBUTIONS TO KNOWLEDGE

The following items are claimed as original contributions to knowledge.

1. Determination of the reactions which contribute and control the various chemical constituents in the ground water in the Eustis Mine area.
2. Demonstration that H_4SiO_4/Na^+ ratio is a useful parameter for estimating the relative depth of origin of ground waters.
3. Demonstration that analysis of ground water composition can be used to locate areas of carbonatization.
4. Demonstration that Cl^- can be contributed by the decay of vegetation when the plants become dormant.
5. Calculation of the quantity of zinc, copper and iron which has been leached from the Albert Mine dump since the mine closed and determination that most of this metal has reprecipitated in the bedrock.
6. Development of methods for estimating the travel distance, the extent of contact with oxidizing sulfides and the approximate source area of a water.
7. Development of a program that calculates the coefficients of an equation which describes the variation of the equilibrium constant of a reaction with temperature.

CHAPTER II RELATION OF WATER COMPOSITION TO LITHOLOGY

The ions whose distribution is useful for comparing water composition and rock type are: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, Cl^{-} and the species H_4SiO_4. These constituents are useful because they are the most mobile species in aqueous solutions produced by the weathering action of meteoric water on bedrock. Precipitation is another important contributor to dissolved solids in ground water. Some constituents in dilute ground water are almost wholly derived from atmospheric sources. Good correlation between bedrock and ground water can only exist where the lithological sources are the major contributors of constituents. The chemical analyses of these lithological sources, which are compared to water composition, must be representative of the total bedrock. This occurs only where the bedrock is homogeneous, which is not the case in the metamorphosed, highly folded and altered bedrock of the Eustis Mine area.

Removal and addition of constituents by chemical and biological reactions other than those directly involved in the weathering of primary bedrock may also contribute to poor correlations. Examples are the regulation of H_4SiO_4 in ground waters by secondary clay minerals and the removal of K^{+} by the metabolic processes of vegetation.

SOURCES OF THE CONSTITUENTS

Atmospheric sources

The chemical composition of precipitation in the Eustis Mine area was not determined. It is therefore necessary to use other data to estimate atmospheric contributions of chemical constituents to ground water. The chemistry of precipitation has very large daily and yearly variations. Likens et al. (1967) in a study of the central part of New Hampshire (120 miles south of the Eustis Mine area) found weekly variations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+} in bulk precipitation of over two orders of magnitude. Pearson and Fisher (1971) published a summary of the chemical composition of precipitation in the northeastern United States. Their sampling location in Canton, New York is the closest sampling point which had analyses available for three consecutive years. This data is given in Table 2-1 to illustrate the yearly variations. The sample location closest to the Eustis Mine area (40 miles), Pittsburg, New Hampshire, will be used as an estimate for this study (Table 2-1) even though it had data for only one year.

Several water samples have Cl^{-} and Na^{+} concentrations less than that in the precipitation data from Pittsburg, New Hampshire. Therefore the lowest values of Na^{+} and Cl^{-} in the Eustis Mine area waters will be used to estimate the atmospheric contributions; sample 14 for Na^{+} (.0135 millimoles per liter) and sample 51a for Cl^{-} (.0065 millimoles per liter).

The data used in this study to approximate the atmospheric contributions to ground water composition and the maximum percentage that atmospheric contributions represent of the Eustis

TABLE 2-1

Average yearly chemical composition of precipitation from Canton, New York and Pittsburg, New Hampshire (Pearson and Fisher, 1971) (ppm) and the assumed composition of the Eustis precipitation.

LOCATION	YEAR ENDING	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
Canton, N.Y.	9 - 66	.89	.14	.21	.24	.25	5.1	.35
	9 - 67	.96	.22	.35	.17	.15	5.3	.53
	9 - 68	.77	.19	.39	.15	.41	4.4	.40
Pittsburg, N.H.	8 - 66	.54	.083	.47	.135	.51	3.63	.46
Assumed composition of precipitation for this study in millimoles per liter.		.0135	.0034	.0135*	.00345	.0084	.038	.0065*
Percent of constituent in most dilute water from precipitation.		6.4	6.0	100.	75.	1.7	46.	100.
Percent of constituent in median water from precipitation.		2.1	.8	2.1	41.3	.5	13.	46.

*Values estimated from analysis of the most dilute Eustis waters.

TABLE 2-2.

Chemical composition of the Eustis Mine area waters.

RAW DATA IN MILLIMOLES PER LITER MINUS ATMOSPHERIC CONTRIBUTIONS

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
1	210872	0.585	0.704	2.155	0.212	0.034	0.0042	0.0161	0.0000	0.00008	0.00008	0.00000	0.102	7.20	0.000	11.0
6	30672	0.371	0.124	0.978	0.056	0.039	0.0012	0.0090	0.0000	0.00017	0.00008	0.00000	0.109	6.60	0.487	7.0
7	30672	0.438	0.128	1.172	0.056	0.047	0.0014	0.0104	0.0000	0.00088	0.00052	0.00000	0.138	6.60	0.444	9.0
12	30672	0.356	0.210	1.122	0.056	0.034	0.0012	0.0104	0.0000	0.00013	0.00000	0.00000	0.096	6.79	0.445	7.5
14	40672	0.199	0.054	0.500	0.036	-0.000	0.0214	0.0020	0.0000	0.00031	0.00023	0.00255	0.054	6.41	0.436	17.0
30	210872	0.271	0.141	0.614	0.103	0.043	0.0012	0.0076	0.0045	0.00022	0.00040	0.00018	0.130	7.10	0.000	16.0
41	200772	0.635	0.359	1.221	0.358	0.060	0.0070	0.0034	0.0000	0.00024	0.00076	0.00018	0.120	7.30	0.000	16.0
51	290672	0.623	0.416	1.237	0.379	0.056	0.0042	-0.0000	0.0000	0.00000	0.00046	0.00000	0.130	7.58	0.452	15.6
52	290672	0.376	0.301	0.690	0.363	0.082	0.0022	0.0065	0.0000	0.00000	0.00061	0.00000	0.141	6.80	0.507	7.5
53	30672	0.640	1.087	4.318	0.212	0.456	0.0145	0.0189	0.0000	0.00031	0.00000	0.00018	0.181	7.80	0.273	9.0
54	30672	0.638	0.778	3.024	0.264	0.069	0.0050	0.0076	0.0000	0.00031	0.00008	0.00000	0.086	7.46	0.340	9.0
55	30672	0.910	0.527	3.089	0.118	0.060	0.0022	0.0090	0.0000	0.00016	0.00008	0.00036	0.114	7.78	0.432	9.0
58	40672	0.540	0.626	2.368	0.379	0.178	0.0098	0.0076	0.0000	0.00016	0.00000	0.00036	0.157	7.33	0.359	8.0
64	180772	1.059	0.593	2.876	0.243	0.100	0.0063	0.0048	0.0322	0.00079	0.00168	0.00073	0.157	7.40	0.000	9.0
65	180772	0.780	0.198	1.565	0.233	0.065	0.0029	0.0034	0.0000	0.00047	0.00199	0.00036	0.130	7.20	0.000	9.0
66	200772	0.635	0.943	2.778	0.264	0.182	0.0306	0.0048	0.0057	0.00005	0.00008	0.00073	0.250	7.70	0.000	9.0
68	230772	0.376	0.141	0.909	0.045	0.052	0.0045	0.0118	0.0000	0.00000	0.00015	0.00073	0.120	6.60	0.000	9.0
70	210872	0.635	0.379	1.614	0.462	0.108	0.0096	0.0048	0.0555	0.00110	0.00237	0.00382	0.226	7.00	0.000	9.0
71	290672	5.001	2.596	4.974	6.239	0.243	0.0630	0.0640	0.0466	0.00047	0.04436	0.10375	0.275	6.60	0.256	7.8
72	290672	8.593	3.452	6.187	12.766	0.491	0.1347	0.0186	1.2713	0.00132	0.00719	0.11832	0.230	6.40	0.178	7.9

Mine waters are also given in Table 2-1. It should be noted for future discussion that, at most, 7% of Ca^{2+}, Mg^{2+} and HCO_3^- in ground waters come from atmospheric sources whereas substantial amounts of the other constituents may come from precipitation.

Table 2-2 gives the composition of the Eustis waters after corrections for atmospheric contributions have been made. The corrected composition should be due to weathering in the soil and bedrock.

Mineral sources

The rocks in the Eustis Mine area are largely meta-volcanics and albite porphyry metamorphosed to the greenschist facies and consist of a mixture of chlorite and sericite schists. Stevenson (1934) in describing the metamorphism and mineralization of the Eustis Mine, found that the schistose rocks contained the following minerals: muscovite, quartz, albite (5-10 mole % anorthite), chlorite, calcite, ankerite, anthophyllite, and minor epidote.

Stevenson (1934) described the main chlorite as being diabandite and this is the mineral that will be referred to in the following discussion using the composition from an analysis in Deer et al. (1962). Anthophyllite is often a common silicate in the ore gangue, but it is quite minor in the country rock (Stevenson, 1934). The composition of anthophyllite is approximated in this study as; $Mg_6FeSi_8O_{22}(OH)_2$. The stoichiometric

formula of the other silicate minerals will be used as an estimate of their chemical compositions. There is an abundance of carbonate minerals as solid masses, vein and fracture fillings, and in some instances disseminated throughout the rock (Stevenson, 1934; Holyk, 1953; St-Julien and Lamarche, 1965). The composition of these carbonates varies from an almost pure calcium carbonate to ankerite, and probably there is partial solid solution between the various end members. For simplicity the carbonate minerals in this area will be treated as end members in this study.

WEATHERING RELATIONS

Decomposition of the primary silicate minerals and formation of clay minerals

The weathering relations discussed in this section are partially based on the summary given by Loughnan (1969). The breakdown of primary silicates depends largely on the availability of hydrogen ions. The primary source of H^+ in the weathering environment is the reaction of carbon dioxide with water to form HCO_3^- and H^+. Waters with a high dissolved CO_2 content are termed aggressive waters. The small size of the hydrogen ion permits easy access into the crystal lattice, whereupon the high charge to radius ratio causes a substantial disruption of the lattice. The type of secondary product formed immediately upon breakdown is influenced largely by the structure of the parent mineral. In podzolic soils typical of this area the primary silicate minerals will break down to form kaolinite

when there is abundant precipitation and good drainage. Other minerals, primarily vermiculite, montmorillonite, illite and chlorite will form as intermediate products and may eventually alter to kaolinite. Detailed analyses of the soil in this study were not conducted, but other studies will give insight into the clay minerals which should be formed from the respective primary silicates.

Paces (1973) has summarized the literature for the weathering of albite and found that dilute waters with a high concentration of carbon dioxide react to form an amorphous aluminosilicate which slowly crystallizes to kaolinite. Reaction with less reactive, more concentrated, waters results in formation of a montmorillonite whose composition depends on the concentration of Ca^{2+}, Mg^{2+} and Na^{+} in solution. Quartz is one of the most resistant minerals to chemical attack and will not be removed except under conditions of intense leaching. Muscovite will form illite or an aluminous vermiculite as an intermediate weathering product. The amphibole, anthophyllite, will alter to form poorly crystalline clay size chlorite. Epidote will break down directly to form kaolinite. Chlorite breaks down by initially releasing its brucite layer and eventually forming vermiculite. Under leaching conditions similar to those in the Eustis Mine area (e.g., Feth et al., 1964; Bricker et al., 1968) these intermediate clay minerals will break down to form kaolinite. Due to kinetic and structural considerations these intermediate clay minerals may persist for a considerable length of time. During periods of high rainfall

and in the upper soil zone minute amounts of this kaolinite will break down to form gibbsite (Bricker et al., 1968). A drastic change in the weathering environment can lead to reversals in the weathering cycle with respect to the clay minerals (Grim, 1953). Such a change would occur between periods of infiltration due to high rainfall, and capillary movement during dry periods. The reversal in this case would be due to concentration of vadose water by evapotranspiration.

Mineral contributions of dissolved constituents to ground water

Table 2-3 gives the proportions of dissolved constituents produced by the reaction of dissolved CO_2 with the minerals found in this area. The end product for the silicate reactions is assumed in each case to be kaolinite, whereas in fact some of the other intermediate clays may persist metastably. These reactions are written so that aluminum remains in a solid phase. Also given are the proportions of constituents for the main carbonate and sulfide reactions of interest. The albite-kaolinite reaction is the only reaction which releases Na^+ into solution. The only primary silicate reactions which release H_4SiO_4 into solution are those in which the primary silicate has a Si/Al ratio greater than 1. These reactions are albite-kaolinite, diabandite-kaolinite and anthophyllite-kaolinite. Chlorite weathers much more slowly than albite and anthophyllite to produce vermiculite, releasing little H_4SiO_4 into solution. The eventual breakdown of vermiculite will be quite slow and will release only small amounts of H_4SiO_4 at any one time.

TABLE 2-3.

Proportions of dissolved constituents produced (+) or removed (-) in solution by the reaction of CO_2 with minerals as the reactions progress from left to right. The proportions are relative to 1 mole of the mineral on the left hand side of the equation.

REACTION	CONSTITUENTS	PROPORTIONS
Muscovite $\longrightarrow$ Kaolinite	$K:Si:HCO_3$	1:0:1
Albite $\longrightarrow$ Kaolinite	$Na:Si:HCO_3^-$	1:2:1
Diabandite $\longrightarrow$ Kaolinite	$Ca:Mg:Si:HCO_3^-$	.1:2.6:2.8:5.4
Anthophyllite $\longrightarrow$ Kaolinite	$Mg:Si:HCO_3$	7:8:14
Anorthite $\longrightarrow$ Kaolinite	$Ca:Si:HCO_3$	1:0:2
Epidote $\longrightarrow$ Kaolinite	$Ca:Si:HCO_3$	2:0:4
Calcite $\rightleftharpoons$ Solution	$Ca:HCO_3$	1:2
Magnesite $\rightleftharpoons$ Solution	$Mg:HCO_3$	1:2
Kaolinite $\rightleftharpoons$ Ca-Mont.	$Ca:Si:HCO_3$	-.17:-1.3:-.33
Kaolinite $\rightleftharpoons$ Mg-Mont.	$Mg:Si:HCO_3^-$	-.17:-1.3:-.33
Illite $\rightleftharpoons$ Kaolinite	$K:Si:HCO_3^-$	1:0:1
Vermiculite $\longrightarrow$ Kaolinite	$Mg:Si:HCO_3^-$	3.5:0:6.9
Pyrite $\longrightarrow$ Solution	$SO_4^{2-}:HCO_3^-$	2:-4

Anthophyllite is common only near mineralization. It initially weathers fairly rapidly forming clay chlorite, and releasing little H_4SiO_4.

Breakdown of the intermediate clay minerals to kaolinite can release significant H_4SiO_4 at certain times, and may be responsible for the rapid influx of H_4SiO_4 into rain water and snow melt as they react with the soil zone (e.g., Paces, 1972). The breakdown of muscovite is responsible for the K^+ concentration in solution derived from rock weathering. Ca^{2+} and Mg^{2+} are contributed into solution by both carbonate and silicate reactions, with the carbonate contribution far outweighing the silicate portion. These two ions are also the ones which may combine with kaolinite to form montmorillonite during periods of low rainfall.

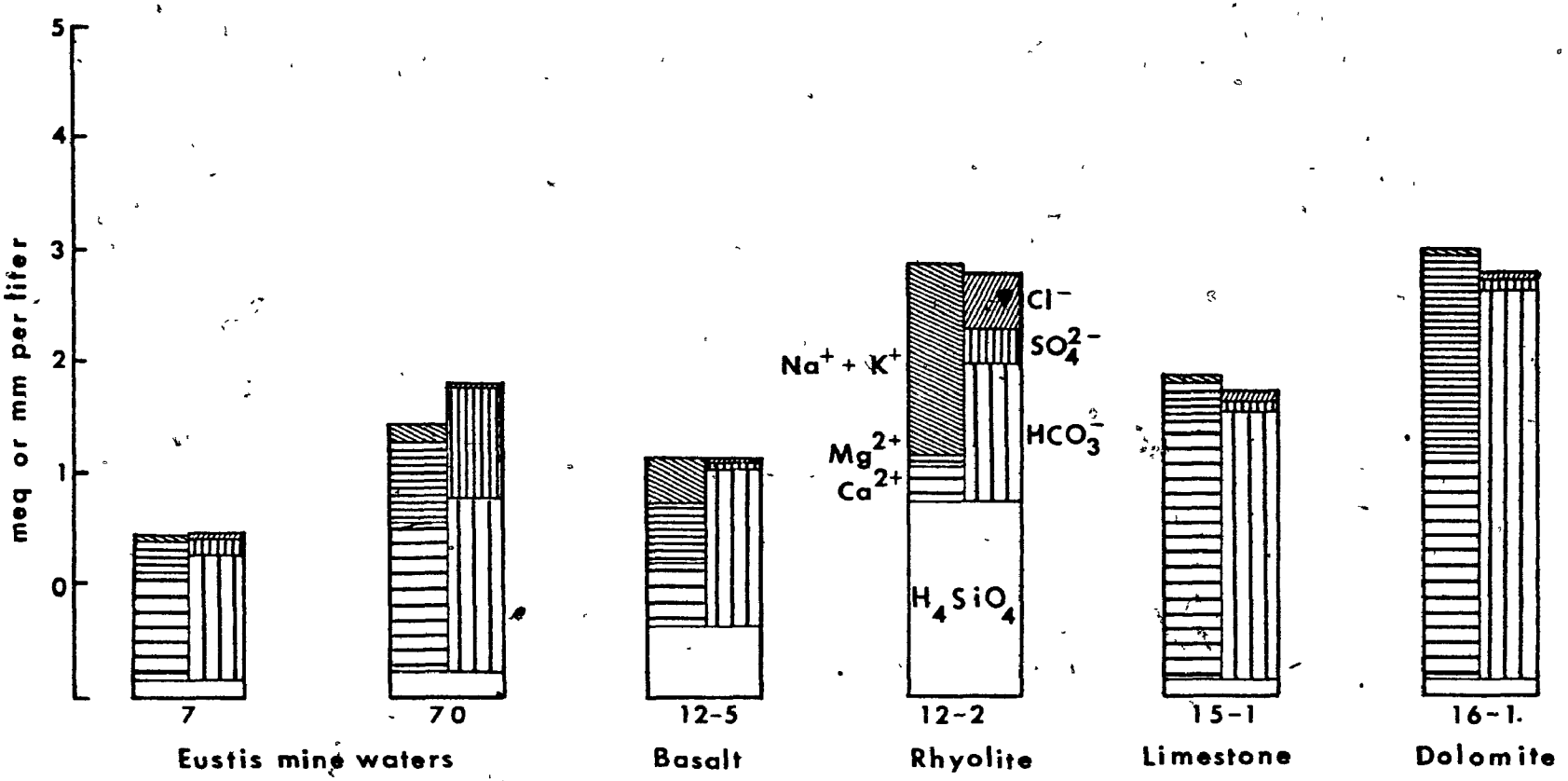
RESULTS AND INTERPRETATION OF THE CHEMICAL DATA

Chemical characteristics of the Eustis Mine waters

The bar graph is one of the most simple and effective methods for visual comparison of the gross features of water composition. This method entails the representation of each analysis as two parallel bars whose height is proportional to the total concentration of anions or cations in milliequivalents per liter. The left bar represents cations and the right bar anions. These two bars are then divided by horizontal lines to show the concentrations of the major ions.

Hem (1970) uses these diagrams to compare waters from rocks of different lithology. Figure 2-1 shows several bar

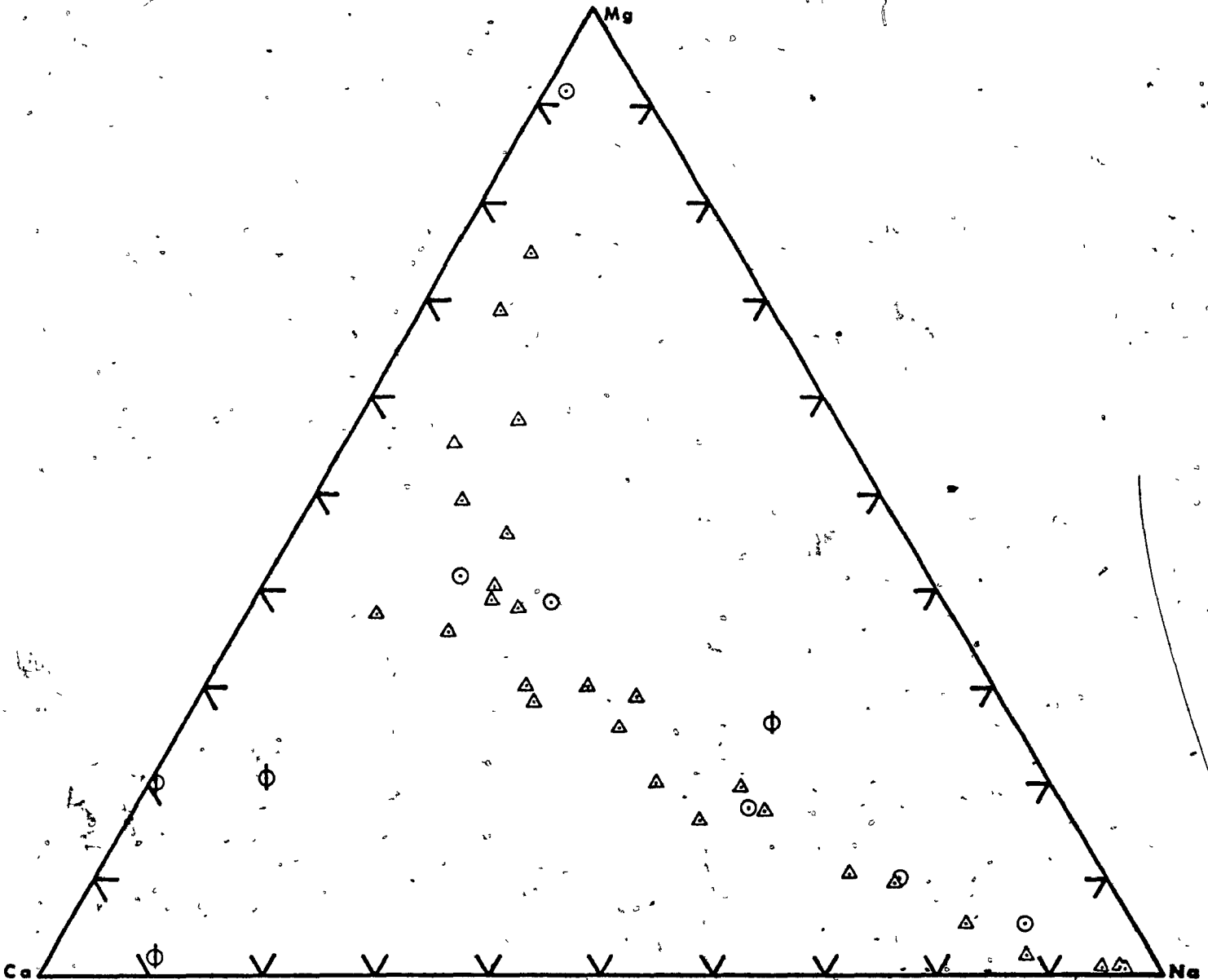
Figure 2-1. Bar graphs of two representative samples of the Eustis Mine waters (Spring 7, Drill hole 70) and samples of ground waters from different rock types from Hem (1970). 12-5 basalt, 12-2 rhyolite, 15-1 limestone, 16-1 dolomite.


meq or mm per liter
5
4
3
2
1
0
$Na^+ + K^+$
Mg^{2+}
Ca^{2+}
Cl^-
SO_4^{2-}
HCO_3^-
H_4SiO_4
7
70
12-5
12-2
15-1
16-1.
Eustis mine waters
Basalt
Rhyolite
Limestone
Dolomite

graphs typical of the Eustis Mine area compared with waters from Hem which typify unmetamorphosed volcanic rocks. Also shown are bar graphs of waters from Hem which are similar to those in the Eustis Mine area. The cation bar and the anion bar are not always the same height for three reasons. The cations Fe^{2+}, Zn^{2+} and Mn^{2+} are not represented, the method of sulfate analysis allows a precision of probably not much better than 10%, and other constituents which may be present, such as NO_3^-, were not determined. It should be emphasized that the natural waters used by Hem (1970) were selected because the proportions of the various ions closely approximate those in the enclosing rocks. In many cases this relationship will not hold true due to factors such as those mentioned earlier. From the bar graphs it can be seen that the waters from the Eustis Mine area resemble waters from a limestone or a dolomite terrain with an excess of sulfate.

A potentially more useful diagram is a trilinear plot of the molar proportions of Na, Ca and Mg. These cations were selected because they are the most mobile rock-forming constituents, and most rock types can be distinguished by comparing them. Potassium is not represented because it is less mobile than the other cations, and is a minor constituent in the waters. Figure 2-2 is a trilinear plot of the averages of various rock types (Turekian and Wedepohl, 1961; Irvine and Baragar, 1971). There is a well defined trend away from the Na apex with increasing mafic character. To my knowledge the Na, Mg, Ca triangular diagram has not been used to distinguish

Figure 2-2. Triangular diagram showing the relative proportions of calcium, magnesium and sodium in different rock types. Points designated by △ are analyses of volcanic rocks from Irvine and Baragar (1971) and points designated by ⊙ world averages of igneous rocks from Turekian and Wedepohl (1961). Samples designated by ⌀ are sedimentary rocks or recent sediments from Turekian and Wedepohl (1961).


Mg
Ca
Na

rock types. The extremely consistent trend that is seen in Figure 2-2 is too obvious to overlook, and must be considered as an important geochemical relationship until proven otherwise. It is not the purpose of this study to investigate this relationship, but it was felt that it should be reported. Waters influenced only by the silicate character of the bedrock should have similar proportions of Na, Mg and Ca. Figure 2-3 is a similar trilinear plot of the Ascot Volcanic Belt rocks (data from Alsac et al., 1971), waters from different lithologies (Hem, 1970) and the waters collected in this study.

The Ascot rocks show a similar but more diffuse trend away from the Na apex compared to the rocks depicted in Figure 2-2. It is notable that the felsic rocks show a magnesium enrichment relative to the average volcanic rocks. Magnesium enrichment has been attributed as characteristic of mineralized volcanic terrane (Descarreaux, 1973), and may be a useful technique for defining volcanic belts with associated mineralization.

Figure 2-3 shows that there are only two rocks with a relative Ca% greater than 40% and only two waters less than this value. There are only three rocks with a relative Na% less than 14% and only one water greater. The Ascot rocks have a roughly similar Ca/Mg ratio with Na varying widely, but the waters have a constantly changing Ca/Mg ratio with very little variation of Na. This changing Ca/Mg ratio must be due to variations in the quantities of Ca and Mg in carbonates in the bedrock. The point is emphasized that a few rock analyses do not necessarily represent the bulk composition of the bedrock. Secondary minerals

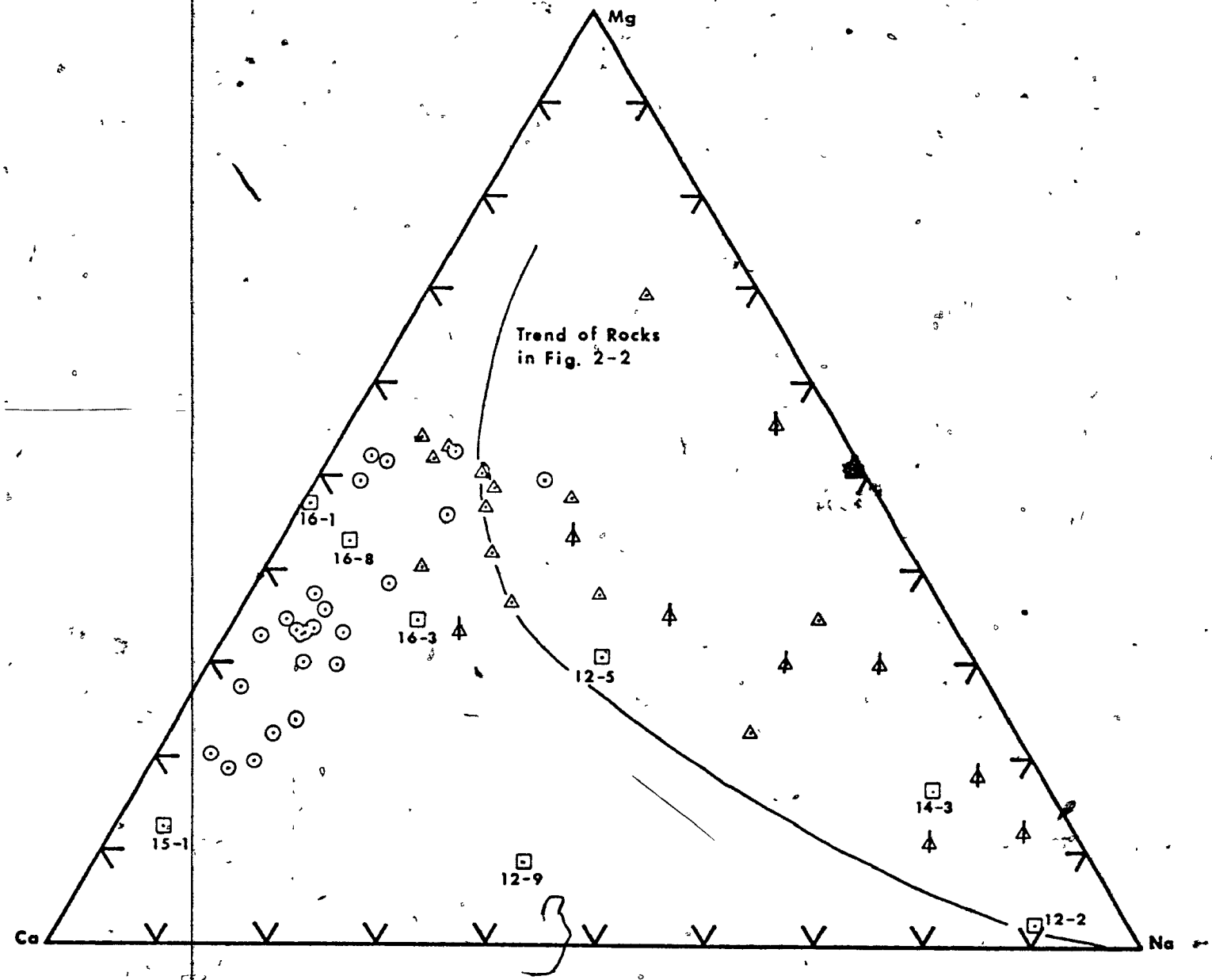
Figure 2-3. Triangular diagram showing the relative proportions of calcium, magnesium and sodium in the Eustis Mine waters and ideal waters from Hem (1970), and in rocks from the Ascot volcanic belt (Alsac et al., 1971).

⊙ = Eustis Mine waters. △ = Rocks. ⊡ = Hem's waters.

⏃ = rocks with an Na/K ratio less than 20.

The following numbers designate the lithology of Hem's waters.

12-2 = rhyolite	12-5 = basalt	12-9 = mica schist
14-3 = shale	15-1 = limestone	16-1 = dolomite
16-3 = olivine tuff	16-8 = quartzite	


Mg
Trend of Rocks
in Fig. 2-2
16-1
16-8
16-3
12-5
14-3
15-1
12-9
12-2
Ca
Na

are often purposely avoided, so that the rock sample represents fresh bedrock. Unfortunately this practice causes problems when trying to compare waters with bedrock composition. The Eustis Mine waters are influenced largely by the vein and disseminated carbonates in the metamorphosed volcanic bedrock.

Correlation coefficients

The interrelationship between constituents was found by determining the product-moment correlation coefficients of the data (Figure 2-4). The major cations and anions, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-} and SO_4^{2-} are all highly correlated, as would be expected from waters of similar composition, but with varying concentrations. The best correlation for Na^{+} and H_4SiO_4 (Si on correlation matrix for simplicity) is between each other. This may indicate that albite is the main source for Na^{+} and H_4SiO_4. The good correlation between Zn^{2+} and SO_4^{2-} indicates that the major source of SO_4^{2-} is from the oxidation of sulfides, and zinc is an important pathfinder element, a fact well known. The good correlation between SO_4^{2-} and Ca^{2+} and Mg^{2+} is due to the reaction of acid-sulfate waters with vein and disseminated carbonates.

Perhaps more important are the low correlations of Cl^{-}, Zn^{2+}, pH and to a lesser extent H_4SiO_4, with most of the other constituents. The low correlation of Cl^{-} is probably due to the fact that much of the Cl^{-} comes from the atmospheric precipitation. Uneven distribution of zinc minerals in the bedrock causes its low correlation with every constituent except SO_4^{2-}. Biologic activity probably influences the pH and causes its poor cor-

Figure 2-4. Correlation matrix of the Eustis Mine waters. The 99% confidence level corresponds to a value of .515.

CORRELATION MATRIX

	CA	MG	HCO3	SO4	NA	K	CL	ZN	SI	PH	TEMP
CA	1.000										
MG	0.839	1.000									
HCO3	0.813	0.910	1.000								
SO4	0.905	0.832	0.659	1.000							
NA	0.710	0.823	0.799	0.683	1.000						
K	0.738	0.675	0.606	0.792	0.597	1.000					
CL	0.572	0.574	0.528	0.534	0.454	0.424	1.000				
ZN	0.644	0.409	0.258	0.741	0.296	0.483	0.464	1.000			
SI	0.654	0.684	0.607	0.658	0.850	0.537	0.424	0.496	1.000		
PH	-0.104	0.263	0.331	-0.163	0.241	-0.211	-0.300	-0.377	0.111	1.000	
TEMP	-0.355	-0.373	-0.450	-0.244	-0.475	-0.099	-0.513	-0.125	-0.419	0.160	1.000

relation. The highest correlation of pH is the negative one with Zn^{2+}, indicating the concentration of Zn^{2+} in natural waters is partially controlled by the pH of solutions. The fairly low correlation of H_4SiO_4 is due to the fact that H_4SiO_4 concentration is regulated by the clay mineral reactions, and therefore varies very little.

Equilibrium relations

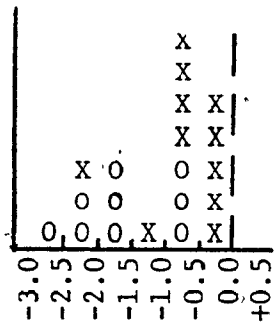
Saturation indices were found for the mineral water reactions of importance in this study by the method described in Appendix II. Figure 2-5 is a series of histograms depicting some of these indices. The complete data is given in Appendix VI. Because of analytical error and thermodynamic uncertainties, equilibrium of a reaction is assumed to occur in samples which have values of the saturation index in the range $0 \pm .5$. It should be noted that the indices for the montmorillonite reactions are at best only estimates, since the free energy of formation for ideal montmorillonite is estimated (Helgeson, 1969). Also the composition of any natural montmorillonite which might exist, and therefore the free energy, is not known. Newer values of natural montmorillonites indicate that these indices may be too negative by as much as one unit (Norton, 1974; Kittrick, 1971 a, b; Weaver et al., 1971). This would result in many of the samples being saturated with respect to Ca and Mg-montmorillonite.

Many of the waters are saturated or close to saturation with respect to Ca and Mg-montmorillonite, calcite, dolomite and malachite. None are close to saturation with respect to the

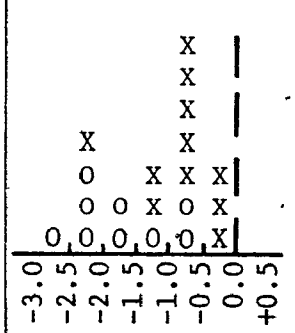
Figure 2-5. Histogram showing the saturation indices for the Eustis Mine waters. A value of zero represents saturation with respect to the mineral on the right, a negative number undersaturation and a positive number supersaturation. Because of analytical error and other considerations saturation is assumed to occur at a value of the saturation index of $0.0 \pm .5$. The chlorite-kaolinite histogram is typical for all primary silicates, in that the waters are highly unsaturated with respect to primary silicates.

O = a spring water; X = a drill hole water; sol. = solution; Ca-mont. = Ca-montmorillonite.

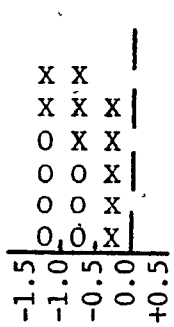
Sol.-Calcite



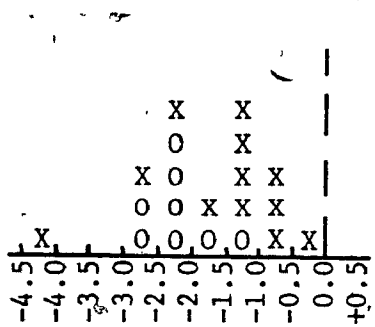
Sol.-Dolomite



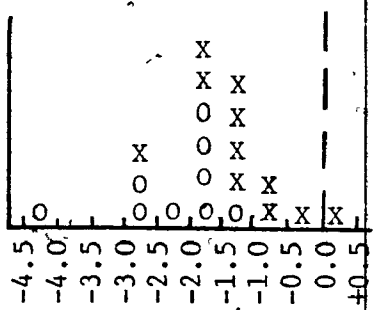
Sol.-Malachite



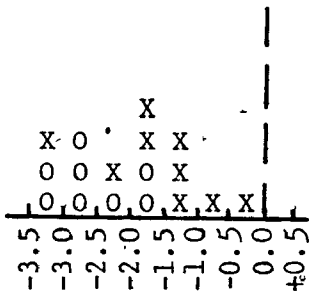
Kaol.-Ca-Mont.



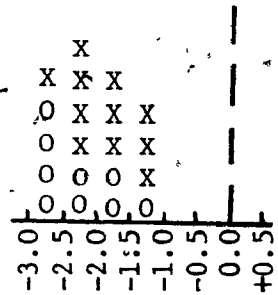
Kaol.-Mg-Mont.



Sol.-$ZnCO_3$



Kaol.-Chlorite



primary silicate minerals. This indicates that the chemical composition of these waters is controlled by the carbonate and the secondary silicate mineral-water reactions. The near saturation of malachite indicates that copper is controlled in solution by this mineral. On the other hand zinc is not controlled by its carbonate. Its low-concentration must be due to the low abundance of sphalerite and the difficulty of sphalerite being dissolved by these ground waters.

DISCUSSION

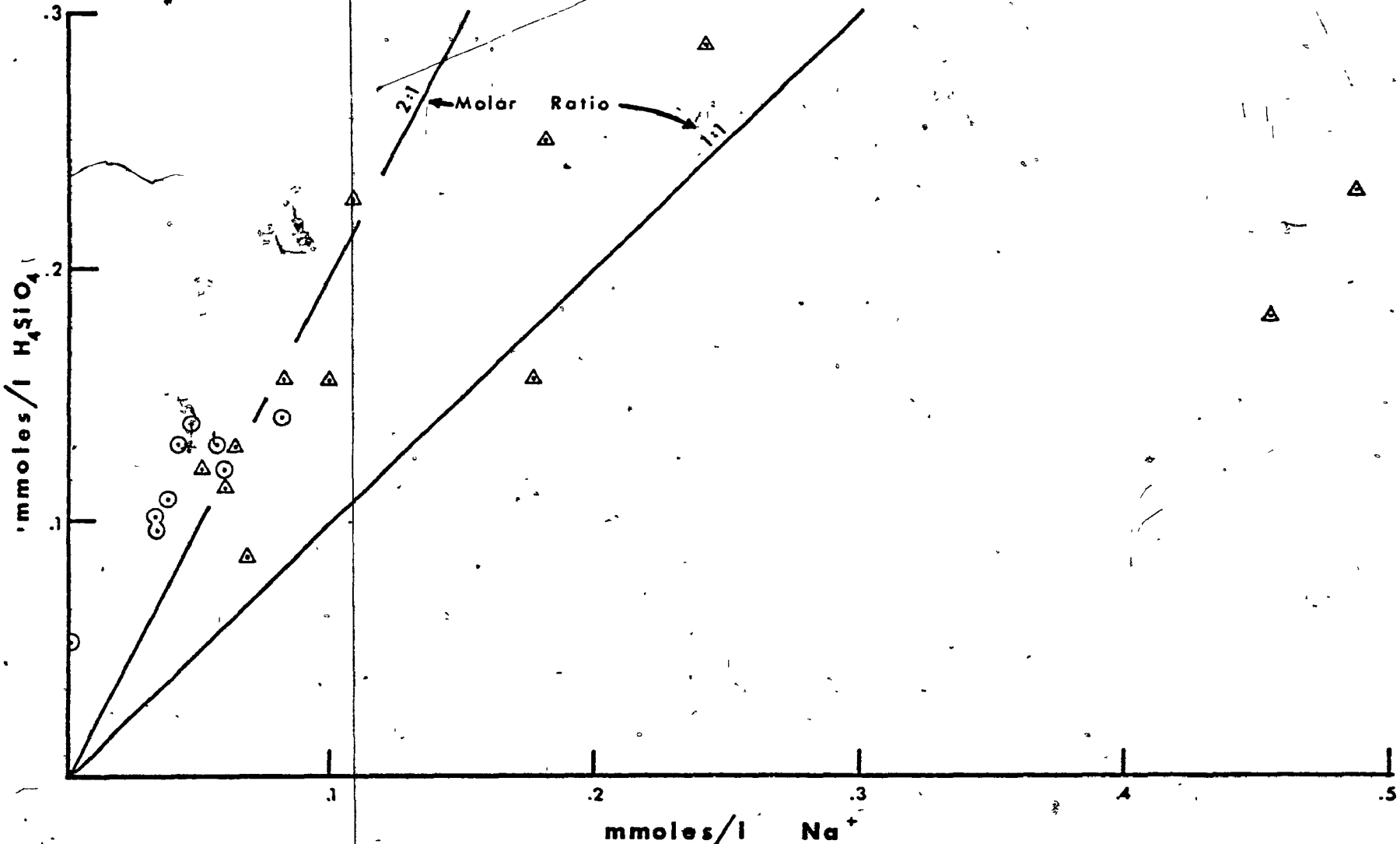
Comparison of the estimated chemical composition of the precipitation with the chemistry of the waters shows that most of the total dissolved solids, primarily Ca^{2+}, Mg^{2+}, HCO_3^- are due to the dissolution of carbonate minerals. In the more dilute springs, however, substantial amounts of Na^+, Cl^- and K^+ are contributed from the atmosphere although 50% of the samples gain less than 2% of their Na^+ from atmospheric sources. At the most 46% of the sulfate is due to atmospheric sources, indicating that the rest is due to oxidation of sulfides. Since this is a highly mineralized area it is not unusual to have such a high concentration of sulfate in the ground water.

The water in this area gains most of its cations from its reaction with carbonate minerals. The quantity of Ca^{2+} and Mg^{2+} gained depends upon the pH of the waters. The high correlation between Ca^{2+}, Mg^{2+} and SO_4^{2-} indicates that acid waters produced locally by the oxidation of sulfides are quickly neutralized by reaction with carbonates, producing Ca-Mg-SO_4 waters.

The only rock forming minerals which weather and produce H_4SiO_4 in solution are albite, anthophyllite and diabandite (Table 2-3). Anthophyllite is more easily weathered than either albite or diabandite (e.g., Loughnan, 1969), but it is not common in most of the bedrock and is present in abundance only near zones of mineralization (Stevenson, 1934). In the bulk of the bedrock therefore, albite and diabandite are the most important sources of H_4SiO_4. The framework silicates are more easily weathered than the sheet silicates, thus the weathering of albite to kaolinite should be responsible for most of the H_4SiO_4 in solution. The high correlation between Na^+ and H_4SiO_4 supports this hypothesis. The weathering of albite to kaolinite results in a 2 to 1 molar ratio of H_4SiO_4 to Na^+, therefore if H_4SiO_4 were added to the ground waters by the breakdown of anthophyllite or chlorite a plot of H_4SiO_4 versus Na^+ would have samples with a ratio greater than 2. Figure 2-6 is such a plot for the Eustis Mine area waters with the Na^+ concentration corrected for atmospheric contributions. All but one of the samples with an H_4SiO_4/Na^+ ratio greater than 2 are small springs and seeps with a low total dissolved solids content.

Waters which percolate near mineralization may react with anthophyllite releasing H_4SiO_4 into solution, but no Na^+. In these circumstances the H_4SiO_4/Na^+ ratio will be higher than expected. The only sample which appears to be affected by this reaction is drill hole 70 (Figure 2-6). This hole was drilled into known mineralization, and the water is anomalous with zinc. On the other hand, other anomalous samples do not show this H_4SiO_4

Figure 2-6. Molar plot of H_4SiO_4 versus Na^+ for the Eustis Mine waters. The concentration of Na^+ in precipitation has been subtracted from the samples. The 2:1 molar ratio represents the proportions of H_4SiO_4 and Na^+ released by the reaction albite to kaolinite. The 1:1 ratio represents the proportions produced from the weathering of albite to Na-montmorillonite. Waters which precipitate a montmorillonite of a different composition or a silica-rich aluminosilicate containing no Na^+ will have an H_4SiO_4/Na^+ ratio less than 1. ⊙ indicates springs. △ indicates drill holes.


.3
.2
.1
mmoles/l H_4SiO_4
2:1
Molar Ratio
1:1
.1
.2
.3
.4
.5
mmoles/l Na^+

enrichment. It therefore must be concluded that the role of anthophyllite in contributing H_4SiO_4 to solution is minor.

From the descriptions of the rocks in the area there is no other major source of Na^+. Na^+ is also the most mobile cation, and is not readily removed from solution. The deviation of the samples from the ideal 2 to 1 ratio of H_4SiO_4 to Na^+ must then be due to controls on H_4SiO_4.

Control of H_4SiO_4

The typical weathering sequence which affects the water composition is most likely the following. The H_4SiO_4 content rises rapidly when rain water or snow melt comes in contact with silicate minerals (Feth et al., 1964; Davis, 1964; Paces, 1972). The initial increase is due to the reaction of kaolinite with water, forming minute amounts of gibbsite in the upper soil zone (Bricker et al., 1968). Percolating downward the water then reacts with silica-rich clay minerals (Si/Al ratio greater than 1), formed during periods of low rainfall, such as montmorillonite, chlorite, or some amorphous silica-rich secondary silicates, releasing additional H_4SiO_4 and minor amounts of adsorbed Na^+, forming kaolinite. Further movement downward through the overburden and bedrock results in the water reacting with albite producing an amorphous aluminosilicate (Polzer, 1967; Wollast, 1967; Paces, 1973) which slowly crystallizes to kaolinite. Continued contact with the bedrock results in equilibrium of the water with montmorillonite (Garrels and Mackenzie, 1967; Norton, 1974), or a silica-rich amorphous silicate, causing the H_4SiO_4/Na^+

ratio to be equal to or less than 1 depending on the composition of the montmorillonite.

During periods of low rainfall, when evapotranspiration is dominant, the reactions important in the soil zone may reverse themselves to a certain extent (Grim, 1953). These reactions probably replenish the kaolinite and montmorillonite in the soil zone. The movement of water at this time of year is probably by capillary action, with the water being saturated with and precipitating the secondary phases. The H_4SiO_4/Na^+ ratio can therefore be used to estimate the relative depth of a water. The waters with an H_4SiO_4/Na^+ ratio greater than 2 have significant amounts of soil water present, whereas the samples with an H_4SiO_4/Na^+ ratio less than 2 have significant amounts of deeper water which is losing H_4SiO_4 due to the formation of montmorillonite, an amorphous aluminosilicate or some other silica-rich secondary silicate mineral.

Production of HCO_3^-

The reaction of dissolved CO_2 with silicate and carbonate minerals produces HCO_3^-. This production of HCO_3^- is then also a measure of extent of reaction. Rocks which are higher in carbonate minerals will react faster, and produce more HCO_3^- sooner than rocks with less carbonate, due to the lower stability of carbonate minerals and to the addition of HCO_3^- from the carbonates themselves. Garrels (1967) found that many natural waters in granitic terrane approach saturation with montmorillonite at an HCO_3^- concentration around 100 ppm and then become saturated

with calcite at about 200 ppm HCO_3^-. Figures 2-7 and 2-8 show plots of the saturation index of Mg-montmorillonite (a plot of Ca-montmorillonite is similar), and the saturation index of calcite versus HCO_3^- concentration. Figure 2-8 compares very favorably with what Garrels (1967) found, but Figure 2-7 indicates that equilibrium between montmorillonite is reached at a higher HCO_3^-. This is what would be expected if an appreciable amount of the HCO_3^- came from the dissolution of carbonate minerals. Also noted from these diagrams is that drill holes are distinguished from springs, in that spring waters have lower concentrations of HCO_3^- and are more unsaturated with respect to calcite and montmorillonite.

It has been suggested that at an H_4SiO_4/Na^+ ratio less than 2 and at an HCO_3^- concentration greater than 100 ppm, the water becomes saturated with respect to montmorillonite. Figure 2-9 is a plot of H_4SiO_4/Na^+ versus HCO_3^-. The majority of samples with an H_4SiO_4/Na^+ ratio less than 2, i.e., those waters where H_4SiO_4 is being removed, have an HCO_3^- content greater than 150 ppm. The minor scatter is probably due to variable amounts of carbonates in the bedrock and minor amounts of other minerals which produce H_4SiO_4 upon weathering. This diagram also indicates that drill holes have a higher HCO_3^- content and lower H_4SiO_4/Na^+ than springs, again supporting the usefulness of these two parameters as indicators of depth and reaction time.

Figure 2-7. A plot of the saturation index of the reaction Mg-montmorillonite going to kaolinite versus HCO_3^-. Negative values of the saturation index indicate undersaturation and positive values supersaturation with respect to Mg-montmorillonite.

⊙ indicates springs. △ indicates drill holes.

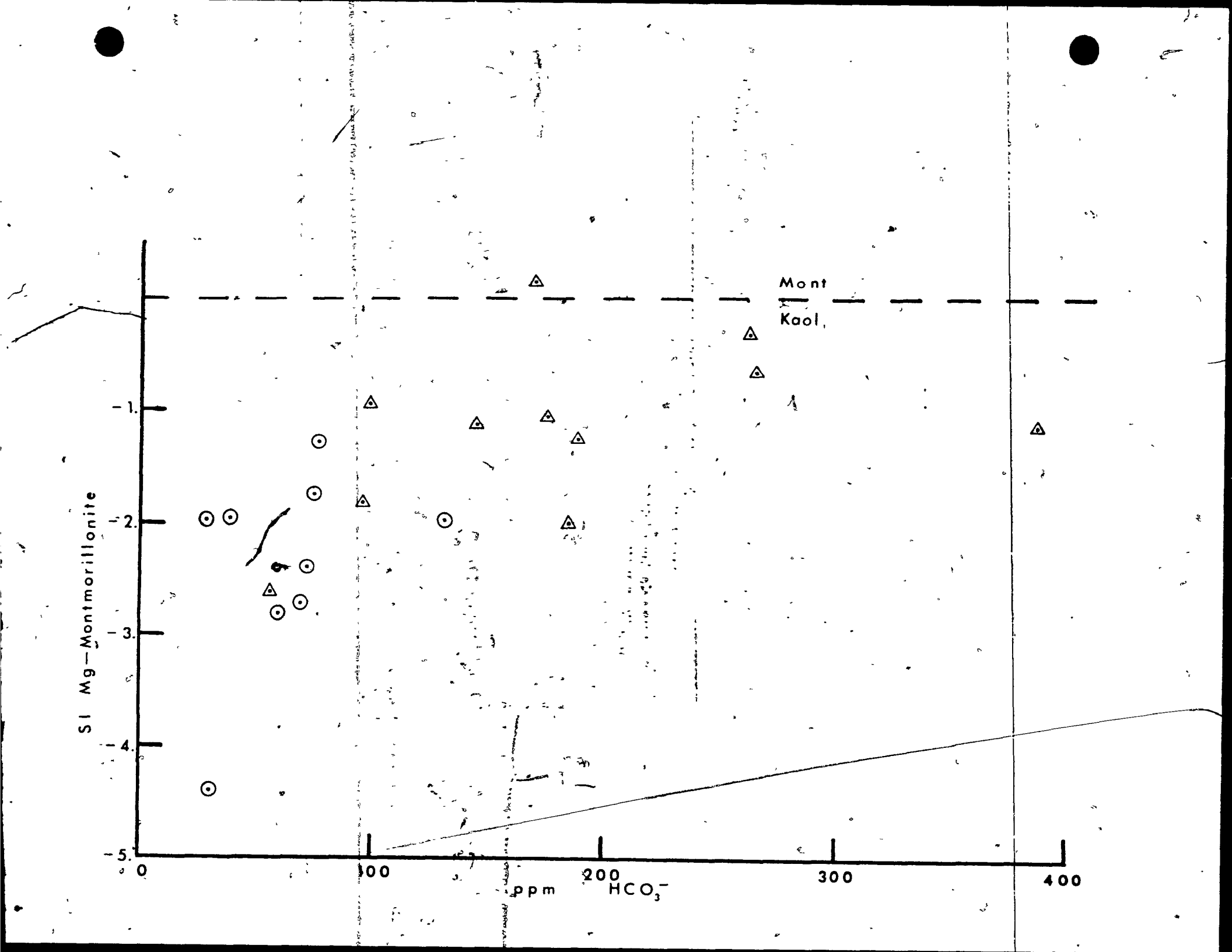

Mont
Kaol.
SI Mg—Montmorillonite
-1.
-2.
-3.
-4.
-5.
0
100
200
300
400
ppm HCO_3^-

Figure 2-8. A plot of the saturation index for the solubility of calcite versus HCO_3^-. Negative values of the saturation index indicate undersaturation and positive values supersaturation with respect to calcite.

⊙ indicates springs. △ indicates drill holes.

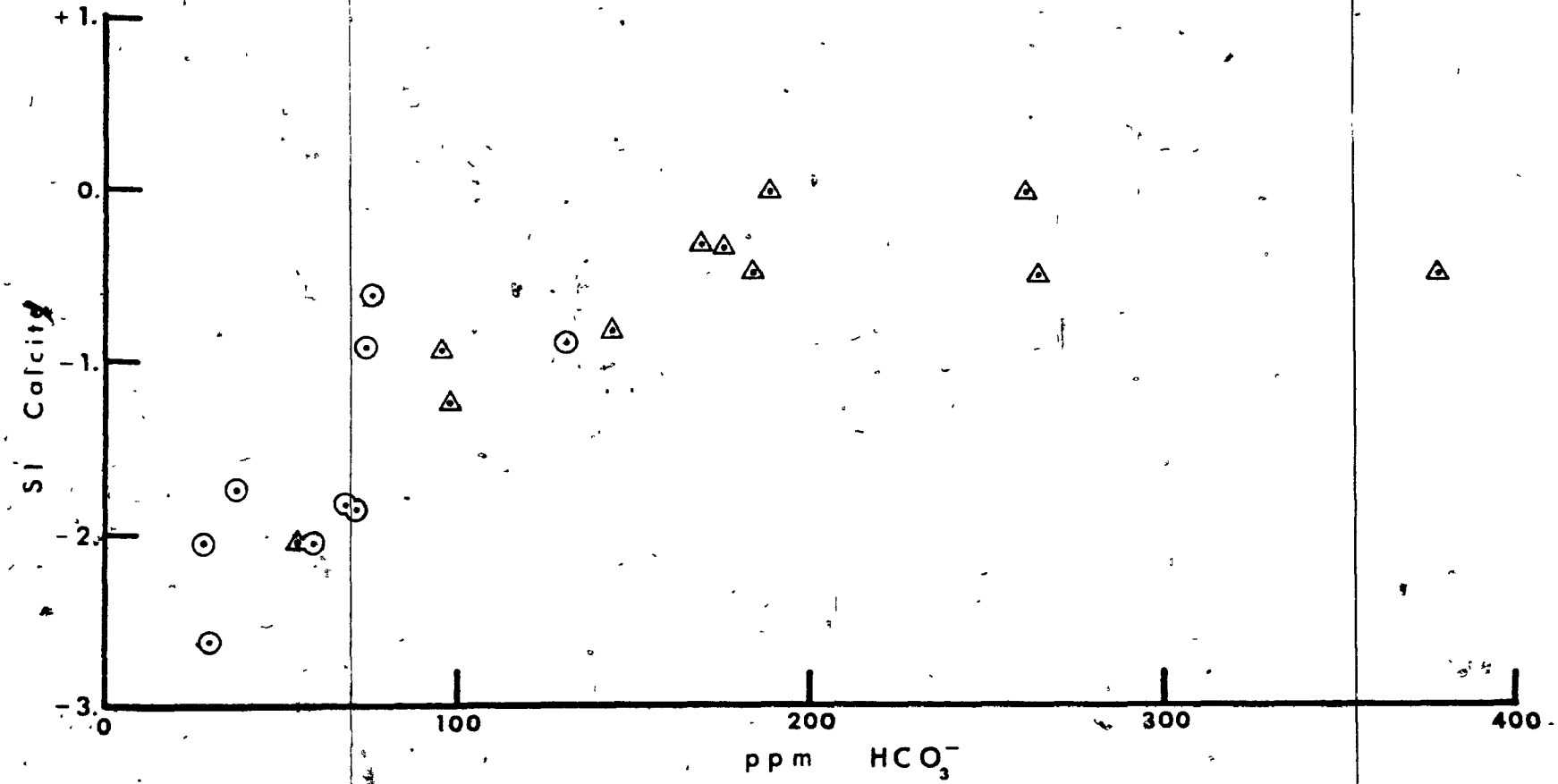
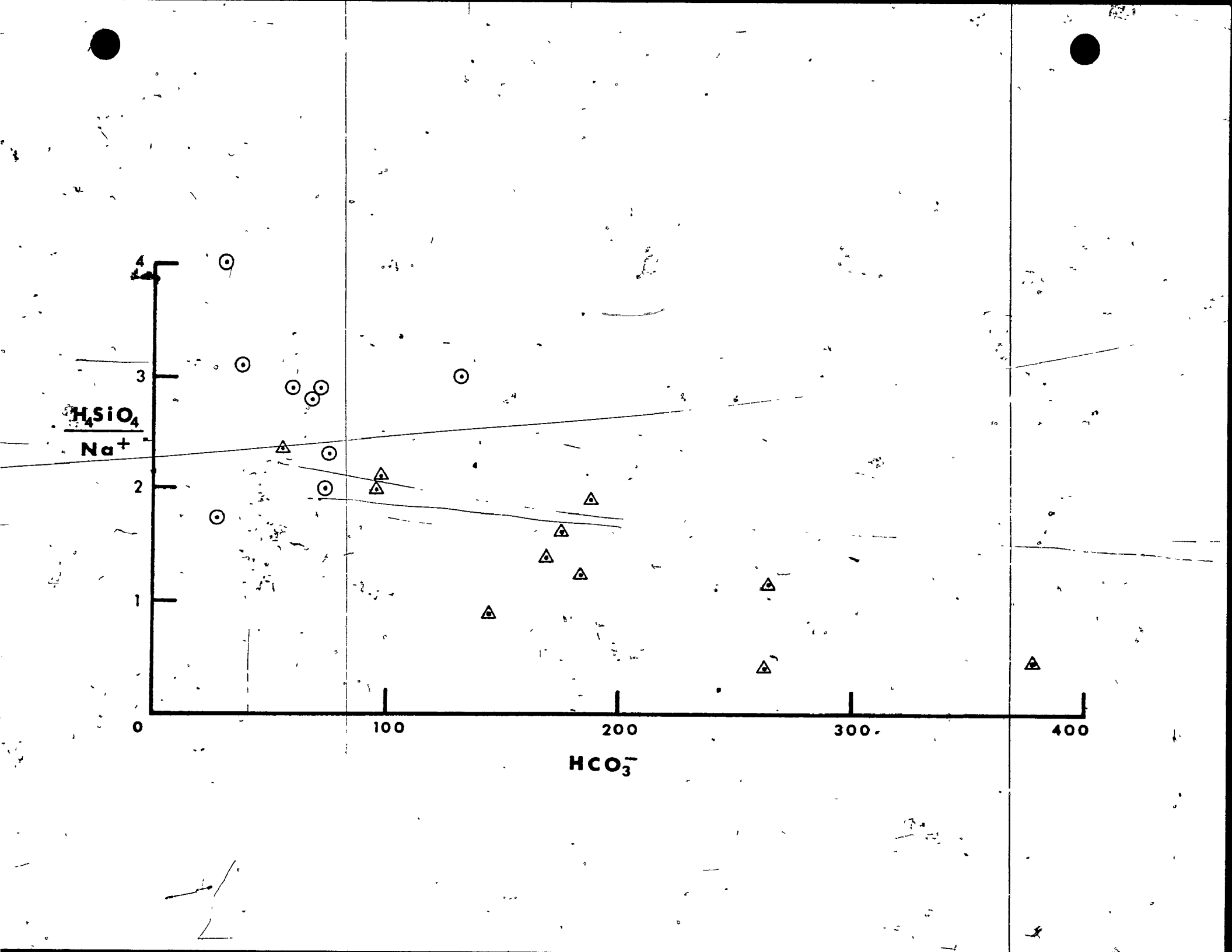

+1.
0.
-1.
-2.
-3.
SI Calcite
0
100
200
300
400
ppm HCO3-

Figure 2-9. A plot of the H_4SiO_4/Na^+ ratio versus ppm HCO_3^-. ⊙ indicates springs. ⚠ indicates drill holes.


4
3
2
1
0
$\frac{H_4SiO_4}{Na^+}$
100
200
300
400
HCO_3^-

Zn^{2+} and SO_4^{2-} significance

The good correlation between Zn^{2+} and SO_4^{2-} indicates that SO_4^{2-} may be a useful indicator of mineralization. Ginsburg (1960) notes that in many parts of the U.S.S.R. SO_4^{2-} has been used successfully for locating mineralization. Only a few samples were analyzed for SO_4^{2-}, therefore its usefulness cannot be adequately evaluated. Its extreme mobility would make it a useful regional indicator of mineralization (Dall'Aglio and Tonani, 1973). In any case, high SO_4^{2-} is indicative of surface oxidation. This only applies, of course, where there are no soluble sulfate minerals present. The SO_4^{2-} - Zn^{2+} association is even more significant when one notes that the Eustis Mine area was primarily a copper and pyrite producer. This association is therefore probably due to two reasons. Sphalerite is electrochemically less stable than the Cu sulfides and pyrite, and Zn^{2+} is more mobile than Cu^{2+} or Fe^{2+} once in solution. Therefore the most useful element for the location of mineralization in this area is Zn.

Proportions of minerals destroyed

The character of this water is therefore attributed to the weathering of three mineral groups, carbonates (mainly Ca and Mg), silicates (mainly albite) and sulfides (mainly pyrite). The number of moles of primary silicates, carbonates and sulfides destroyed to produce one liter of water is estimated in the following way, after subtraction of the contributions from atmospheric sources. It has been determined that the number of

moles of albite and muscovite destroyed per liter is equal to the concentration of Na^+ and K^+ in solution. The sulfide fraction destroyed, assuming it is mostly pyrite, is equal to $\frac{1}{2}$ the sulfate concentration (Table 2-3). The amount of carbonates destroyed is equal to the amount of Ca^{2+} and Mg^{2+} in solution minus a quantity derived from the weathering of Ca and Mg silicate minerals. Individual contributions of Ca^{2+} from epidote and anorthite cannot be distinguished, therefore these contributions are considered to come only from anorthite. Contributions of Mg^{2+} from anthophyllite and chlorite also cannot be distinguished, thus they are considered to come from chlorite in the calculations.

The first step is to compare the Na to K ratios of bedrock to the water. Albite weathers faster than muscovite and K^+ can be adsorbed from solutions more easily than Na^+ (e.g., Loughnan, 1969). Therefore the Na to K ratio of the waters should be greater than or equal to the ratio in the rock from which it was derived. From Table 2-4 one sees that all the waters, with the exception of one, have an Na/K ratio less than 20. Except for the felsic and spilitized rocks, all the rocks have a ratio greater than 20. This means that the waters could only have obtained their sodium and potassium from rocks of a felsic or spilitized type. Figure 2-3 is a triangular Ca-Mg-Na plot with the Na/K ratios of the Ascot rocks less than 20 designated. From this plot one sees that most of these rocks have at least 40% Na relative to the sum of the molecular concentrations of Na, Mg and Ca. This puts an upper limit on the amounts of the Ca^{2+} and Mg^{2+} in the waters derived from the dissolution of the silicates.

TABLE 2-4.

Na/K molar ratios for the Eustis Mine area waters and the Ascot volcanic belt rocks.

Waters			Rocks		
Sample	Na/K Ratio	Description	Sample	Na/K Ratio	Description
1	6.2	Spring	A5	.27	Orthokeratophyre
6	11.3	"	A6	9.9	Qtz. keratophyre
7	12.4	"	A9	35.	Basalt
12	10.4	"	A15	13.3	Spilitized basalt
14	.54	Stagnant Pool	A16	13.6	Spilite
30.	12.3	Spring	A17	69.	Metabasalt doleritic
41	7.0	"	A19	.8	Metagranophyre
51	9.0	"	A20	41.1	Qtz. keratophyre
52	17.1	"	A21	92.	Andesite
53	26.2	Drill Hole	A37	.5	Rhyolite
54	9.8	" "	A38	40.	Basalt
55	13.2	" "	A39	86.	Dolorite
58	14.4	" "	A91	52.	Basalt
64	11.6	" "	A93	123.	Basalt
65	12.2	" "	A94	34.	Basalt
66	5.8	" "	A98	31.	Basalt
68	8.3	" "	A109	2.5	Orthokeratophyre
70	9.4	" "	A111	1.16	Rhyolite
71	3.9	" "	S1	14.8	Qtz. keratophyre
72	3.7	" "	S2	136.	Qtz. keratophyre
73	5.9	" "	S3	27.4	Qtz. keratophyre
			S4	42.	Basalt

Also from this diagram it appears that the Ca/Mg ratio is approximately constant at 1. The calculation of the silicate minerals destroyed is based on these assumptions:

(1) ~~Assume that Na equals 40% of the sum of the~~ Molecular concentrations of Na, Mg and Ca in the silicate minerals.

(2) Assume that equal molal proportions of Ca and Mg are released into solution from the silicate minerals (Figure 2-3).

After making these assumptions the proportions of Na:Ca:Mg released from the silicate minerals are 4:3:3. Using the above assumptions and the reaction coefficients in Table 2-3, the formulae given in Table 2-5 are obtained. These formulae calculate the moles of silicate, carbonate and sulfide minerals which were destroyed to produce one liter of water of the present composition. Figure 2-10 is a triangular diagram showing the proportions of silicates, carbonates and sulfides destroyed, as variables. Again from this diagram one notes that these waters derive most of their dissolved solids from the dissolution of carbonates. Sample 53, the same sample which had an Na/K ratio greater than 20 (27) is also the sample with the greatest silicate character. It therefore appears that this water gained a large proportion of its constituents from a rock other than the felsic metavolcanics. The bedrock which underlies the sample sites is not all felsic metavolcanics, as there is a fairly large proportion of meta-andesites, which are now chlorite schists. This emphasizes the fact that the

TABLE 2-5.

Equations used to determine the number of moles of various minerals destroyed necessary to explain the composition of one liter of water.

Moles of silicate destroyed

$M_{Na^+} = M_{Albite}$

$M_{K^+} = M_{Muscovite}$

$3/4M_{Na^+} = M_{Anorthite}$

$3/4M_{Na^+} = M_{Chlorite}$

Moles of carbonates destroyed

$M_{Ca^{2+}} - 3/4M_{Na^+} = M_{Calcite}$

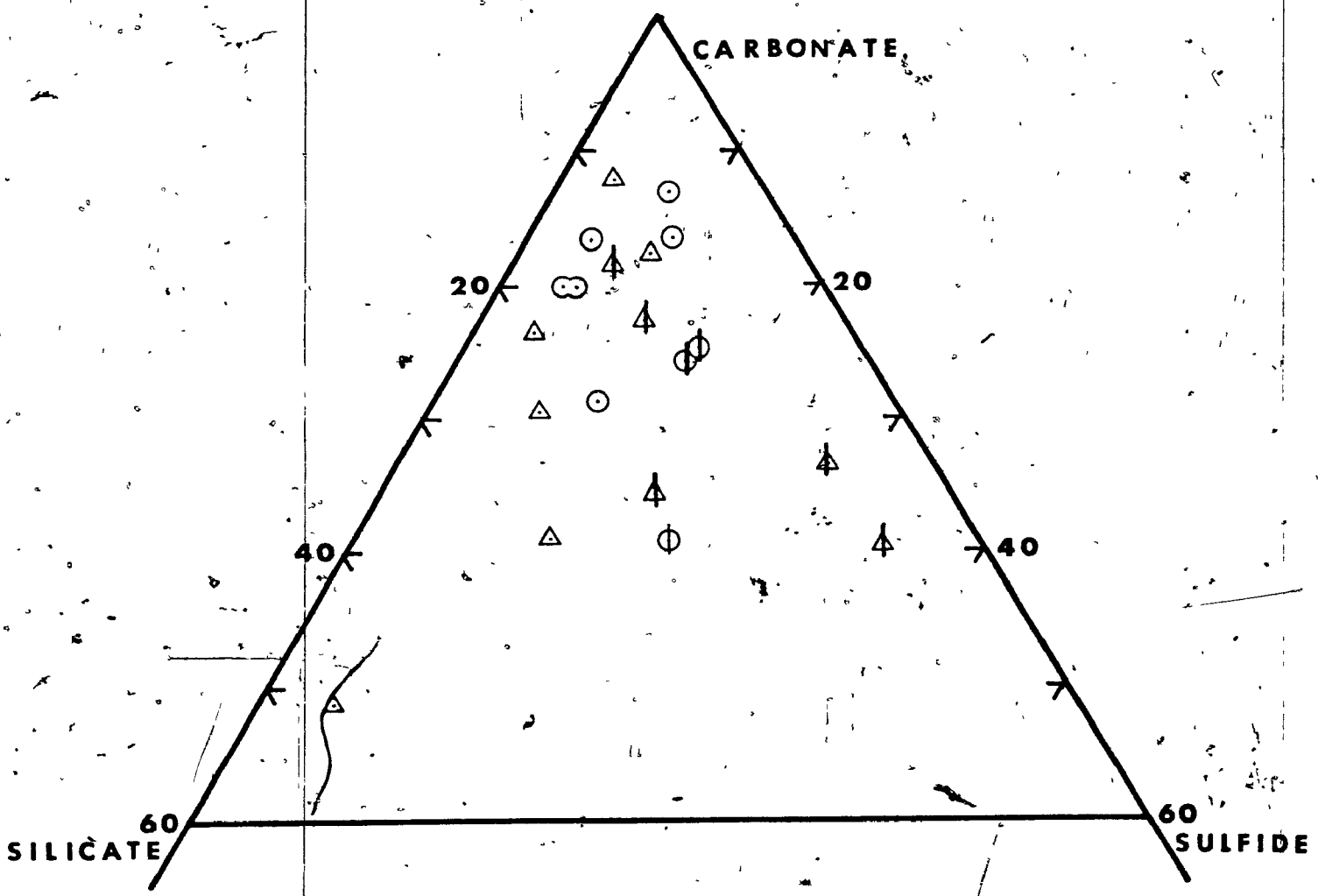
$M_{Mg^{2+}} - 3/4M_{Na^+} = M_{Magnesite}$

$M_{Mn^{2+}} = M_{Rhodocrosite}$

Moles of sulfides destroyed

$\frac{1}{2}M_{SO_4^{2-}} = M_{Pyrite}$

Figure 2-10. Triangular diagram showing the relative molar percent of silicate, carbonate and sulfide minerals which make up the Eustis Mine area waters. ⊙ indicates a spring. △ indicates a drill hole. Symbols with a slash through them, ⊘ and ⧋ indicate samples with greater than 30 ppb Zn^{2+}.


CARBONATE
20
20
40
40
60
60
SILICATE
SULFIDE

felsic rocks are more easily weathered than the intermediate rocks. At depth the metavolcanics are underlain by black slates. It could be that sample 53 gains its water from these rocks.

The samples with a zinc concentration greater than 30 ppb are also designated on this diagram. These anomalous samples are quite well separated toward the sulfide apex from the non-anomalous samples, as would be expected.

The extensive carbonatization in the Eustis Mine area is not locally indicative of mineralization (Holyk, 1953). The possibility of it being an indicator on a regional scale has not been investigated in this area. The analysis of ground waters would be an effective prospecting method for locating carbonatized zones.

SUMMARY AND CONCLUSIONS

The main sources of constituents in the Eustis Mine waters are atmospheric contributions, vein and disseminated carbonates, albite and sulfides (mainly pyrite).

Atmospheric contributions of Na^+, Cl^- and K^+ make up a significant percentage of the total concentrations of these constituents in the more dilute waters. The atmospheric contributions of Ca^{2+} and Mg^{2+} are insignificant compared to those derived by dissolution of carbonate minerals, whereas SO_4^{2-} may have as a maximum 50% of its concentration due to precipitation.

The chemical composition of the Eustis Mine waters does not resemble that expected from dissolution of the sericite-chlorite

schist bedrock. The chemical character of these waters is similar to waters derived from carbonate terrane. In every water sample, except one (53), at least 60% of the dissolved solids are calculated to be derived from vein and disseminated carbonate minerals.

The contribution to water chemistry of the Ca and Mg silicates is minimal compared to the carbonate minerals. The dissolution of albite affects the water composition to a greater degree, and all of the Na^+ and much of the H_4SiO_4 in solution are due to the breakdown of albite. The concentration of H_4SiO_4 in solution is regulated by various clay minerals, which are in a state of semi-equilibrium among themselves. The behavior of Na^+ and H_4SiO_4 is summarized as follows. Precipitation and snow melt react quickly with the soil zone, dissolving more H_4SiO_4 than Na^+. Continued reaction through the overburden and bedrock results in a steady increase in Na^+, but a slow increase and leveling off of H_4SiO_4 concentration. Consequently the H_4SiO_4/Na^+ ratio becomes less as the contact time increases.

The concentration of HCO_3^- is also a measure of reaction time. Compared to studies done in mainly silicate rocks, these waters reach saturation with respect to montmorillonite at a higher HCO_3^- concentration. This is due to the additional quantity of HCO_3^- contributed from the carbonate minerals.

The usefulness of HCO_3^- and H_4SiO_4/Na^+ ratio as indicators of contact time is confirmed when plotted against one another, since most drill hole waters are easily distinguished from most spring waters. The most useful parameter is the H_4SiO_4/Na^+

ratio for distinguishing waters containing appreciable soil zone water from those with appreciable deep water present. The H_4SiO_4/Na^+ ratio is greater than 2 for waters which receive the majority of their dissolved constituents from the soil zone. Waters which come from a deep source have an H_4SiO_4/Na^+ ratio less than 2. Thus, in any area where most of the H_4SiO_4 and Na^+ can be attributed to the breakdown of albite, the H_4SiO_4/Na^+ ratio is indicative of the relative depth of origin of the water.

The approach to equilibrium of many of the waters to Mg and Ca-montmorillonite, calcite and dolomite indicates that these minerals are important in the control of Ca^{2+}, Mg^{2+} and H_4SiO_4 in solution. There is no direct evidence for the presence of montmorillonite, however there is evidence that an Si-rich secondary silicate mineral is controlling the H_4SiO_4 concentration of the waters. Precipitation of malachite controls the concentration of copper in many of the Eustis Mine area waters. Zn^{2+} appears close to saturation with respect to smithsonite in only one Eustis water (71), otherwise it is very undersaturated. This is probably due to the relatively minor abundance of sphalerite in the bedrock and to its difficulty in going into solution as the sulfide. It is, however, the best constituent to use as an indicator for locating mineralization.

It has been demonstrated from this study that major element analysis of ground waters can contribute to the understanding of the history of these waters to a significant degree. Water quality analysis is an effective method of locating carbonatized zones. If carbonatization is an indication of mineralization on a

regional scale in volcanic terrane, then hydrogeochemistry would be a useful prospecting tool for locating this mineralization.

CHAPTER III PERIODICAL VARIATION OF DISSOLVED CONSTITUENTS

In contrast to single samples from many sample sites a periodical sampling study at one sampling site minimizes water quality variations due to variable bedrock composition and shows the magnitude and importance of seasonal influences on water composition. The variation of chemical constituents over time in ground waters is caused by one or more of the following factors.

(1) Precipitation and evapotranspiration.

(2) Mixing of waters from different sources.

(3) Inorganic and organic chemical reactions.

This study will attempt to assess the importance of each of the above factors and how they affect the individual constituents in the spring and drill hole waters. This is done by taking samples periodically over a 14 month period (June, 1972 to August, 1973) from five sample sites. Emphasis will be on inorganic rather than organic reactions.

LOCATION AND PHYSICAL CHARACTERISTICS OF THE SAMPLE SITES

The following criteria were used for the selection of the five areas of study; the water at these locations is perennial, contains heavy metals, is easily accessible and the locations are environmentally different. Four of the sample sites, 71, 72, 51 and 52 are located near the Eustis

Mine and are plotted on Figure 3-1. Also shown are the results of previous mining activities and zones of known mineralization, either of which might have contributed constituents to the waters. Sample site 73, a flowing drill hole, is located near the King and Howard Mines, two miles to the west-northwest of the Eustis Mine. Site 73 was sampled because it is very unusual in that a large volume of water issues out of the hole and it contains an appreciable amount of zinc. Figure 3-2 is a topographic map showing the location of sample site 73 in relation to known contamination and mineralization.

The physical characteristics of the individual sample locations are given as follows:

Sample site 71 is a cased drill hole whose water is flowing at a rate of approximately 10 liters per minute. There is a gossan of iron oxide built up downslope from the drill hole with a diameter of approximately 15 meters. The reported depth of the drill hole is 92 meters. The iron in solution is actively oxidizing at depth as indicated by iron oxides in suspension. An attempt was made to sample the drill hole vertically, but at a depth of 37 meters the drill hole was found to be partially blocked with iron oxides. This probably indicates the depth at which oxygenated water enters the drill hole.

Sample site 72 is an uncased drill hole whose water is flowing at a rate of about 5 liters per minute. A gossan is developed around this hole with a diameter of 23 meters. In this drill hole the iron in solution does not oxidize until it reaches the surface. The reported depth of this hole is 370 meters.

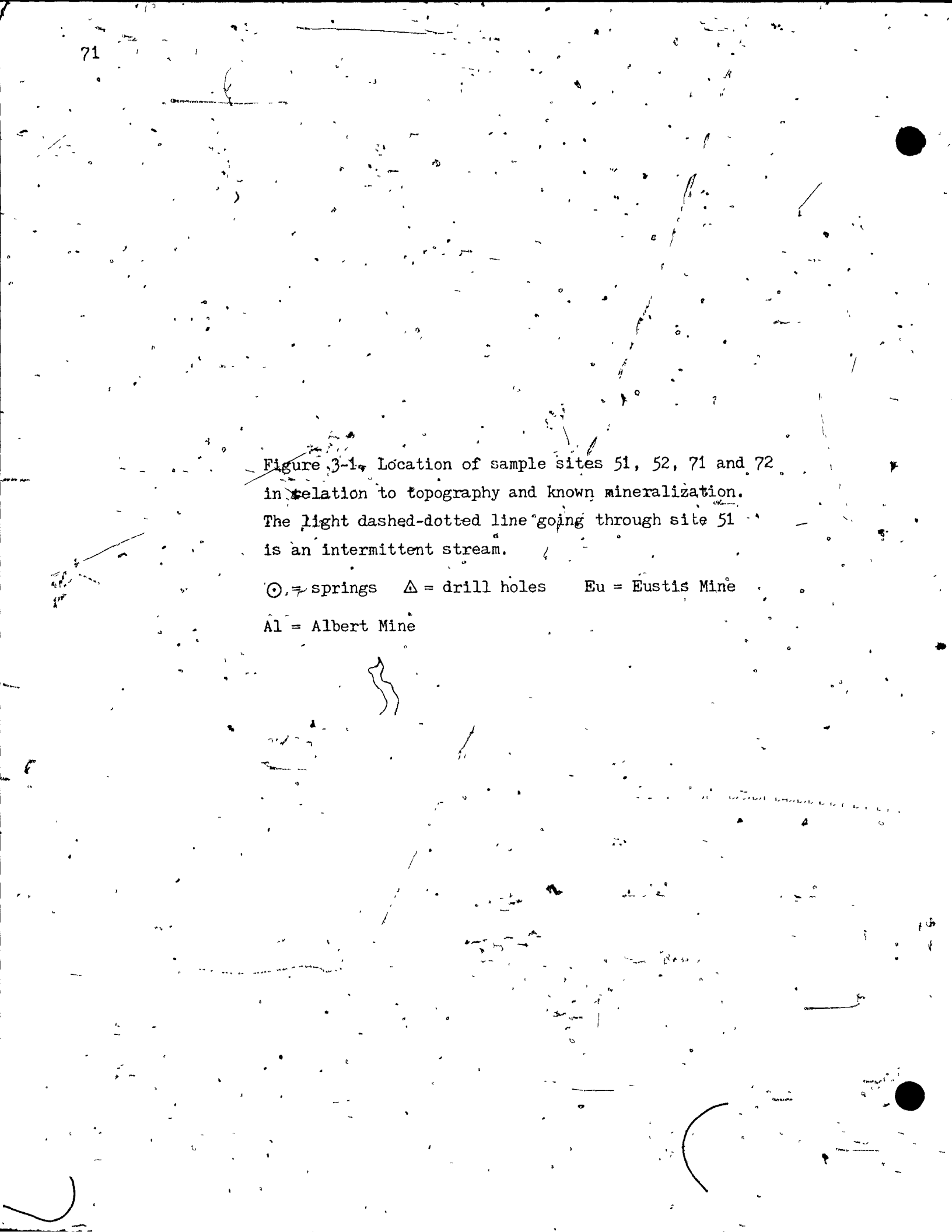
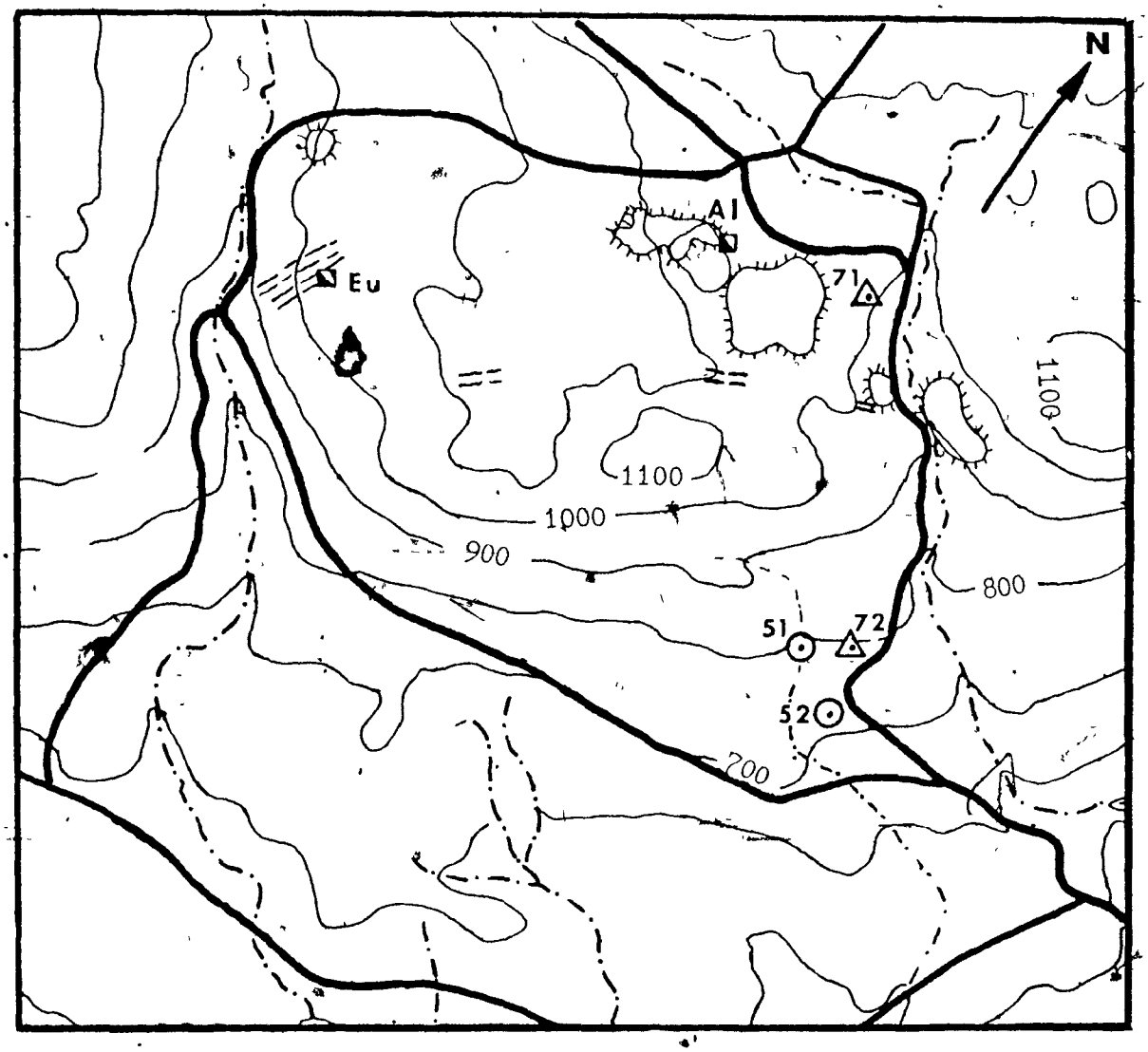


Figure 3-1. Location of sample sites 51, 52, 71 and 72 in relation to topography and known mineralization. The light dashed-dotted line going through site 51 is an intermittent stream.

⊙ = springs △ = drill holes Eu = Eustis Mine

Al = Albert Mine



LEGEND

- Road
- Stream
- 70 Sample location
- 1000 Contour lines 100 foot interval
- Mineralization
- Mine shaft
- Mine dump

200 Meters

1000 Feet

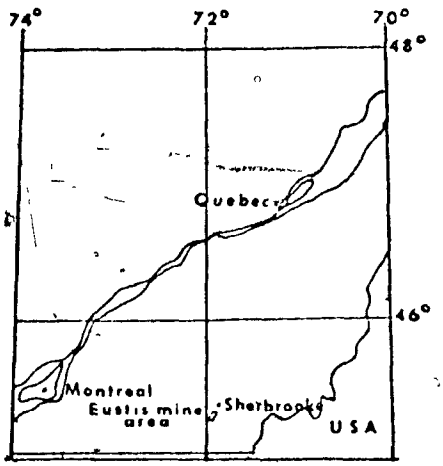
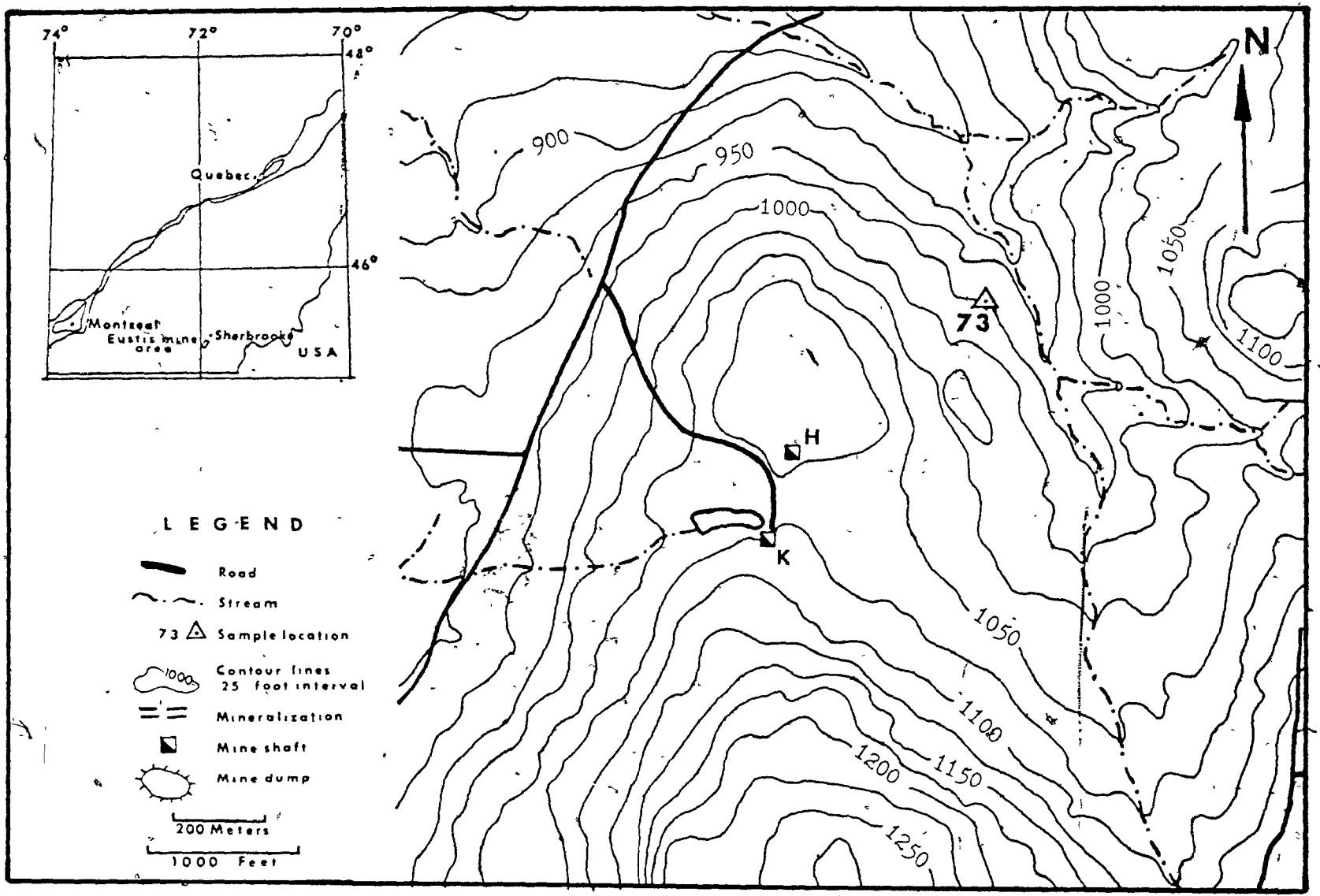


Figure 3-2. Location of flowing drill hole site 73 in relation to topography.
K = King Mine H = Howard Mine


74°
72°
70°
48°
46°
Quebec
Montreal
Eustis Mine area
Sherbrooke
USA
LEGEND
Road
Stream
73 Sample location
1000 Contour lines 25 foot interval
Mineralization
Mine shaft
Mine dump
200 Meters
1000 Feet
900
950
1000
1050
1100
1150
1200
1250
N
73
H
K

Sample site 73 is a cased drill hole whose water is flowing at a rate of approximately 40 liters per minute. No appreciable gossan has developed because the flow rate is too fast, even though iron oxides are in suspension. There is no record of this drill hole having been drilled, thus the depth is not known. From information about other drill holes in the area it is probably not much more than 60 meters deep.

Sample site 51 is an intermittent stream on a slope of approximately 20°. The overburden is quite thin, no more than 2 meters thick. The source of the metals is approximately 460 meters upstream, where a spring emerges which is actively precipitating iron oxides. This spring water then flows downhill, disappearing and reappearing at irregular intervals. At periods of dryness this spring does not emerge until it reaches the 51 sample location. The flow rate varies from a trickle to over 100 liters per minute during the spring of the year. The bedrock is sericite-chlorite schist and there is no known mineralization nearby.

Sample site 52 is a dug well, 3 meters deep, lined with concrete. The water level varies from overflowing to about 1 meter below the surface. The bedrock here is also sericite-chlorite schist. The well is located at the base of a 20 meter gravel hill, and its water probably percolates a good distance through thick glacial overburden. This well-water gains no visible surface runoff.

CHEMICAL VARIATIONS OF DISSOLVED CONSTITUENTS OVER TIME

Effect of precipitation on periodical variations

Source and averaging of precipitation data

Precipitation data for this study are from the Bureau Météorologique in Sherbrooke, Quebec. The data were collected at the Sherbrooke Airport 7 miles from the sample sites. Therefore there are errors introduced because the data collected may not be entirely representative of the rainfall at the sample sites. Raw precipitation data are very irregular, and comparisons between them and dissolved constituents are very unsatisfactory. For this reason the precipitation data was averaged. The interval which best correlated with the chemical data was 20 days. Appendix IV has a plot of the 20 day average and 2 day average for comparison with the chemical data. An average of zero rainfall is plotted as an arbitrarily chosen low value of .01 inches. The data were plotted on a log scale with the lower averages at the top and higher averages at the bottom of each graph in order that the shapes of the curves could be directly compared to the change in the chemical constituents. The larger the number of days averaged the smoother the precipitation versus time plot. The 2 day average is meant to point out any immediate effects of precipitation, therefore only the 2 day averages immediately preceding the sample date were plotted. The twenty day average had a plot interval of 5 days.

Effect of precipitation volume

Plots of the molarities of the constituents versus time are given in Appendix IV. The relative importance of analytical

error is indicated by the analytical error bars of plus and minus two standard deviations, which is a pooled estimate from duplicate determinations. By plotting the data on a log scale the relative variations of all constituents can be compared visually. These data plotted versus time are useful in comparison to averaged rainfall data, when trying to determine what effect precipitation has on the chemical composition.

The periodical variations of most of the constituents (in particular Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-} and H_4SiO_4) in waters from sample sites 51, 71 and 73 can be roughly compared with the 20 day average of the precipitation. Correlation with the 2 day average is much poorer and is nonexistent much of the time. The comparisons are not good enough to make any quantitative deductions other than the travel times from recharge to discharge for samples taken in late summer are approximately 30 days for samples from site 51, 55 days for samples from site 71 and 20-30 days for samples from site 73. Waters from sample sites 52 and 72 show very poor, if any, correlation with the precipitation data.

Effect of precipitation composition

The chemical composition of the precipitation effects the composition of waters from sample sites 51, 52 and 73. Comparison of the precipitation data from Pittsburg, New Hampshire (Table 2-1) with the chemical analyses of the sample sites indicates which elements might be affected by the precipitation. The two elements most affected will be Cl^{-}

and K^+ as 10-100% of the Cl^- and 20-100% of K^+ may come from precipitation. Less than 30% of Na^+ and less than 20% of SO_4^{2-} comes from precipitation. A maximum of 5% of Ca^{2+}, Mg^{2+} and HCO_3^- will come from precipitation. These observations are in accord with the usual poor correlations of Cl^- and K^+ with the other constituents. On the other hand the Cl^- and K^+ concentrations in the ground waters generally do not reflect the order of magnitude differences in concentration of these constituents that Likens et al. (1967) found in the daily precipitation data from central New Hampshire that they analyzed. One would have expected similar variations of these constituents in the most dilute waters. However, sample site 51 has a large peak of increased concentration of Cl^- and K^+ during the fall of the year (Appendix IV). The increase in these constituents is over a sequence of four sample dates. The precipitation during this time was quite low, with no large storms. This behavior will be discussed later, and will be attributed to contributions of constituents by decaying vegetation. The lack of order of magnitude differences must be due to smoothing of the constituent variations by adsorption and buffering in the soil zone.

Comparisons of constituent variations

Correlation coefficients between constituents

Product-moment correlation coefficients were calculated between constituents for each of the sample sites (Appendix V).

The correlation coefficients are useful for determining linear trends between constituents. As a general rule, good correlations between all constituents in a sample location result when there are large variations in the individual chemical constituents due to the mixing of a dilute water with a concentrated water. Poor correlations between dissolved species can be caused by the mixing of more than two waters, analytical variability, biologic activity and atmospheric contributions.

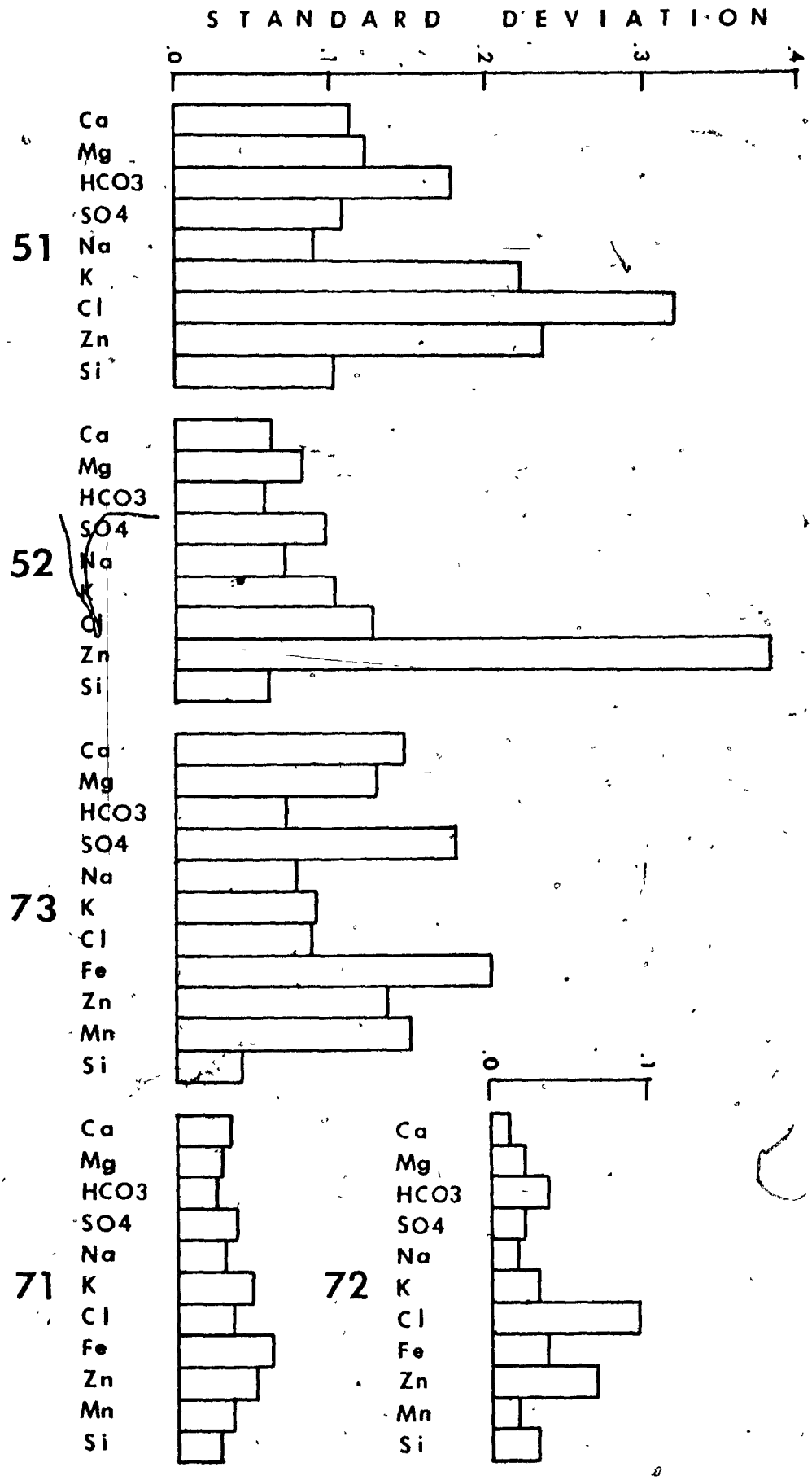
The general order of good correlations to poor correlations for the waters from the five sample locations is: 73, 51, 71, 52, 72. In waters from sample site 73, a flowing drill hole, every constituent except Cl^-, Fe^{2+}, pH and temperature have very high correlations. These good correlations are probably due to mixing of a dilute surface water with a deeper more concentrated water. This possibility will be investigated in more detail later. Sample site 51 is an intermittent stream, which during the dry season becomes a spring. The good correlations of most of the constituents in its waters are probably due to infiltration all along the flow path during periods of high rainfall. This infiltrating water rapidly gains constituents but is very dilute compared to the concentration of constituents in the base flow waters emerging at sample site 51. Sample site 71 is a flowing drill hole with many fair correlations. It appears that this drill hole contains a deep, highly concentrated water at depth which mixes with a more dilute water. This dilute water probably enters the drill hole at about 37 meters as in-

dicated by partial stoppage of the drill hole by iron oxides at this point. Sample site 52 has relatively poor correlations between constituents. This site is a cement cased well which gains its water from relatively thick (20 meters) glacial overburden. Apparently infiltrating water reacts with the overburden long enough to reach a fairly constant concentration over time with respect to most of the constituents. Sample site 72 is a flowing drill hole with very poor constituent correlations and low seasonal variations. These facts indicate that no mixing occurs. This results in random analytical variations becoming important relative to the periodical variations, thus obscuring any underlying relationships.

Standard deviation of the log transformed chemical data

The concentrations of the constituents in each sample site are log transformed, and the standard deviations for the periodical constituent variations are found. The standard deviation of the log transformed data is used as a measure of variability because constituents whose concentrations differ by orders of magnitude can be directly compared to one another. A relatively large standard deviation indicates either that mixing waters have larger differences in concentration of a constituent or that there is an external source for the element which is quite variable with time. A small standard deviation indicates either that the water is reaching a steady state with respect to a mineral which controls the ion in question or that the mixing waters have similar concentrations of the particular constituent. Figure 3-3 is a bar graph of the standard deviations

Figure 3-3. Bar graph of the standard deviation of the log transformed data of the periodical sampling data.


STANDARD DEVIATION
0
1
2
3
4
Ca
Mg
HCO3
SO4
51
Na
K
Cl
Zn
Si
Ca
Mg
HCO3
SO4
52
Na
K
Cl
Zn
Si
Ca
Mg
HCO3
SO4
Na
73
K
Cl
Fe
Zn
Mn
Si
0
1
Ca
Mg
HCO3
SO4
Na
71
K
Cl
Fe
Zn
Mn
Si
Ca
Mg
HCO3
SO4
Na
72
K
Cl
Fe
Zn
Mn
Si

for comparison between the five sample locations. This method of calculating the standard deviation allows one to compare the variation of constituents within waters from one sample site and between waters from all sample sites. The sample sites whose waters are most variable to least variable are 51, 52, 73, 71, 72. There are exceptions for individual constituents. With respect to the individual constituents within sample sites, Na^+ and H_4SiO_4 tend to be the least variable and Zn^{2+}, pH and Fe^{2+} tend to be the most variable constituents. The low seasonal variability of Na^+ and H_4SiO_4 might be an indication of kinetic control and rapid partial equilibrium of both dilute and concentrated waters with respect to albite and secondary aluminosilicate minerals. The poor correlations of Zn^{2+} and Fe^{2+} are due to the instability of these ions in solution. The large variability of pH is probably due to analytical error and organic influences.

DISCUSSION AND INTERPRETATION OF THE CHEMICAL DATA

Equilibrium relations

The degree of saturation with respect to 24 mineral-water reactions was calculated with the computer program described in Appendix II. The saturation indices for the reactions are given in Appendix VI.

Waters from drill hole 71 are near saturation with $CaCO_3$, $FeCO_3$, $ZnCO_3$, $MnCO_3$, $CaSO_4 \cdot 2H_2O$, $Fe(OH)_3$ and Ca and Mg-montmorillonite. It is noteworthy that none of the samples which were analyzed for copper are saturated with respect to malachite. This is true for the other sample locations as well. In Chapter

II it was determined that many of the areal samples were close to saturation with respect to malachite. It appears that some other mineral may be controlling the Cu^{2+} in these samples. According to the Eh-pH diagram by Garrels and Christ (1965) waters from drill hole 71 and drill hole 72 lie in the stability field of cuprite (Cu_2O) and this mineral may be controlling the concentration of Cu^{2+} in solution.

Waters from drill hole 72 are close to saturation with $CaCO_3$, $FeCO_3$, $MnCO_3$, $CaSO_4 \cdot 2H_2O$, $Fe(OH)_3$. They are not saturated with respect to $ZnCO_3$ and Ca and Mg-montmorillonite as are waters from sample site 71.

Samples from drill hole 73 were close to saturation with respect to only $ZnCO_3$ and $Fe(OH)_3$. These minerals control the concentration of Zn^{2+} and Fe^{2+} in solution.

Samples from site 51 are close to saturation with respect to $CaCO_3$, dolomite, Ca and Mg-montmorillonite (using data of Norton, 1974) only during the dry periods of the year when evapotranspiration is important.

Samples from site 52 are not close to saturation with respect to any mineral at any time of the year.

Contamination by mine workings

Contamination due to old mine workings is a real possibility in this extensively mined area. Figure 3-1 shows the physical relationship between the sources of contamination and the water sources. The proximity between drill hole 71 and the Albert Mine dump indicates that this sample site is likely affected

by contamination. There is no direct field evidence for contamination by surface waters, but the water draining the dump would have a greater hydraulic head than the drill holes, thus subsurface flow would be possible. The surface drainage from the mine dump is away from sample sites 72, 51 and 52 and the distance is substantial (430 meters), therefore there does not appear to be any contamination from surface waters. In addition to the possibility of surface contamination, drill holes 71 and 72 intersect the lateral extension of the Albert mineralized zone. This zone consists of unmined sheared rhyolite porphyry with minor amounts of pyrite. The actual underground workings are at a lateral distance of approximately 250 meters southwest of the drill holes. The water in the mine shaft could not be sampled, but the shaft gains much of its water from surface water leaching the tailings. A good portion of this water percolates through the tailings and into the shaft.

A sample of acid surface water leaching the Howard Mine dump was taken and will be used to approximate the shaft water. Table 3-1 gives the chemical characteristics of this water. Assuming that all the copper came from chalcopyrite, all the zinc came from sphalerite and that the remaining iron came from pyrite, then 21 moles of sulfate should have been produced. It is apparent that either there is a source of the sulfur other than sulfides and/or there are iron, zinc or copper minerals precipitating. The very low amount of K^+ indicates the precipitation of jarosite in these very acid (pH = 2.) waters. An increase in the pH from 2 to greater than 3 would result in the breakdown of jarosite to form limonite (Brown, 1971) and

TABLE 3-1.

Chemical characteristics of the water leaching the Albert Mine dump.

Constituent	Concentration (ppm)	Concentration (mmoles/liter)
Ca^{2+}	240.	6.0
Mg^{2+}	113.	4.7
Na^{+}	15.	.65
K^{+}	.37	.01
Fe^{2+}	550.	9.8
Zn^{2+}	89.	1.4
Cu^{2+}	120.	1.9
SO_4^{2-}	3000.	31.25

thereby make the K^+ and SO_4^{2-} available for further migration, but removing iron from solution.

Grouping of sample sites

The various sample locations can be divided into three groups with the following characteristics.

Group 1 consists of drill holes 71 and 72. Their waters are close to saturation with many minerals, including minerals common in mineralized areas: $ZnCO_3$, $Fe(OH)_3$, $MnCO_3$ and $FeCO_3$. The constituent correlations are good for samples from site 71 but poor for samples from site 72. There are abundant iron oxides precipitating around the orifice of both drill holes. Waters from these two drill holes also have the lowest variability of the constituents as determined by the standard deviation of the log transformed data (Figure 3-3). They have abnormally large sulfate concentrations which could only be caused by surface oxidation.

Group 2 consists of spring 51 and well 52. Waters from these sites have the most variable chemical constituent variation and are the most likely to have been affected by surface influences.

Group 3 consists of drill hole 73 whose waters have characteristics of both Groups 1 and 2. Its waters have large element variations but are close to saturation with $ZnCO_3$, as are waters from drill hole 71. It is proposed that this sample represents the mixing of two waters which are similar to Group 1 and 2 waters. This possibility will be discussed in more detail later.

Chemical evolution of Group 1 waters (drill holes 71 and 72)

The most direct evidence indicating contamination of waters flowing from sites 71 and 72 by the Albert Mine dump is the extremely high sulfate content. Any sulfate concentration greater than 25 ppm must come from surface oxidation (Chapter IV). If this high sulfate content were due to oxidizing mineralization then an extensive gossan zone would have been developed, but there is no field evidence for such a zone. Therefore the high sulfate concentration must be due to contamination from the mine workings.

Waters from drill hole 71 are probably a mixture of shaft water and percolating surface water. This hypothesis is supported by the precipitation of Fe^{2+} as $Fe(OH)_3$ at a depth of approximately 37 meters (indicating oxygenated water entering the drill hole at this point) and considerable variation of the chemical constituents with time, compared to waters from drill hole 72, as indicated by the standard deviation (Figure 3-3). The positive correlations of all constituents indicate that the shaft water has higher concentrations of these constituents than the oxygen-rich surface water. The relative importance of the two waters in contributing constituents can be estimated from the standard deviation of the log transformed data (Figure 3-3). The order of greatest variability to least is: Fe^{2+}, Zn^{2+}, K^+, SO_4^{2-}, Cl^-, Mn^{2+}, Ca^{2+}, Na^+, Mg^{2+}, H_4SiO_4, HCO_3^-. The most variable constituents come primarily from the shaft water whereas the concentrations of the least variable constituents are more similar in both waters. The correlation coefficients of waters

from drill hole 71 (Appendix V) show strong associations of Fe^{2+}-Zn^{2+}-Mn^{2+} and Ca^{2+}-Mg^{2+}-SO_4^{2-}. Fe^{2+} and Zn^{2+} come mainly from the shaft water whereas Mn^{2+} comes from both waters. Ca^{2+}, Mg^{2+} and SO_4^{2-} appear to come from both waters with a substantial contribution from the shaft water. HCO_3^- and H_4SiO_4 appear to be almost equally abundant in both waters.

The lack of particulate iron hydroxide and the relatively little variation over time of the constituents indicates that the waters from drill hole 72 come solely from the shaft. The correlation coefficients for the waters from site 72 are very low due to the low variability of the data which results in the analytical error variability becoming more important.

Waters from drill holes 71 and 72, as indicated from the saturation indices (Appendix VI), are in equilibrium or very nearly in equilibrium with $CaCO_3$, $FeCO_3$, dolomite, $MnCO_3$, $CaSO_4$ and $Fe(OH)_3$. Waters from sample site 71 are also almost saturated with $ZnCO_3$, but waters from sample site 72 are not. The Zn^{2+} concentration must decrease upon traveling down the shaft since the waters from drill hole 72 have less Zn^{2+} than waters from drill hole 71 and drill hole 72 goes much deeper than drill hole 71. Waters from drill hole 72 are unsaturated with respect to $ZnCO_3$ thus the decrease in zinc is probably not due to precipitation of $ZnCO_3$. One explanation might be sorption by precipitating iron oxides in the shaft.

The amount of sulfate in the drill hole waters is an indication of the quantity of sulfides which were oxidized to produce this sulfate. A corresponding amount of metals must

also have been released and this quantity is estimated in the following way.

Quantity of metals precipitated in the bedrock

The quantity of Fe, Zn and Cu which has been removed from waters flowing from drill holes 71 and 72 since the two drill holes were drilled is calculated. These calculations assume that the measured flow rate (10 liters per minute for waters from sample site 71 and 5 liters per minute for waters from sample site 72) has remained constant for the 22 years since the drill holes were drilled and that the ratios of Fe^{2+}, Zn^{2+} and Cu^{2+} to Na^{+} in the waters leaching the mine dump are constant over time. If it is assumed that Na^{+} in the drill holes was derived from the leaching of the mine dump material with only negligible contributions from the bedrock, then Na^{+} can be used as a measure of dilution. The mean concentrations of the necessary constituents in waters from drill holes 71 and 72 (Table 3-2) are used in conjunction with the concentration of the constituents in the surface water to perform these calculations. The quantity of Cu^{2+} precipitated in drill hole water 72 is given as an example.

From Table 3-1 the quantity of Cu^{2+} and Na^{+} in the surface water is 120 ppm and 15 ppm respectively. The quantity of Cu^{2+} and Na^{+} in the drill hole water is .05 ppm and 11.5 ppm respectively. The dilution factor is equal to the concentration of Na^{+} in surface water divided by the concentration of Na^{+} in the drill hole water, which equals 1.3. The quantity of Cu^{2+} precipitated equals: $120 - 1.3(.05) = 119.94$ ppm. The flow rate is 5 liters

TABLE 3-2.

Average concentration of constituents in waters from drill holes 71 and 72.

Constituent	Drill hole 71 (mmoles/liter)	(ppm)	Drill hole 72 (mmoles/liter)	(ppm)
Na^{+}	.260	6.0	.500	11.5
Fe^{2+}	.0495	2.77	.274	71.2
Zn^{2+}	.049	3.2	.0078	.51
Cu^{2+}	.0005	.04	.0005	.05
Dilution Factor	2.5		1.3	

per minute, which is equivalent to a total water volume of 57.8 million liters in 22 years. The total mass of copper precipitated is then 6.93 million grams or 7.6 tons. The quantity of Cu^{2+}, Zn^{2+} and Fe^{2+} precipitated from waters flowing from each drill hole is given in Table 3-3.

The total tonnage of metal removed from the mine dump since the mine ceased operation (1907) is estimated from data given in Table 3-4. This calculation is made by assuming that the concentration of the constituents in waters from sample site 72 (shaft water) represents the final character of the precipitation which falls only on the mine dump area. Again the ratios of constituents in the mine dump water are used to make this calculation. As a check on these calculations an estimate was made of the total mass of the mine dump (Table 3-4) and the percentage of metals removed seems reasonable in light of this mass (Table 3-4). For example, only .05% Cu has been leached from the dump in 68 years. At the end of the active period of mining the Cu value in the waste material was probably greater than .1%, therefore a rough estimate is that 50% of the total copper has been leached. It appears through these calculations that a good portion, if not most of these metals, are reprecipitated in the overburden and bedrock.

The geochemical investigations of these drill holes indicate that the vein and disseminated carbonates are effective in removing the bulk of metals from acid mine waters. This recharge system may be a useful technique for purifying mine dump waters in areas where acid mine waters are an environmental

TABLE 3-3.

Tons of metal precipitated by the waters in each drill hole since the drilling of 71 and 72 in 1953.

Drill hole 71		Drill hole 72	
Metal	Tons	Metal	Tons
Cu	15.2	Cu	7.6
Zn	10.31	Zn	5.6
Fe	69.	Fe	29.

TABLE 3-4.

Data necessary for the comparison of the flow rate of waters from drill holes 71 and 72 with the volume of precipitation falling on the mine dump, and for the comparison of the total metals removed from the mine dump with the mass of the dump.

Parameter	Value
Measured area of the Albert Mine dump.	23,000 M^2
Estimated volume of the Albert Mine dump assuming an average depth of 6 meters.	138,000 M^3
Mean yearly precipitation.	106 cm
Volume of precipitation which falls on the mine dump per year.	24,400 M^3
Estimated density of mine dump material including voids.	3 gm/cc
Mass of the mine dump.	4.6×10^5 tons
Total amount of metal removed per year from the mine dump assuming water from drill hole 72 represents the final quality of the precipitation which falls on the mine dump.	Cu = 3.2 tons Zn = 2.4 tons Fe = 12.3 tons
Total amount of metal removed since cessation of operations in 1907.	Cu = 218 tons Zn = 163 tons Fe = 836 tons
Percentage of Cu, Zn and Fe of the total mass of the mine dump which has been leached.	Cu = .047% Zn = .035% Fe = .18 %

problem.

Seasonal variations of the spring samples (Group 2)

A comparison of water composition from sample site 51, an intermittent stream-spring, and sample site 52, a cement cased well, illustrates differences in chemical composition of waters caused by variable overburden thickness (stream - 2 meters, well - 20 meters). Table 3-5 lists the primary differences between the two sample sites.

The composition of the water sampled at site 52 appears to have been averaged out or buffered by its percolation through the thicker overburden. This is indicated by the lower variations and correlations of the constituents in waters from site 52 (Figure 3-3, Appendices IV and V). Likens et al. (1967) noted a similar phenomenon in their study of a forested watershed in New Hampshire. They attributed the chemical stability of the drainage water to mature and highly permeable podzolic soils which buffer the chemical composition of waters passing through the soil zone. The lower concentration of constituents in waters from sample site 52 causes a larger percentage of the variability to be due to analytical precision.

The mean and the standard deviation of the water temperature (Table 3-5) from sample site 51 are higher than sample site 52. This indicates that water from sample site 51 is near surface and influenced more by air temperature than water from site 52. This confirms observations that water from site 51 flows through very thin overburden, whereas water from site 52

TABLE 3-5.

Differences in chemical composition of waters caused by variable overburden thickness (Site 51 - 2 meters, Site 52 - 20 meters).

Spring site 51	Well site 52
Very smooth element variation which is directly comparable to the 20 day average of the precipitation	The element variation is less and cannot be compared to average precipitation data. The lower element concentrations make variability due to analytical precision more important.
Good element correlations.	Most correlations are poor, which is due to averaging by the soil zone.
K^+ and Cl^- have large peaks in the fall of the year.	No large peaks for K^+ and Cl^-.
Water temperature very variable with a high mean temperature. Mean = 11.2 Standard Deviation = 4.9	Water temperature not very variable, but more variable than water from the drill holes. Mean temperature is slightly warmer than the drill holes, much colder than waters from site 51. Mean = 8.2 Standard Deviation = 2.2
The saturation index for the montmorillonite to kaolinite reaction is bimodal with many samples close to saturation.	The saturation index for the montmorillonite to kaolinite reaction is not bimodal and not close to saturation.

comes from deeper overburden.

Constituent associations

A comparison between the correlation matrices of constituents in waters from sample sites 51 and 52 (Appendix V) shows three associations which are similar in waters from both sites: Ca^{2+}-Mg^{2+}-SO_4^{2-}, Na^+-H_4SiO_4 and pH-temperature-HCO_3^-.

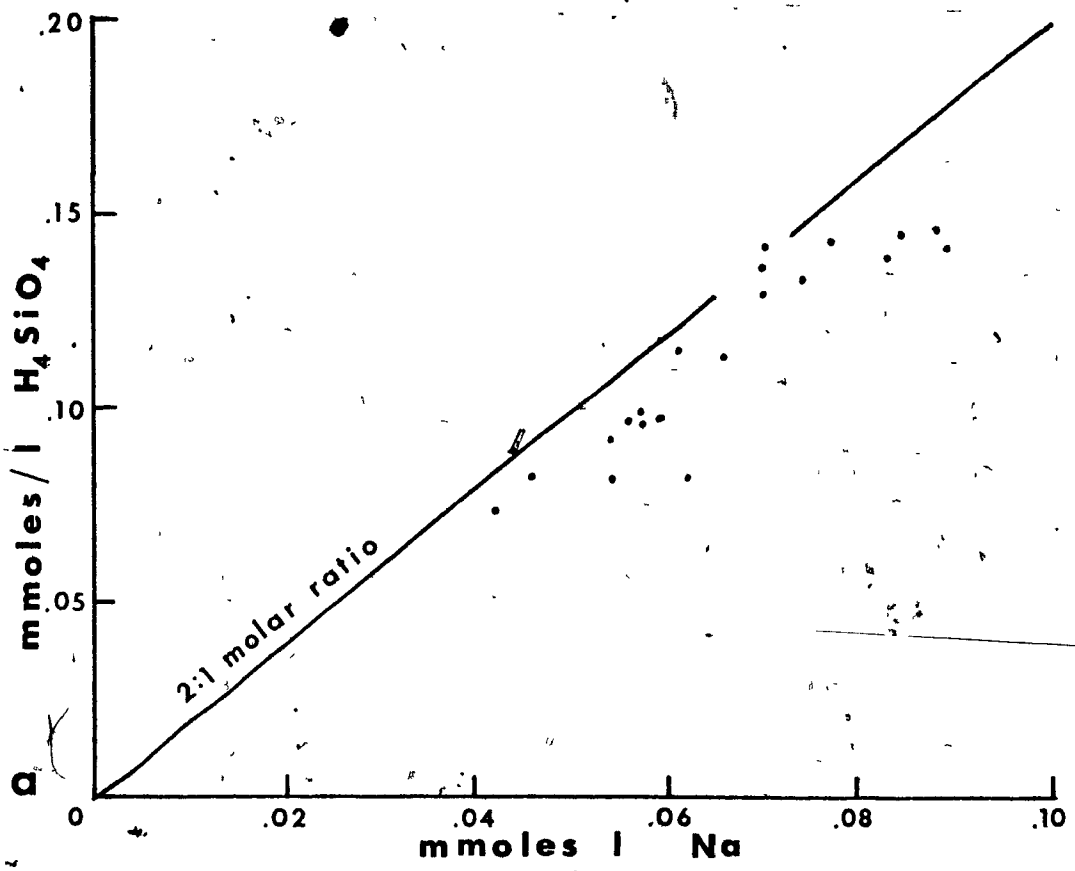
The pH, temperature and HCO_3^- association is probably due to increased biologic activity during the warmer months, which increases the HCO_3^- and pH. The exact mechanisms are not known, but investigation of this association is warranted.

The Mg^{2+}-SO_4^{2-} and Ca^{2+}-SO_4^{2-} correlations are due to the reaction of sulfuric acid, produced by the oxidation of sulfides, with Mg-rich carbonates. The cement casing of sample site 52 may also contribute Ca^{2+}, Mg^{2+} and SO_4^{2-} to the samples from that site.

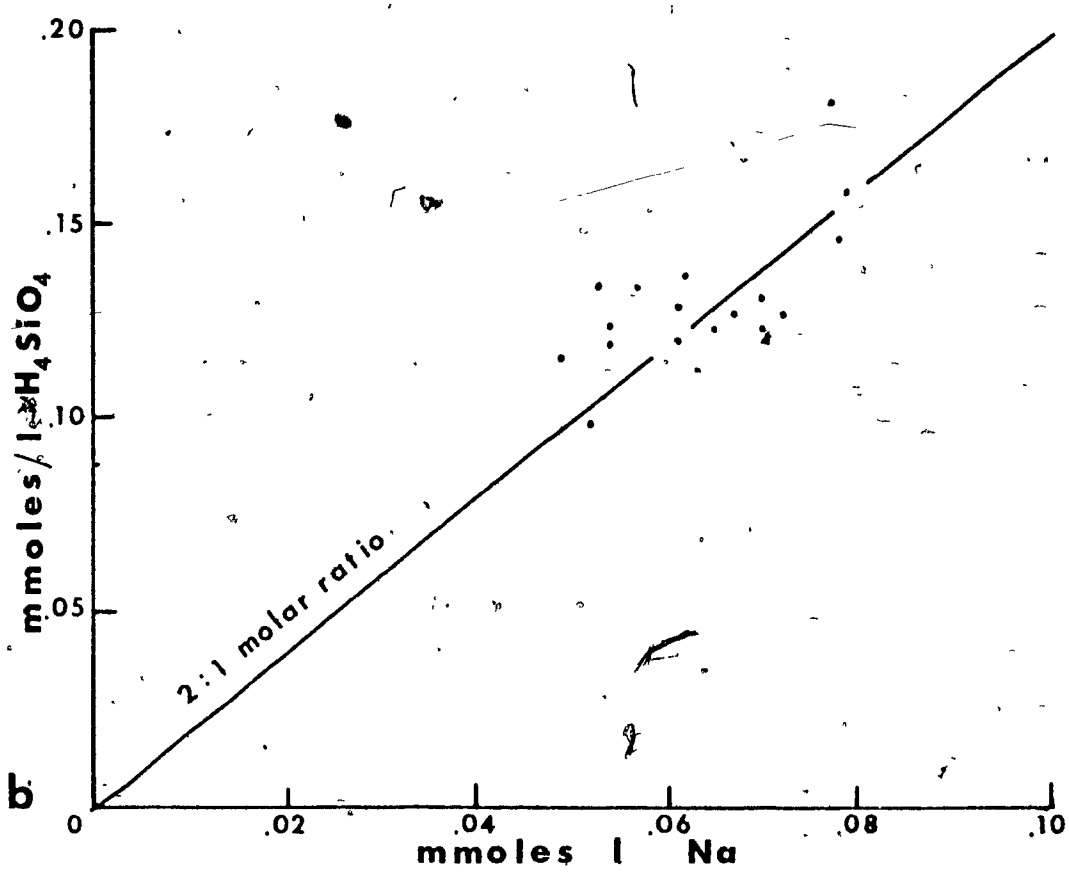
The Na^+-H_4SiO_4 association affirms the hypothesis that these two constituents come from the same source, the primary silicate albite. Figures 3-4 a and b are plots of Na^+ versus H_4SiO_4 for waters from sites 51 and 52. The samples fall very close to an H_4SiO_4/Na^+ molar ratio of 2 to 1, as predicted from the breakdown of albite to kaolinite. Waters from site 52 appear to be slightly more silica-rich than waters from site 51. This is probably due to the addition of minute amounts of H_4SiO_4 from the concrete casing, or may be due to the removal of H_4SiO_4 in waters from site 51 by the precipitation of a secondary aluminosilicate. The H_4SiO_4 concentration appears to be controlled at a maximum

Figure 3-4. Plots of Na^+ versus H_4SiO_4 for waters from sites 51 (3-4a) and 52 (3-4b). The 2:1 molar ratio is the molar ratio of H_4SiO_4 to Na^+ in solution when albite breaks down to form kaolinite.

51


.20
.15
.10
.05
0
mmoles / l H_4SiO_4
2:1 molar ratio
a
.02
.04
.06
.08
.10
mmoles l Na

52


.20
.15
.10
.05
0
mmoles / l H_4SiO_4
2:1 molar ratio
b
.02
.04
.06
.08
.10
mmoles l Na

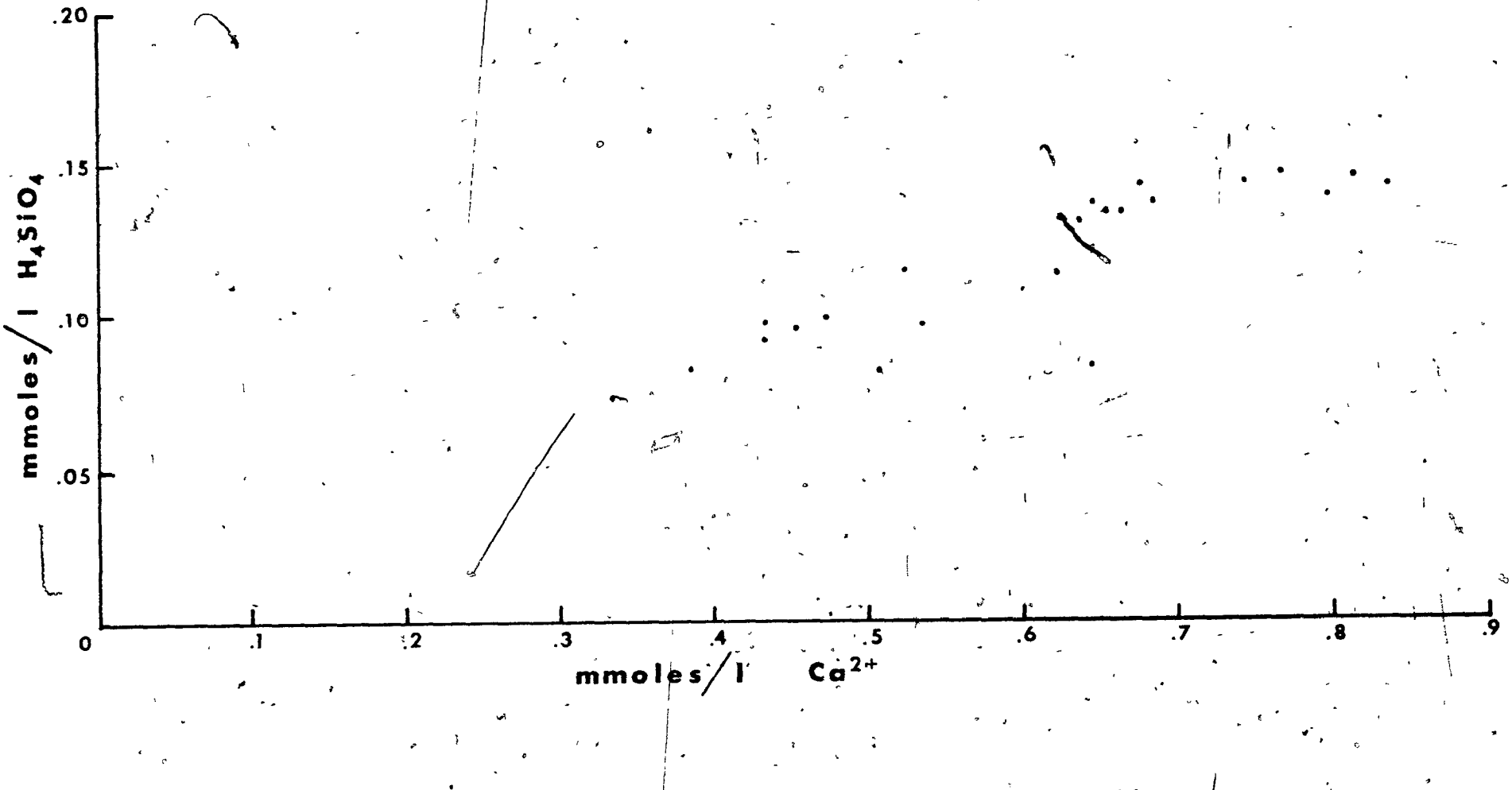
of .15 millimoles in the waters of site 51 as indicated by the leveling off of the Na^+ versus H_4SiO_4 curve. There is a similar, admittedly less conclusive, relationship between Na^+ and H_4SiO_4 in the waters from sample site 52, if one excludes samples 52k, 52l and 52m. One notes on the constituents versus time plot (Appendix IV) that these three samples also have high Mg^{2+} and SO_4^{2-} and low K^+. The water level was higher than it had been all summer, and probably this resulted in dissolution of the cement casing which had been disintegrating but not removed during the period of low water.

Control of H_4SiO_4

The leveling off of the Na^+ versus H_4SiO_4 curve is probably due to control of H_4SiO_4 by a secondary aluminosilicate mineral. Figure 3-5 gives a plot of H_4SiO_4 versus Ca^{2+} for waters from sample site 51. There is a very good trend, which closely approaches that expected from dilution by a pure water, up to about .14 millimoles per liter H_4SiO_4, at which point H_4SiO_4 levels off. The exact same relationship is found for a plot of Mg^{2+} versus H_4SiO_4. Either Ca or Mg-montmorillonite could be precipitating since the Ca^{2+} or Mg^{2+} decrease would be insignificant compared to the total concentration of these ions in the water, and thus would have no effect on Figure 3-5. The precipitation of some other silica-rich secondary aluminosilicate would also cause a leveling off of H_4SiO_4 content.

The four samples in Figure 3-5 which lie off the trend were sampled on consecutive dates from 27/10/72 to 18/1/73. No explanation can be offered as to why these samples are H_4SiO_4

Figure 3-5. Plot of H_4SiO_4 versus Ca^{2+} for waters from sample site 51.


.20
.15
.10
.05
0
mmoles/l H_4SiO_4
.1
.2
.3
.4
.5
.6
.7
.8
.9
mmoles/l Ca^{2+}

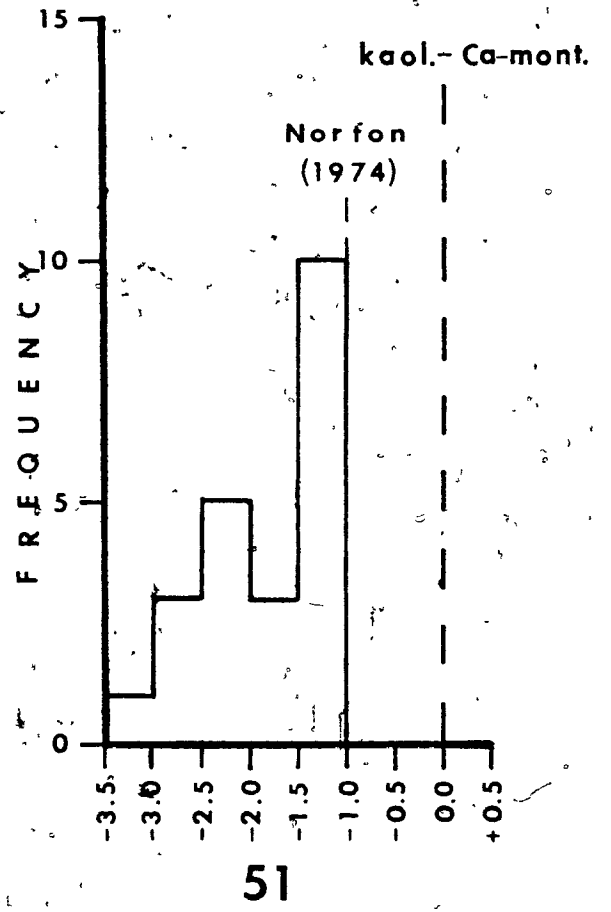
poor, but it appears to be caused by some seasonal effect.

Figure 3-6 shows two histograms of the distribution of the saturation indices of Ca-montmorillonite in waters from sample sites 51 and 52. This figure points out the difference between waters from the two sample sites. The waters from site 51 are closer to saturation than waters from site 52. In fact, if the data from Norton (1974) are used, then the waters are saturated with respect to Ca-montmorillonite and probably with Mg-montmorillonite, therefore either of these minerals may be precipitating in the soil zone. The distribution for site 51 is bimodal in contrast to site 52. These differences are probably caused by the effect of evapotranspiration on the concentration of constituents in the soil water. Sample site 51 has thinner overburden and the waters are nearer the surface than site 52. These waters will therefore be affected more by evapotranspiration and thus the constituents in the soil waters will become more concentrated. Apparently evapotranspiration has little effect on the waters from site 52, as would be expected due to the thick overburden. The waters closer to saturation from site 51 were all taken in the period late spring to early fall, thereby giving fairly conclusive evidence to the above phenomenon. The other secondary silicates show similar distributions and no conclusions can be reached as to the composition of the compound which may be forming in the soil zone.

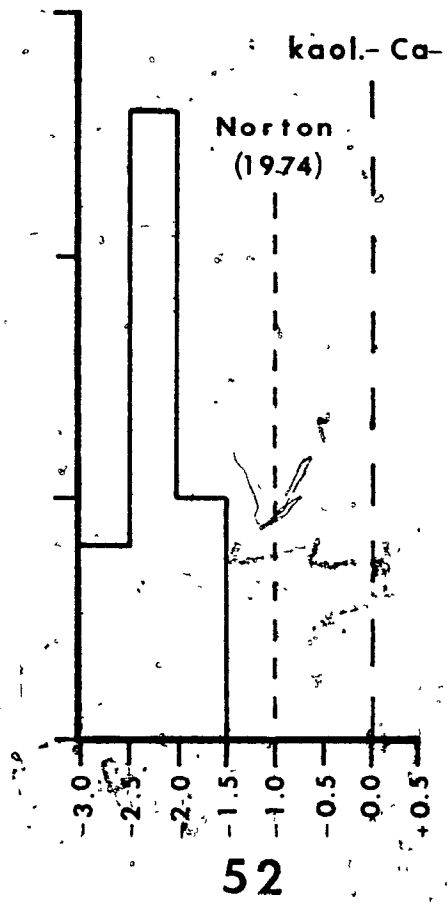
Influence of vegetation

From the plots of the constituents versus time (Appendix IV) one notes a relative increase of K^+ and Cl^- in the fall of

Figure 3-6. Histograms for the distribution over time of the saturation indices of the reaction Ca-montmorillonite to kaolinite for sample sites 51 and 52. The dashed line labled Norton (1974) refers to the saturation point recommended by him for this reaction.


15
10
5
0
FREQUENCY
kaol.- Ca-mont.
Norfon
(1974)
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
+0.5

51


kaol.- Ca-mont.
Norton
(1974)
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
-0.0
+0.5

52

the year for waters from sample site 51. This behavior is not apparent in waters from sample site 52. This anomalous behavior of K^+ and Cl^- is attributed to the uptake of these constituents by vegetation in the spring and summer and their release when the plants become dormant and decay in the fall of the year. Table 3-6 gives the average elemental concentrations in various types of vegetation (Bowen, 1966). Table 3-7 gives the ratios of constituents in plants to average concentration of these constituents in waters from sites 51 and 52. The highest ratios for all plants are K^+ and Cl^-, which indicates that addition of these two ions to the water by organic matter may be significant. Waters from site 52 do not show these features because K^+ and Cl^- are adsorbed by the overburden before the water reaches the well. The drill hole waters also do not show this effect for the same reason.

The zinc concentration in waters from site 52 was very low and near the detection limit. Therefore the analytical precision was very poor, and the periodical variations are quite inconclusive. Waters from site 51 had a higher zinc concentration, and thus more reliability. Samples 51d, 51h and 51j were the only samples which had particulate organic matter in them and had very high zinc values. If these samples are removed a much better correlation results between Zn^{2+} and the other constituents. There was no erratic machine noise upon analyzing these samples, thus the particulate organic matter was probably not aspirated directly into the flame of the atomic absorption spectrometer. The Zn^{2+} must therefore

TABLE 3-6.

Chemical composition of various plants. (Bowen, 1966)

Element	Mean Plant Concentration (ppm)			
	Bryophytes	Ferns	Gymnosperms	Angiosperms
Ca	3000.	3700.	6500.	18,000.
Mg	800.	1800.	1300.	3200.
Na	1100.	1400.	340.	1200.
K	2400.	18,000.	6300.	14,000.
S	1100.	1000.	1100.	3400.
Cl	670.	6000.		2000.
Si	2000.	5500.		200.
Zn	50.	77.	26.	160.
Cu	7.	15.	15.	14.

TABLE 3-7.

Plant-water ratios for the mean concentrations of constituents in waters from sample sites 51 and 52. These ratios indicate the constituents whose concentration in the water will be significantly affected by decaying plant material.

Element	Mean Water Concentration in (ppm)		Bryophyte Water in (ppm)		Fern Water in (ppm)		Gymnosperms Water in (ppm)		Angiosperms Water in (ppm)	
	51	52	51	52	51	52	51	52	51	52
Ca	23.4	14.0	128.	214.	158.	264.	278.	464.	770.	1290.
Mg	9.6	6.7	83.3	119.	188.	269.	135.	194.	333.	478.
Na	1.5	1.47	733.	748.	933.	952.	227.	230.	800.	816.
K	.18	.26	13,000.	9231.	100,000.	69,000.	35,000.	24,231.	77,800.	53,850.
S	14.6	11.0	75.3	100.	68.5	91.	75.3	100.	233.	310.
Cl	.61	.48	1100.	1396.	9800.	12,500.			3280.	4170.
Si	3.2	3.6	625.	556.	1720.	1530.			62.5	56.
Zn	.075	.021	667.	2381.	1030.	3670.	347.	1240.	2130.	7620.

have been released into solution after acidification. Only the samples with visible organic matter in them had high zinc during the fall, therefore contribution of Zn^{2+} directly into ground water by vegetation is not important. However, the plant water ratios indicate that zinc from vegetation could influence the water composition. It is therefore concluded that zinc remains complexed to the organic matter and is not readily leached except with acid solutions. The good correlation with Zn^{2+} and the other constituents after removal of the erratic values indicates that Zn^{2+} is not influenced by sorption onto soils or organic matter. This probably indicates that the various sediments are near saturation with respect to Zn^{2+}, and any additional adsorption is minor compared to the total zinc concentration.

Variations in the composition of waters from sample site 73

Waters from drill hole 73 have the most variable composition of waters from all the sample locations. Drill hole 73 also has the greatest flow rate, in the order of 40 liters per minute. Although site 73 is not in the immediate Eustis Mine area, it was sampled because of its unique character in having the largest flow and containing appreciable amounts of zinc (up to 7 ppm). The concentration versus time plot (Appendix IV) shows the large variation of the constituents with time. It should be noted that there is a large difference in the magnitude of the variation between the different constituents, which is pointed out by the standard deviations of the

log transformed data (Figure 3-3). A comparison of the raw data to the precipitation data (Appendix IV) indicates the strong dependency of the water composition on precipitation. The correlations of the elements in the raw data are excellent for all elements except HCO_3^-, Cl^-, pH and Fe^{2+} (Appendix V). This indicates that factors must control these parameters other than dilution or mixing of two waters. Biological activity may influence HCO_3^- and pH. Variable amounts of Cl^- may be due to variable concentrations of this ion in precipitation. The relatively poor correlation of Fe^{2+} is due to its removal by oxidation and precipitation.

The variation of the waters from sample site 73 cannot be considered to be dilution of a more concentrated water by a pure water. Plots of one constituent versus another never go through the origin, as would be the case for dilution. The constituent variation must therefore be due to mixing of a dilute water and a concentrated water.

Linear regression

Because the correlations of the constituents are so high it is possible to separate the waters into a dilute and a concentrated water. The most variable constituent is SO_4^{2-}, thereby indicating that it is the most likely constituent to have come mostly from the more concentrated water. Regression analysis with SO_4^{2-} as the independent variable should enable one to calculate the concentration of the other constituents by assuming a value for SO_4^{2-}. The correlations of SO_4^{2-} with HCO_3^- and Cl^- are relatively poor compared to the other con-

stituents, and these constituents were not estimated by regression analysis. Chloride concentration is low and is not a significant variable for the purposes of this discussion, thus it will be neglected. HCO_3^- will be calculated by charge balance equations. The two samples taken on the 17th of July, 1972 and on the 10th of October, 1972 had erratic iron values. The removal of these two samples resulted in much better correlation of iron with the other constituents and made a regression analysis meaningful. Table 3-8 gives the data resulting from these regression analyses.

Composition of the dilute water

In Chapter IV it is estimated that $10^{-3.5}$ molar was the maximum amount of sulfate which could result from oxidation of sulfides by oxygen-saturated surface water percolating below the water table. This value will be used for the concentration of sulfate in the dilute water. Inserting this value into the various regression equations results in the chemical composition of the dilute water. The charges are then balanced by the addition of HCO_3^-. The least precise variable to be estimated is the pH. It is unlikely that a dilute water will be saturated with respect to any minerals. One way of estimating the pH is by assuming a certain partial pressure of CO_2. Commonly the partial pressure of CO_2 in ground waters is well above atmospheric concentrations. This phenomenon has been attributed to biologic activity in the soil zone (Buckman and Bradey, 1960). A good average value is $10^{-2.5}$ and this is the value which will be used in the initial calculation. The following equation is what determines the pH.

TABLE 3-8.

Regression analysis of the constituents from waters flowing from drill hole 73 with SO_4^{2-} as the independent variable. Concentrations of the constituents in ~~millimoles per liter~~.

Dependent Variable	Correlation Coefficient	Intercept	Regression Coefficient	Standard Error of Estimate	Standard Error of Regression Coefficient
Ca^{2+}	.978	.275	.562	.076	.027
Mg^{2+}	.980	.376	.563	.073	.026
Na^{+}	.954	.0565	.025	.005	.002
K^{+}	.926	.00753	.0043	.001	.000
Zn^{2+}	.970	.01646	.0317	.005	.002
Mn^{2+}	.982	.00382	.0147	.002	.001
Fe^{2+}	.893	.00244	.00896		
HCO_3^{-}	.781	1.432	.392	.200	.070
H_4SiO_4	.907	.122	.0197	.006	.002

$$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$$

Therefore, $pH = \log a_{HCO_3} - \log P_{CO_2} - \log K_{B2}$

where a_{HCO_3} is the activity of HCO_3^-, P_{CO_2} is the partial pressure of CO_2 and K_{B2} is the equilibrium constant for this reaction. The activity coefficient of HCO_3^- was calculated with the Debye-Hückel equation. The equation for calculating this equilibrium constant at any temperature is given in Appendix I and is labeled B2. Table 3-9 gives the characteristics of this water after the above calculations have been performed.

Composition of the concentrated water

The concentration of the constituents in the concentrated water was calculated by analogy with sample sites 71 and 72. These two drill holes were very close to saturation with respect to gypsum, therefore the assumption that the concentrated component of the water from site 73 is saturated with respect to gypsum is reasonable. First a plot of Ca^{2+} activity versus SO_4^{2-} activity for the data from sample site 73 is made from data in Appendix VI. Lines are drawn for the stability boundary of gypsum, and the intersection of the Ca^{2+} activity versus SO_4^{2-} activity line with the gypsum boundary gives the activities of Ca^{2+} and SO_4^{2-} in the concentrated water.

A plot of ionic strength versus activity of Ca^{2+} and versus activity of SO_4^{2-} for the data from sample site 73 yields a straight line. The activity of Ca^{2+} or SO_4^{2-} at saturation with gypsum is plotted and the subsequent ionic strength is found. This makes it possible to calculate the activity coefficients and thus the total molarities of Ca^{2+} and SO_4^{2-} at

TABLE 3-9.

Chemical composition of the dilute and concentrated waters which mix to form the water flowing from drill hole 73.

Constituent	Dilute Water (ppm)	Dilute Water (mmoles/liter)	Concentrated Water (ppm)	Concentrated Water (mmoles/liter)
Ca^{2+}	18.1	.452	421	10.5
Mg^{2+}	13.5	.554	259	10.7
Na^{+}	1.5	.0644	11.8	.51
K^{-}	.35	.0089	3.4	.097
Fe^{2+}	.30	.0053	9.3	.17
Zn^{2+}	1.73	.0265	38.9	.60
Mn^{2+}	.47	.0085	14.9	.27
HCO_3^{-}	95.4	1.563	519	8.5
SO_4^{2-}	30.4	.316	1750	18.2
H_4SiO_4	12.2	.127	47	.49
pH	7.36		6.77	

gypsum saturation. This method is only accurate for ionic strengths below about .01, and since the ionic strength of this water is .05 there is a certain amount of error involved. This value for SO_4^{2-} is then inserted into the regression equations for the other elements and the concentrations are obtained. Again Cl^- will be ignored and bicarbonate will be calculated by charge balance. The pH will be calculated by assuming the water is in equilibrium with calcite, using this reaction:

$$H^+ + CaCO_3 \rightleftharpoons HCO_3^- + Ca^{2+}$$

The methods used to estimate the activities of Ca^{2+} and SO_4^{2-} will be used to estimate the activity of HCO_3^-. The final characteristics of this water are given in Table 3-9.

Saturation indices were calculated for the concentrated water, and for the dilute water assuming P_{CO_2}'s of 10^{-2}, $10^{-2.5}$ and 10^{-3}. The most important information is given in Table 3-10. The concentrated water is not saturated with respect to calcite and gypsum because of the error in estimating the activity coefficients.

The important point to emerge from these calculations is that the concentrated water must be considerably undersaturated with respect to calcite or highly supersaturated with respect to $ZnCO_3$, in order to have as much zinc present in solution. Another alternative would be that the concentrated water is in fact not as concentrated as believed. This would allow higher concentrations of zinc without being saturated with respect to $ZnCO_3$. Regardless of the exact composition, the concentrated water

TABLE 3-10.

Saturation indices of the two waters which mix to form the water flowing from drill hole 73.

Sample	pCO_2	$CaCO_3$ Solution	$FeCO_3$ Solution	Dolomite Solution	$ZnCO_3$ Solution	$MnCO_3$ Solution	$CaSO_4 \cdot 2H_2O$ Solution	Ca-mont. Kaolinite	Mg-mont. Kaolinite
Concentrated water	-1.27	-.106	-.781	-.086	.883	.063	-.347	+.489	+.666
Dilute 1	-1.988	-1.635	-2.46	-1.59	-.49	-1.36	-2.70	-2.255	-2.050
Dilute 2	-2.489	-1.136	-1.97	-1.087	+.005	-.86	-2.70	-1.755	-1.965
Dilute 3	-2.992	-.639	-1.49	-.59	+.50	-.36	-2.70	-1.255	-1.465

is remarkably similar to waters from sites 71 and 72. The main differences are high manganese, zinc and H_4SiO_4 concentrations in the waters from site 73. The abnormally high H_4SiO_4 does not fit in with what has been found in the areal samples (Chapter II). It is reasonable to expect that the H_4SiO_4 concentration is controlled by mechanisms similar to those hypothesized in Chapter II, therefore the concentrated water probably was in equilibrium with a secondary silicate and was in fact more dilute than that calculated and given in Table 3-9.

The H_4SiO_4/Na^+ ratio of the concentrated water is near 1 whereas for the dilute water the ratio is about 2. This corroborates the findings in Chapter II that the H_4SiO_4/Na^+ ratio is useful in distinguishing shallow water from deeper water. The dilute water resembles waters from sites 51 and 52. This indicates that all these waters had a similar evolutionary history.

Considering that sample site 73 gets a minimum of 82% of its water from the dilute and presumably near surface water, the water temperature is remarkably stable. The standard deviation indicates the temperature variation of the water is similar to waters from sites 71 and 72 and that the temperature variation is much less than the waters from the spring sample sites 51 and 52. The mean water temperature is also similar to waters from sample sites 71 and 72 (Table 3-11). These facts indicate that the dilute water has been in the ground sufficiently long to have equilibrated with the temperature of the bedrock.

TABLE 3-11.

Means and standard deviations of water temperature of samples taken periodically.

SAMPLE SITE	MEAN	STANDARD DEVIATION
71	7.68	.161
72	7.86	.126
73	7.68	.176
51	11.2	4.9
52	8.18	2.2

It therefore can be concluded that the water flowing out of sample site 73 is a mixture of two waters. The concentrated water has participated in the surface oxidation of sulfides, producing sulfuric acid. This acid water then was neutralized mainly by carbonate minerals. The composition of the dilute water resulted from the reaction of carbonic acid with silicates and carbonates, and is probably buffered by the soil zone, similar to waters from sample site 52.

Source of the water flowing from drill hole 73

The most concentrated water comprising waters from sample site 73 indicates extensive surface oxidation. There is no field evidence for any oxidizing mineralization, therefore the high sulfate content must be due to contamination from previous mining activity. The nearest source of contamination is the old Howard Mine (closed ca. 1893), which reached a depth of 92 meters. This mine is located topographically higher than drill hole 73 (Figure 3-2) thus there would be enough head for the water to travel to the drill hole. Drill logs of other drill holes located between sample site 73 and the mine shaft indicate zones of fractured rock stained with rust at depths varying from 7 to 15 meters. The drilling water was lost in these holes. This is good evidence for a highly permeable fractured rock, which could easily transmit water from the old mine shaft to the drill hole. It must be concluded then that the Zn^{2+} and SO_4^{2-} concentration in waters from drill hole 73 is due to contamination from old mine workings.

SUMMARY AND CONCLUSIONS

Precipitation and evapotranspiration do not have a drastic effect on the periodical variations of the chemical constituents in this area. Rather the effect of both precipitation composition and volume appear to be averaged over time. Apparently the infiltrating water gains constituents rapidly upon infiltrating through the soil zone, and therefore has its composition buffered by the soil zone. Evapotranspiration does appear to cause the precipitation of secondary clay minerals in the upper soil zone, as indicated by the variations of constituents in waters from sample site 51. This water becomes saturated with respect to these minerals during the months from late spring to early fall when evapotranspiration is important. The poor correlations of K^+ and Cl^- with many of the constituents in waters at most of the sample sites may be due to variations in the concentrations of these constituents in precipitation, but the effects are quite minor. During the fall of the year, when most of the vegetation becomes dormant, K^+ and Cl^- are released by the decaying vegetation in quantities which markedly increase the concentration of these constituents in the dilute surface water. This phenomenon, however, is not observed for a sample which gains its water after percolating through extensive overburden. Apparently this again is due to adsorption and buffering by the overburden. Release of Zn^{2+} by decaying vegetation might also be important, but this element appears to stay in the biomass and is released into solution only upon acidification.

Drill hole waters 71 and 72 gain most of their dissolved constituents from contamination by the Albert Mine dump. Water percolates downward from the mine dump and seeps into the old shaft. This shaft water percolates at least 245 meters through fractured metarhyolite until it is intercepted by the drill holes. During this passage most of the Zn^{2+}, Fe^{2+} and Cu^{2+} are lost from solution. Equilibrium relations indicate that these ions are precipitated as $FeCO_3$, $Fe(OH)_3$, malachite or cuprite, $ZnCO_3$ and adsorption on $Fe(OH)_3$. Approximately 218 tons of Cu, 163 tons of Zn and 836 tons of Fe have been leached from the mine dump, with most of it being reprecipitated in the bedrock. The effectiveness of the bedrock in removing the high concentrations of metals in solution indicates that a method might be developed similar to this in areas of problem mine drainage to cleanse the water of most of its unwanted constituents.

Waters from drill holes 71 and 73 appear to gain their water from two sources, one dilute and oxygenated and the other concentrated due to surface oxidation of sulfides. The excellent correlations between constituents allows one to calculate the concentration of the various constituents in the dilute and concentrated portion of waters from drill hole 73. The dilute water resembles waters from sample sites 51 and 52, while the concentrated portion resembles waters from drill holes 71 and 72. The source of the concentrated water in sample site 73 is from contamination by old mine workings, whereas the dilute water probably represents infiltrating precipitation which percolates downward and mixes with the concentrated water.

CHAPTER IV HYDROGEOCHEMICAL EXPLORATION AND SOURCES OF ANOMALOUS WATERS

Reconnaissance sampling of springs and drill holes with analysis for copper and zinc was conducted so that the anomalous areas could be investigated in more detail. The purpose of this study was to develop a method, using chemical analyses of water in conjunction with geomorphic and geologic evidence, for locating the sources of anomalous waters, whether they be from contamination, known mineralization or hidden mineralization. This investigation has resulted in the development of methods for estimating the travel distance, the extent of contact with oxidizing sulfides and the approximate source area of a water. The location of new hidden ore deposits was not an immediate goal of this study because extensive contamination due to past mining activity in the area of investigation makes the results difficult to interpret.

THEORETICAL CONSIDERATIONS

Estimation of the time of contact and travel distance of the Eustis waters

Albite is the only significant Na-bearing mineral in the Eustis Mine area (Stevenson, 1934). I have used Paces (1973) method to determine time of contact of waters with albite and then have estimated the distance of water travel using Darcy's Law. Paces determined that the weathering of albite, with subsequent release of Na into solution, is a good method of estimating time of contact between rock and water. The following

equations derived by Paces are appropriate for use when the system is far from equilibrium and the molarity of Na^+ in solution is much less than its equilibrium molarity with albite:

$$tp = (m_i - m_i^o)/k_1 \qquad (4\text{-}1)$$

where tp equals time, in days, of percolation of the water in contact with albite, m_i equals total molarity of Na^+ in water, m_i^o equals Na^+ from sources other than albite in moles per liter, and k_1 equals the rate constant in moles per liter per day for the breakdown of albite to an amorphous aluminosilicate.

$$k_1 = ((\bar{s}/\phi)n_i D)/L_1$$

where $\bar{s}$ is the surface area of albite per 1000 cm^3 of rock, ϕ is the porosity, n_i is the number of moles of Na per unit volume of albite, D is the diffusion of coefficient of Na from albite through the residual amorphous surface layer and L_1 is the steady state thickness of the residual amorphous surface layer. The reaction of albite going to amorphous aluminosilicate is (Paces, 1973, slightly corrected to balance):

$$NaAlSi_3O_8 + H^+ + \left[(7-9x)/(1-x)\right] H_2O =$$

$$\left[1/(1-x)\right]\left[\left[Al(OH)_3\right]_{(1-x)}\left[SiO_2\right]_x\right] + Na^+ +$$

$$\left[(3-4x)/(1-x)\right] H_4SiO_4 \qquad (4\text{-}2)$$

where x represents the molar fraction of silica in the isoelectric amorphous aluminosilicate and is a function of pH.

$$x = 1.24 - .135\ pH$$

The log of the equilibrium constant for this reaction is (Paces, 1973):

$$\log K_1 = \left[3.94 - \left[1 / (1-x)\right] (8.6 - 11.3x)\right]$$

The saturation index which is the log activity product/equilibrium constant for reaction (4-2) has been calculated for each of the samples having complete chemical analyses. These indices are listed in Table 4-1. From this table it can be seen that all of the samples in this study are highly undersaturated, and therefore equation (4-1) can be used.

Distance of water travel can be calculated from Darcy's Law:

$$Q = K_2 A(\Delta H/L_2) \qquad (4-3)$$

where Q equals the quantity of water flowing through a cross section of area, A, in cubic meters per day. K_2 is the coefficient of permeability in meters per day. ΔH is the head loss over the travel distance, L_2, in meters.

$$K_2 = Bk_2 g\rho/\mu \qquad (4-4)$$

where k_2 equals the intrinsic permeability in darcy's, ρ equals the density of the solution and μ is the dynamic viscosity of the solution in centipoise, g is the gravitational force and equals 976 g - cm/sec^2 and B is a constant (8.53×10^{-4}) which changes K_2 into units of meters per day.

ρ/μ varies with temperature and has a value at 5°C of .658 and at 15°C of .877 (Weast, 1969).

TABLE 4-1.

Saturation indices for the reaction albite to amorphous aluminosilicate. A negative saturation index indicates undersaturation with respect to albite.

Drill Hole Waters		Spring Waters	
Sample	Saturation Index	Sample	Saturation Index
53	-2.127	1	-3.993
54	-3.778	6	-4.313
55	-3.264	7	-3.809
58	-2.301	23	-4.315
64	-2.984	25	-5.474
65	-3.499	30	-3.600
66	-1.965	41	-3.545
68	-4.053	51	-3.067
70	-2.826	52	-3.842
71	-2.625		
72	-2.680		

Simplifying (4-4) gives:

$$K_2 = .832\, k_2 \rho/\mu \qquad (4\text{-}5)$$

Since Q/A equals velocity

$$Q/A = L_2/tp \qquad (4\text{-}6)$$

where tp equals time of travel in days.

Substitution of (4-6) and (4-5) into (4-3) and rearranging results in:

$$L_2^2 = .832\, k_2(\rho/\mu)\Delta H\, tp \qquad (4\text{-}7)$$

and substituting equation (4-1):

$$L_2 = \left[.832\, k_2(\rho/\mu)\Delta H(m_i - m_i^o)\, k_1\right]^{\frac{1}{2}} \qquad (4\text{-}8)$$

Equation (4-8) is the basic equation which will be used for determining the travel distance and the source area of anomalous waters in the Eustis Mine area.

Estimation of the length of the flow path in the zone of oxidation in contact with pyrite

The theoretical background for the estimation of the total flow path has been described. The part of this total path which is in the oxidizing zone can also be estimated in the following way. The sulfate concentration is a good indication of the extent of oxidation of sulfides, provided that sulfide minerals are the primary source of sulfur. The only other source of sulfur in this area would be atmospheric contributions. The average concentration of sulfate in precipitation is 0.038 millimoles (Chapter 2, Pearson and Fisher, 1971). This concentration will be assumed to be the lower limit found in waters of this area. There are two types of oxidation of sulfides possible, subsurface oxidation

(mainly inorganic processes) and surface oxidation (including both organic and inorganic processes). These will be discussed with respect to pyrite.

Subsurface oxidation of pyrite

The solubility of atmospheric O_2 in pure water at 0^oC is .44 millimoles per liter. Seven moles of O_2 produce 4 moles of sulfate according to this reaction:

$$FeS_2 + 7/2\ O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$$

If precipitation is saturated with O_2, removed from further contact with the atmosphere and then reacts with sulfide to produce sulfate, .25 millimoles per liter of sulfate will be the maximum amount which can be formed. This figure may vary due to an increase or decrease in the local partial pressure of O_2 in the soil zone. Also the solubility of oxygen is decreased at temperatures greater than 0^oC and in impure aqueous solutions. This subsurface contribution is added to the atmospheric contribution (.038 mmoles/liter) to produce a maximum total sulfate contribution of .29 millimoles per liter (28 ppm). This quantity is further reduced if any of the oxygen is used up by the oxidation of organic carbon. Therefore it is evident that any quantity of sulfate greater than this amount must have been produced by surface oxidation of sulfur-bearing compounds.

Organic surface oxidation of pyrite

Sulfide oxidation rates are greatly accelerated by the activities of acidophilic iron and sulfur oxidizing bacteria (Silverman, 1972). The primary species, thiobacillus ferrooxidans, ferrobacillus ferrooxidans and ferrobacillus sulfooxidans, only

grow well in acidic inorganic media (pH 2.5 - 4.5). Ferrous iron is the major energy source, but these bacteria are differentiated according to their ability to use inorganic sulfur compounds as alternate energy sources. The oxidation by these organisms is by far more rapid than the oxidation by inorganic mechanisms and is probably the most important factor in the oxidation of pyrite under acidic conditions, whereas the opposite is true under near neutral and basic conditions. Waters with an acid pH and a high sulfate content are a sure indication of extensive surface oxidation of sulfide by bacterial action because the rate of oxidation of pyrite by purely inorganic processes is slow at low pH levels, as will be indicated in the next section of this chapter.

Inorganic surface oxidation of pyrite

Stumm and Morgan (1970) cite various authors in summarizing the inorganic oxidation of pyrite under surface conditions in equilibrium with atmospheric oxygen. The oxidation of pyrite is influenced by the following steps:

Initial step:

$$FeS_2 + 7/2\ O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$$

Rate controlling step:

$$Fe^{2+} + \tfrac{1}{4}\ O_2 + H^+ = Fe^{3+} + \tfrac{1}{2}\ H_2O \qquad (4\text{-}9)$$

$$Fe^{3+} + 3H_2O = Fe(OH)_3 + 3H^+$$

$$FeS_2 + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \qquad (4\text{-}10)$$

Two points should be made with regard to these reactions. The slowest reaction or rate controlling step is the oxidation of Fe^{2+}. The fastest reaction is the oxidation of pyrite by

by Fe^{3+} ion. Therefore once the reaction is initiated, the oxidation of pyrite cycles through reactions (4-9) and (4-10).

Stumm and Morgan (1970) also indicate that the reaction rate of ferrous ion oxidation is independent of pH when the pH is less than 4, and obeys the following rate law, where species in parentheses represent activities:

$$k_3 = -d \log (Fe^{2+})/dt$$

where the rate constant $k_3 = 10^{-3.6}$ moles/liter/day at 25°C. When pH is greater than 4 the rate law is:

$$-d(Fe^{2+})/dt = k_4 (Fe^{2+})(OH^-)^2 P_{O_2} \qquad (4\text{-}11)$$

where the rate constant k_4 equals 8×10^{13} min^{-1} atm^{-1} $mole^{-2}$ at 20°C. Therefore the maximum possible amount of sulfate due to inorganic surface oxidation of sulfides is controlled by these kinetic steps.

Extended contact of ground water with oxygen requires near surface flow for a considerable distance. A very rough, order of magnitude, estimate of the distance of water flow in the zone of free interchange with oxygen can be estimated for situations where organic activity is not significant by making the following additional assumptions:

(1) An increase in Fe^{2+} concentration is restricted by the reaction:

$$FeCO_3 + 2H^+ = Fe^{2+} + CO_2 + H_2O$$

The equilibrium constant for this reaction

$$= K_3 = (Fe^{2+}) P_{CO_2}/(H^+)^2 = 10^{8.07} \qquad (4\text{-}12)$$

where P_{CO_2} is the partial pressure of carbon dioxide

gas and is equal to its fugacity.

(2) The pH is assumed to be greater than 4, so that equation (4-11) is used.

(3) The atmospheric partial pressure of O_2 ($10^{-0.7}$) is used and is equal to its fugacity.

(4) The activities and fugacities of the constituents are equal to their respective molarities and partial pressures.

Substitution of equation (4-12) into the rate law equation (4-11) and the values for the partial pressure of oxygen results in the following equation:

$$-d(Fe^{2+})dt = 1 \times 10^{-3.57}/P_{CO_2} \text{ moles/liter/day}$$

From equation (4-10) one notes that for every mole of sulfate produced, 7 moles of Fe^{3+} are reduced. The quantity of Fe^{3+} produced per unit time equals $-d(Fe^{2+})/dt$ (equation 4-9). Therefore:

$$d(SO_4^{2-})/dt = 1/7\ -d(Fe^{3+})/dt = 10^{-4.42}/P_{CO_2} \text{ moles/liter/day}$$

The distance a water has traveled in the oxidation zone, L_{ox}, is determined by using the following equation.

$$L_{ox} = K_2(SO_4^{2-})(P_{CO_2})/10^{-4.42} \qquad (4\text{-}13)$$

The sulfate concentration used in this calculation should be that which is produced solely by the oxidation of sulfides in the surface environment. Contributions from atmospheric, subsurface oxidation, soil and biologic sources should not be included. The atmospheric contributions have already been discussed and may be removed. A difficult contribution to evaluate is that of subsurface oxidation. Nevertheless for this study a

maximum of .25 millimoles will be assumed. Probably the actual amount is considerably less, especially in surface spring waters. Bacterial activity becomes of importance in acid pH conditions ($pH < 4.5$) and would invalidate the distance calculation. Unreasonably large calculated distances would most probably be due to this effect.

RESULTS AND INTERPRETATION

Between-site and within-site compositional variation

During the summer of 1972, fifty-four surface and twenty drill hole waters were sampled from the locations shown in Figures 4-1 and 4-2. These were analyzed for zinc and copper and complete chemical analyses were performed on nine surface and eleven drill hole waters. The analytical techniques used are described in Chapter I. Most of the samples were taken in June and July (Table 4-2) and these two months broke previous records for the greatest total monthly precipitation. Indeed, July was the wettest month in recorded history, with a total of eight inches of rainfall. Duplicate sampling at sample sites 7 and 41 and periodical sampling at sample site 51 in June, July and August showed that variation in water composition at individual sites sampled at different times was small compared to differences between sites. Table 4-3 gives the results of the most variable samples. The differences between paired samples are, in most cases, little greater than possible analytical error, and can be considered as insignificant.

The surface waters were seeps, springs, small intermittent streams and one stagnant pool. The description of the environ-

Figure 4-1. Location of surface waters, recharge areas as determined by the method described in the text, and samples anomalous in copper and zinc. A, B, C are water anomalies referred to in the text. Eu, Al and Ca are the Eustis, Albert and Capel mines respectively.

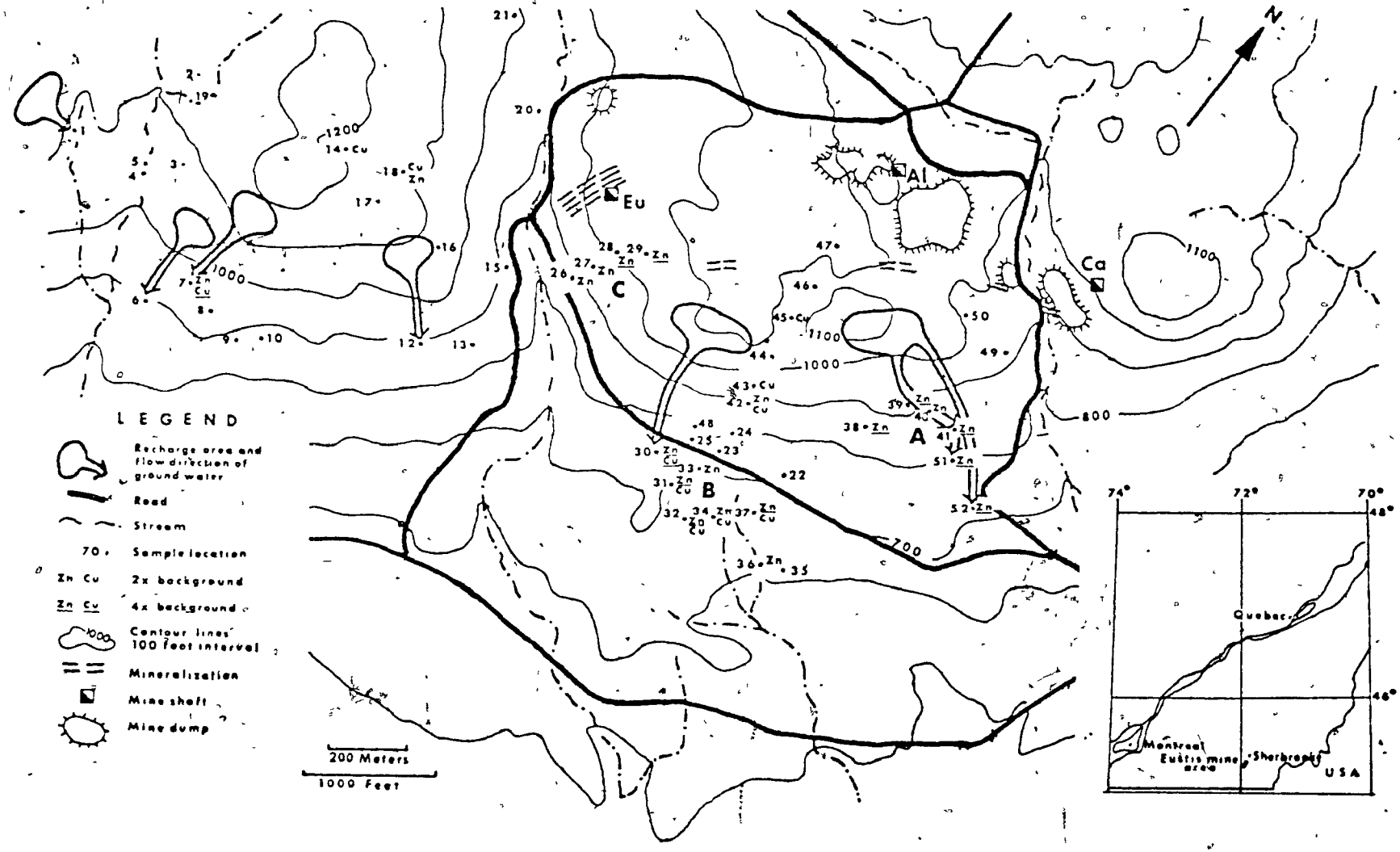

LEGEND
Recharge area and flow direction of ground water
Road
Stream
70 • Sample location
Zn Cu 2x background
Zn Cu 4x background
1000 Contour lines 100 foot interval
Mineralization
Mine shaft
Mine dump
200 Meters
1000 Feet
Eu
Al
Ca
A
B
C
N
74°
72°
70°
48°
46°
Quebec
Montreal
Eustis mine area
Sherbrooke
USA

Figure 4-2. Location of drill hole waters, recharge areas determined by the method described in the text, and samples anomalous in copper and zinc. Eu, Al, Ca and V are the Eustis, Albert Capel and Victoria mines respectively.

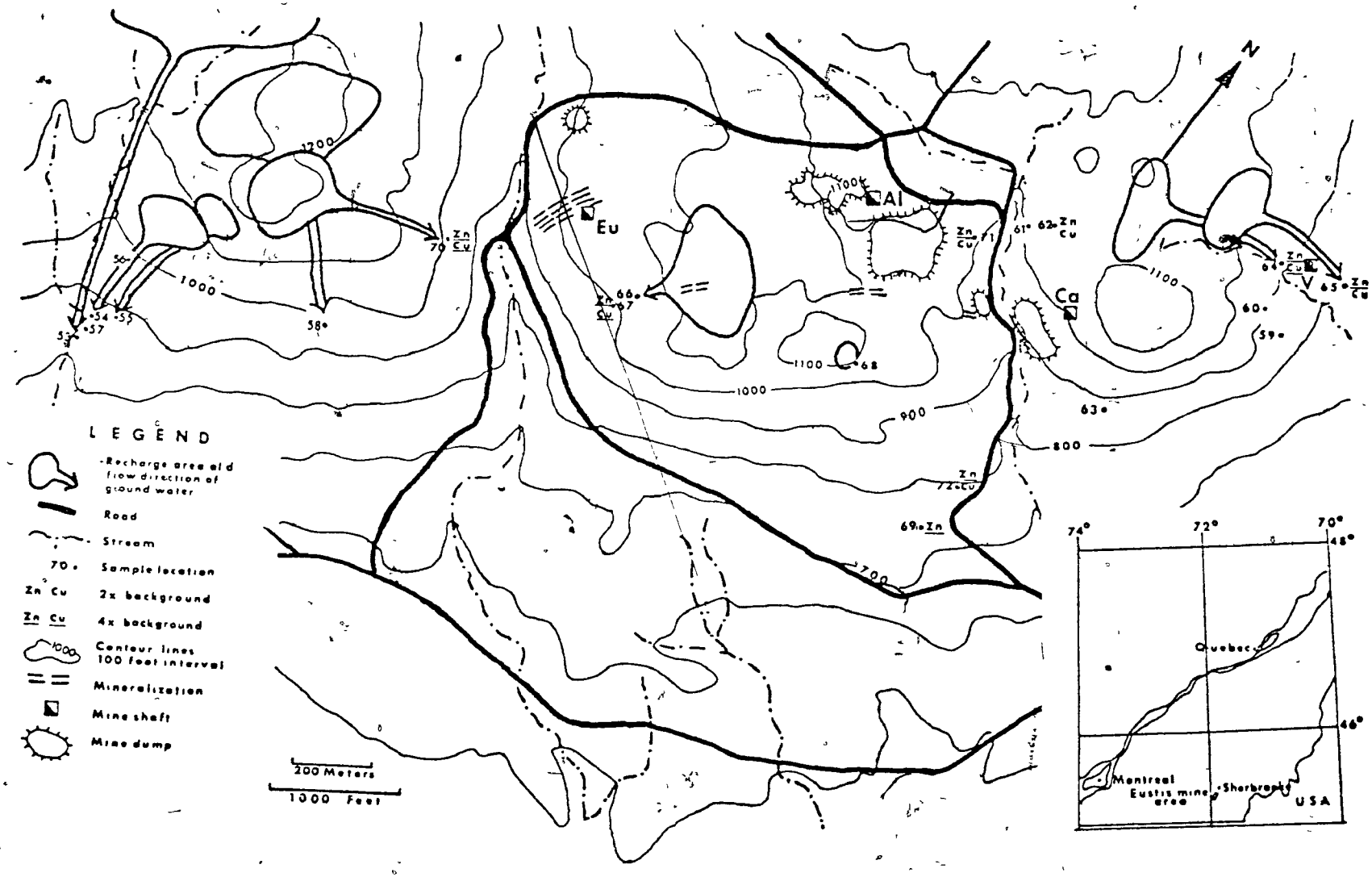

LEGEND
Recharge area and flow direction of ground water
Road
Stream
70 • Sample location
Zn Cu 2x background
Zn Cu 4x background
Contour lines 100 feet interval
Mineralization
Mine shaft
Mine dump
200 Meters
1000 Feet
Eu
Al
Ca
V
1200
1000
1100
900
800
700
N
74°
72°
70°
48°
46°
Quebec
Montreal
Eustis mine area
Sherbrooke
USA

TABLE 4-2.

Dates that springs and drill holes were sampled.

Surface Water

Samples	Date
1 to 13	June 3, 1972
14 to 17	June 4, 1972
18 to 21	June 5, 1972
22 to 41	July 20, 1972
42 to 50, 41a	July 23, 1972
7a	August 21, 1972
51, 52	Periodically

Drill Hole Water

Samples	Date
53 to 57	June 3, 1972
58	June 4, 1972
59 to 65	July 18, 1972
66	July 20, 1972
67	July 21, 1972
68	July 23, 1972
69	August 20, 1972
70	August 21, 1972
71, 72, 73	Periodically

TABLE 4-3.

Comparison of waters taken at the same locations on different dates during the period of June to August 1972. Concentrations in parts per million.

Sample Date	Ca^{2+}	Mg^{2+}	HCO_3^-	SO_4^{2-}	Na^+	K^+	Cl^-	Zn^{2+}	H_4SiO_4
7 3/6/72	18.9	3.2	65.	9.	1.4	.19	.6	.034	13.8
7a 21/8/72	21.	3.5	74.	9.	1.6	.20	.6	0	14.7
41* 20/7/72	26.	8.8	75.	38.	1.7	.41	.34	.05	12.
41a* 23/7/72	27.4	9.4	75.	44.	1.75	.39	.25	.04	11.7
51a 29/6/72	25.5	10.2	76.	40.	1.6	.26	.23	.06	13.
51e 20/8/72	27.5	11.5	85.	46.	1.63	.18	.34	.07	13.6

* 1.5 inches of rain fell on July 21, 1972.

ment is given in Appendix III.

Zinc and copper distribution

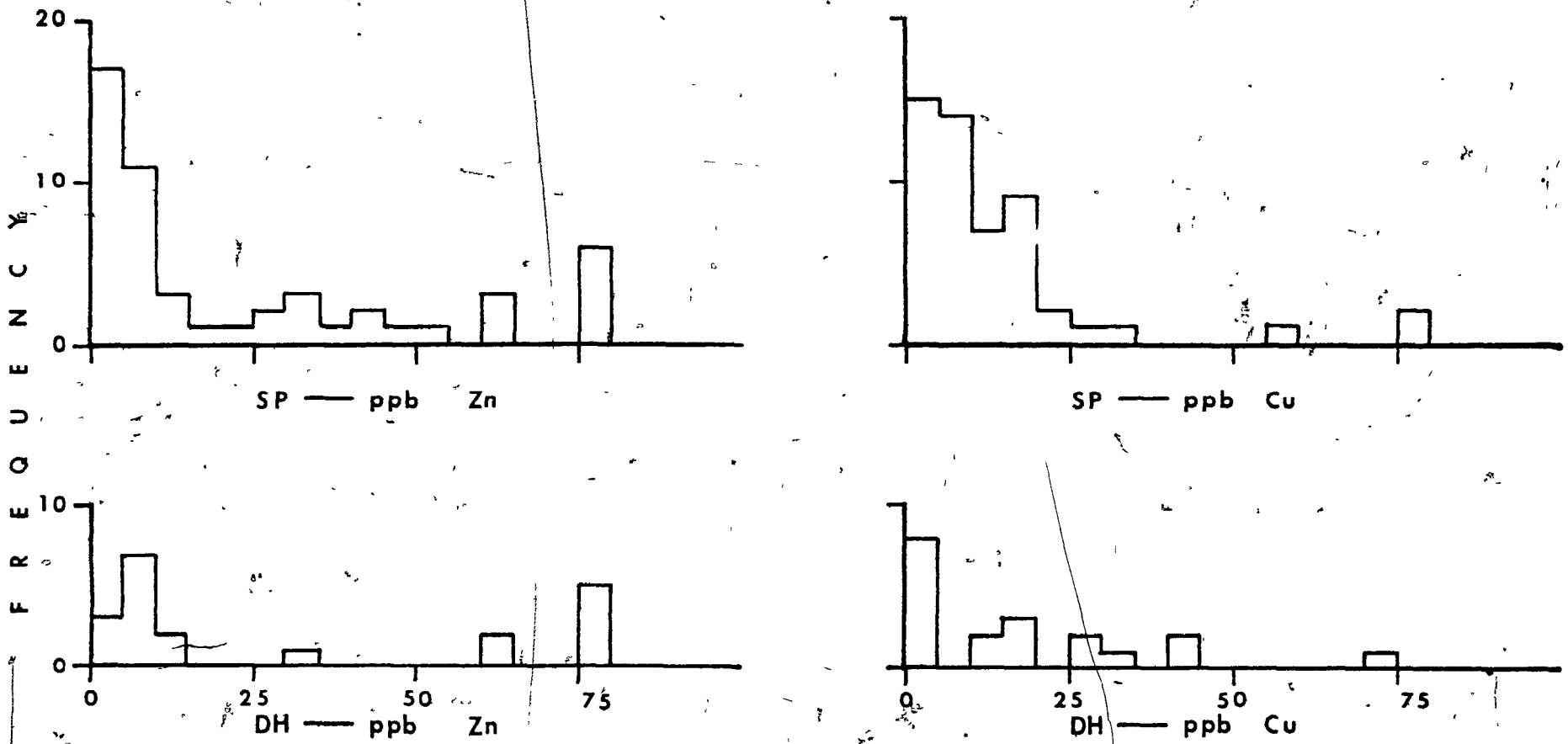
The areal samples which were collected in the Eustis Mine area were analyzed for zinc and copper by the extraction method described in Chapter I. The sample locations and results are shown in Figures 4-1 and 4-2. The median was considered to represent local background and two levels of anomalous values were arbitrarily chosen at two and four times the median values. More sophisticated methods of separation were investigated, but because of the small number of samples and irregular distribution it was decided that the above method would be as good as any. The median for springs is: Zn = 8 ppb and Cu = 8 ppb; and for drill holes: Zn = 8 ppb and Cu = 10 ppb. Figure 4-3 shows histograms of the Cu - Zn distribution.

The area of study is relatively small and has considerable mineralization within it; therefore a high proportion of the samples are anomalous.

Determination of the hydrologic constants in the Eustis Mine waters

One spring (site 51) will be used for calibration purposes to estimate the constants necessary to solve equation (4-8). This requires the assumption of a recharge area for this spring. The time from recharge to discharge can be estimated from comparison of periodical variations in chemical composition to precipitation. Sample 51 was sampled 22 times in a period of 14 months. Comparison of chemical composition with precipitation

Figure 4-3. Histograms showing the zinc and copper distribution in springs (SP) and drill hole waters (DH).


FREQUENCY
20
10
0
SP — ppb Zn
SP — ppb Cu
10
0
0
25
50
75
DH — ppb Zn
DH — ppb Cu

indicates a percolation time of approximately 30 days during the dry season (Appendix IV). The maximum Na^+ concentration during the dry season (sample 51i taken on September 9, 1973, with a concentration of .0886 millimoles/liter) will be used for determining the rate constant k_1.

The atmospheric contribution of Na^+ is assumed to be the only significant source of Na^+ other than the weathering of albite. It has frequently been assumed (e.g., Garrels and Mackenzie, 1967; Bricker et al., 1968; Paces, 1973) that Na^+ from sources other than plagioclase is electrically balanced by Cl^- and that all the Cl^- in solution comes from these sources. In Chapter III it was found that leaching of vegetation can add appreciable amounts of Cl^- but negligible amounts of Na^+ to waters. Therefore erroneous results can occur with the method used by previous authors.

In the present study the Na^+ concentration of sample 41, .0135 millimoles per liter, is used as the atmospheric contribution. It had less Na^+ than the average atmospheric value reported by Pearson and Fisher (1971) and was sampled in June from a small pool which probably gains its water from snow melt and precipitation.

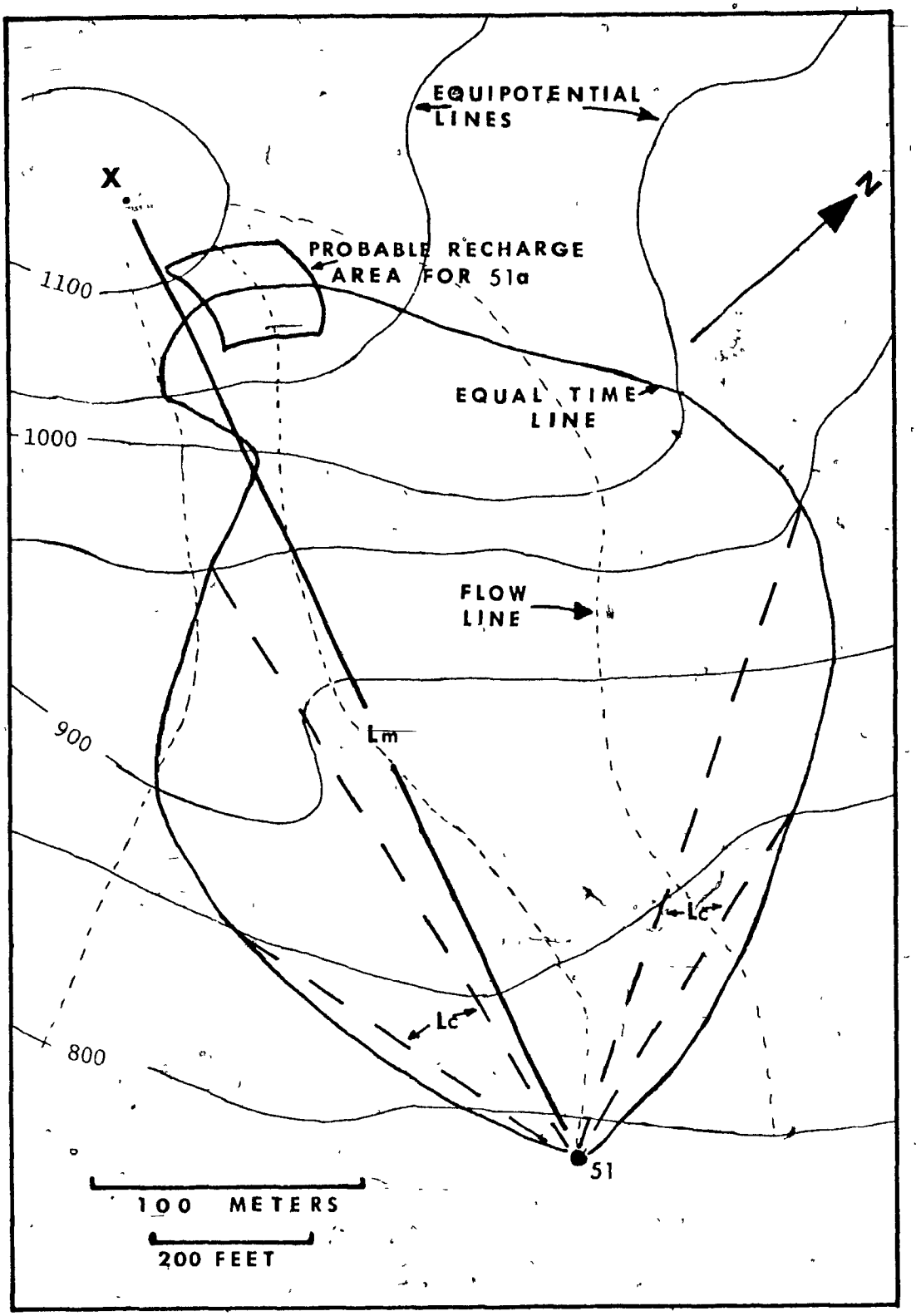
The albite derived Na^+ concentration, $m_i - m_i^o$, is, therefore, .0751 millimoles per liter. Substituting these values into equation (4-1) results in a k_1 equal to 2.5×10^{-6} moles per liter per day. Paces (1973) value for fractured metamorphic rocks is 1.73×10^{-6} moles per liter per day indicating some degree of similarity between terrains.

The permeability in metamorphic rocks may be very low, 10^{-6} darcys (Davis, 1969), or very high, 100 darcys (Paces, 1973), depending upon the abundance of fractures. The permeability is also increased by the dissolution of carbonate minerals so commonly associated with these types of rocks (Davis and DeWiest, 1966).

The intrinsic permeability is estimated using equation (4-7). The water temperature of sample 51i was 13.1°C. This results in a ρ/μ of .83 (interpolated). The horizontal distance of travel and head is estimated from Figure 4-4 which shows the approximate water table and flow direction for the ground waters in the vicinity of site 51. This map was constructed using the available hydrologic information, field observation and topographic contours. The periodical water temperature variations indicate that the water is not in equilibrium with the bedrock temperature, but is affected by the air temperature. This indicates that the water flow path is only a few feet beneath the surface; therefore the nearest recharge area, X (Figure 4-4), should be the source for most of the water. Water may be added all along the flow path during periods of precipitation, but the regularity of chemical variation over time indicates that these additions do not have a sudden influence on the composition of the water.

The measured distance from recharge (point X) to discharge for 51i, L_m, is taken to be 400 meters and ΔH is equal to 90 meters (Figure 4-4). Substitution of these values into equations (4-7) and (4-5) results in an apparent intrinsic permeability of 71 darcys (perhaps fortuitously Paces (1973) estimate of permeability in fractured metamorphic rocks was 50 darcys) and a coefficient of permeability of 49 meters/day.

Figure 4-4. Illustration of the method of determining the location of recharge areas. For convenience of illustration the calibration site and example site are at the same location, site 51. For calibration L_m is the measured distance from the assumed recharge area, X, of sample 51i to the discharge point. Lines L_c are percolation distances to recharge areas calculated from equation (4-8) for sample 51a for different hydraulic heads. Equipotential lines are contoured at 50 foot intervals.


EQUIPOTENTIAL LINES
X
N
PROBABLE RECHARGE AREA FOR 51a
1100
EQUAL TIME LINE
1000
FLOW LINE
900
Lm
Lc
Lc
800
51
100 METERS
200 FEET

This is an apparent permeability because the flow path was taken to be a straight line from recharge to discharge. In reality this will not be the case, but for this discussion a straight flow path is more convenient. This coefficient of permeability will be applied to the other samples in attempting to locate the source areas of the waters.

Determination of the location of recharge areas

The zone of recharge is calculated using equation (4-8), substituting $m_i - m_i^o$ (Table 4-4), the intrinsic permeability calculated above, and the appropriate constants for the temperature of the waters. Increments of ΔH at 50 foot intervals are substituted in equation (4-8) to calculate the percolation distance, L_c, for different heads. The intersection of these distances with the equal potential lines corresponding to the heads forms a line of equal travel time. The flow direction is estimated by constructing flow lines perpendicular to the equal potential lines. The intersection of the flow line with equal time line indicates the probable infiltration area. Figure 4-4 graphically illustrates these features for sample 51a.

The composition of water at any point in a flow path is actually the result of the mixing of waters all along the flow path. During periods of low or no rainfall the water ultimately comes from the main recharge area. During periods of rainfall, however, infiltration all along the flow path reacts with the bedrock and overburden, and then mixes with the water from the main recharge area, diluting it. The recharge area calculated

TABLE 4-4.

Parameters necessary for estimating the environment and depth of the flow path for spring and drill hole waters.

Sample	Na^{+} [a,c]	SO_4^{2-} [a,c]	Zn^{2+} [d]	Cu^{2+} [d]	Fe^{2+} [d]	H_4SiO_4/Na^{+} [a]	log P_{CO_2}	$C/10^6$	L_{ox} [e,f]	L_{ox} [e,g]	pH
1	.034	.24	.005	.005	ND[h]	3.0	-2.2	14	2.2	0	7.2
6	.038	.08	.005	.011	ND	2.9	-1.9	48	1.5	0	6.6
7	.047	.08	.034	.056	ND	2.9	-1.8	29	1.8	0	6.6
12	.034	.08	ND	.008	ND	2.8	-2.1	59	1.1	0	6.8
13		.08	.015	.020	ND	4.0[b]	-2.0		1.4	0	6.4
30	.042	.13	.026	.014	.25	3.1	-2.6	23	.5	0	7.1
31	.039	.28	.05	.015	ND	2.0	-2.5	20	1.7	.6	7.3
51a	.056	.40	.03	ND	ND	2.3	-2.8	26	.9	.3	7.6
52a	.062	.39	.04	ND	ND	1.7	-2.3	24	2.8	1.0	6.8
53	.46	.24	ND	.02	ND	.4	-2.5	58	1.1	0	7.8
54	.068	.29	.005	.02	ND	1.2	-2.3	27	2.0	.7	7.5
55	.060	.14	.005	.01	ND	1.9	-2.6	28	.5	0	7.8
58	.18	.40	ND	.01	ND	.9	-2.3	7	2.8	1	7.3
64	.099	.27	.13	.03	ND	1.6	-2.3	8	2.0	.7	7.4
65	.064	.26	.11	.05	1.8	2.0	-2.3	23	1.7	.7	7.2
66	.18	.29	.005	.01	.32	1.4	-2.6	31	1.0	.4	7.7
68	.051	.07	.01	ND	ND	2.4	-1.9	5	1.2	0	6.6
70	.11	.49	.155	.07	3.1	2.1	-2.1	20	5.1	2.5	7.0
71a	.24	6.3	2.92	.03	2.6	1.1	-1.3	2	440.0	420.0	6.6
72a	.49	12.8	.47	.08	71.0	.5	-1.0	3	1700.0	1700.0	6.4

[a] Atmospheric contribution subtracted. [b] Raw value of Na^{+} used. [c] In millimoles per liter. [d] In ppm. [e] In meters. [f] Assuming no subsurface oxidation. [g] Maximum subsurface oxidation assumed. [h] None detected.

from this mixture will appear to be closer to the discharge point. For this reason an exact point of recharge cannot be determined and the recharge zone is considered to be an area. Figures 4-1 and 4-2 contain the calculated recharge areas and flow paths for the samples which had adequate data.

A simplified method for determination of the location of recharge areas

The method of locating the recharge area can be greatly simplified by making the following assumptions. Assume that effects of temperature variation are minor and the temperature is constant; then ρ/μ in equation (4-8) is constant and can be combined with .832, k_2 and k_1 to form a constant, C (C would have the value 2.4×10^7 meters/mole for the Eustis Mine waters assuming the water temperature of sample 51i, 13.1°C). Therefore equation (4-8) becomes:

$$L_2 = \left[C \times \Delta H \times (m_i - m_i^o) \right]^{\frac{1}{2}} \qquad (4\text{-}14)$$

This simplification eliminates the need of finding the time of contact, permeability, etc. in a new area of exploration. It is only necessary to determine a value for C by calibration with a spring whose recharge area is known. The degree to which this estimate of C will be representative for a given area will be dealt with in the next section.

Factors affecting the estimate of C

A check on the stability of C was made in the Eustis area by arbitrarily assuming the travel distance of each water is the

horizontal distance and that the head is the vertical distance from the sample site to the highest contour line upslope (Figures 4-1 and 4-2). The values for C so calculated are tabulated in Table 4-4, and show that the springs have values of C distinctly higher than most drill hole waters.

If one ignores the temperature effects on the properties of water, then variability in the calculated value of C is due either to error in the assumed location and length of path to the recharge area, or variation in the intrinsic permeability k_2, and the rate constant k_1, which were combined in C. Variation in permeability would be due to changes in the frequency of fractures in the bedrock. In a fractured metamorphic rock the permeability, k_2, is most likely a function of the porosity of the rock mass, and if one increases, so does the other.

Variation in the rate constant would be primarily due to variations in the surface area of albite and the porosity. Extreme variations in pH will also affect the rate constant, k_1, since the diffusion coefficient, D, will increase with increasing H^+ concentration (Paces, 1973).

Therefore the variation in the constant, C, could be caused when:

(1) the measured horizontal distance does not closely approximate the distance of the flow path.

(2) the permeability is variable.

(3) the chemical composition of the bedrock, and therefore the surface area of albite per unit volume of rock, is variable.

(4) acid conditions are caused by the oxidation of sulfides.

The length of the flow path will be underestimated for drill holes whose water comes from depth. The flow path of deeper waters is more arcuate and therefore longer than the projected horizontal distance. Drill holes which were drilled near the recharge area will also have underestimated measured distances since the vertical distance is in many cases greater than the horizontal distance. Samples 66, 68 and 71 fit into this category. The assumed travel distance for spring waters will be an overestimation if the actual recharge area is between the sample site and the assumed recharge area. It appears that samples 6 and 12 fit into this category.

There is no easy way of estimating the variation in permeability except to say that there is no indication of any order of magnitude differences in permeability. The bedrock is highly fractured and sheared throughout. There may be local (a few meters) zones of high or low permeability, but the average permeability of zones covering 10's and 100's of meters probably varies within fairly narrow limits. The permeability will tend to decrease with depth because of increased bedrock pressure. This might affect the drill hole waters to a small extent thereby decreasing the value of C.

The percentage of Na in volcanic rocks of the Ascot volcanic belt varies between 1% and 5.5% (Alsac et al., 1971) with a mean of 3.25% and a standard deviation of .74%. There is no apparent difference in Na concentration between altered felsic

and altered mafic rocks. The bedrock consists of highly folded and fractured interbedded sericite and chlorite schist. Waters which flow for any distance flow in both types of bedrock. Since drill hole waters and spring waters come through the same assemblage of rock types, the difference in C could not be due to variations in bedrock composition.

The pH of ground waters is usually buffered to within fairly narrow limits (about 6.0 - 8.5) by the carbonate and silicate equilibria. The oxidation of sulfides would produce local acid conditions. This excess hydrogen would result in accelerated dissolution of silicates until the pH was raised to normal limits. Therefore samples with extreme SO_4^{2-} will have low values of the constant C. Samples 71 and 72 are examples of this.

The differences in the constant C between spring and drill hole samples (Table 4-4) must be primarily due to deviation of the true flow path distance from the horizontally approximated distance. Variable permeability may also cause variation in the estimates of C. Both of these factors would tend to distinguish drill hole waters from spring waters.

The location of the water-bearing zone in the drill holes is not known, but due to the fact that many of them are flowing at elevations greater than the local water table, the water must be in a semi-confined water-bearing zone. This would also seem to indicate these waters come from a deeper source. It therefore appears that the spring waters are near surface waters whose flow is controlled by fluctuations in the water table and that the drill hole waters are mostly deeper waters controlled by partially

confined fracture zones. The drill hole waters with values of C similar to to the springs are probably gaining most of their water from shallower sources.

It was determined in Chapter II that the H_4SiO_4/Na^+ molar ratio is indicative of the importance of soil water versus deeper water in making up a water. Rain or snow melt reacts with silica-rich clay minerals producing minute amounts of gibbsite and kaolinite and releasing silica in solution. Percolation and reaction of this water with albite releases H_4SiO_4 and Na^+ in a 2 to 1 molar ratio, producing kaolinite. Continued contact with the bedrock results in removal of H_4SiO_4 by precipitation of Ca and Mg-montmorillonite. Therefore waters with an H_4SiO_4 to Na^+ ratio greater than 2 have significant amounts of soil water present, whereas the samples with an H_4SiO_4 to Na^+ ratio less than 2 have significant amounts of deeper water.

Estimation of the distance of surface oxidation

The distance of travel of spring and drill hole waters through a zone of actively oxidizing sulfides was estimated (Table 4-4) by using equation (4-13) assuming two extremes - no subsurface oxidation and the maximum possible subsurface oxidation. P_{CO_2} values necessary for the calculation were determined from the measured pH and HCO_3^- at the time of sampling or analysis. Any change in pH or HCO_3^- from those values which existed during oxidation to those determined later will affect the P_{CO_2} correspondingly. Fluctuations of these parameters

could be due to change in temperature, variable biologic activity due to variable air temperature, or exposure to sunlight, and insufficient buffering capacity of the water to cope with these changes.

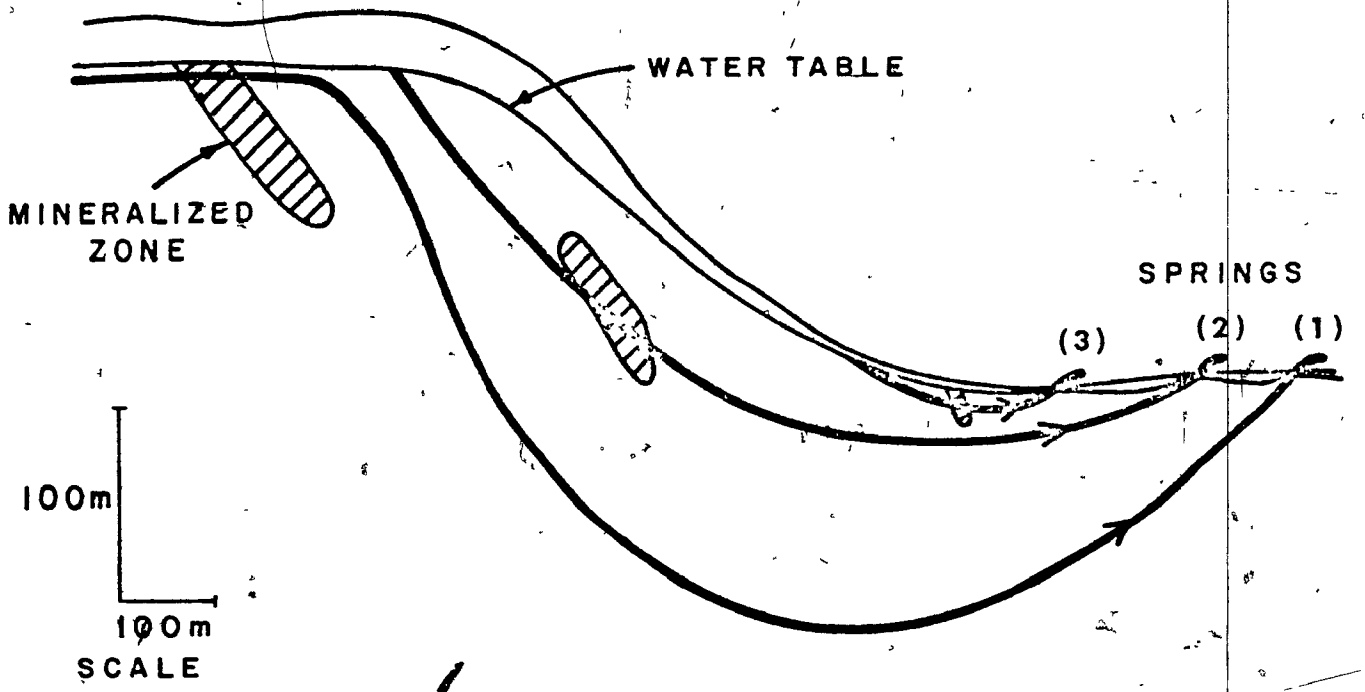
For samples 71 and 72 these estimates of L_{ox} are not compatible with the distance to the source areas of the waters as calculated by the sodium concentration. Bacterial activity in acid surface waters is probably responsible for this discrepancy. At depth these two drill holes intersect the lateral extension of the mineralized zone of the Albert Mine whose shaft contains abundant surface runoff from the leaching mine dump. These runoff waters probably reached the drill hole by movement along the mineralized zone (Chapter III).

Interpretation of waters anomalous in zinc or copper

Figure 4-5 is a diagram incorporating all the features which have been used to explain the characteristics of anomalous and non-anomalous waters in the Eustis Mine area. Although only three paths are included on this diagram, there are many other possible paths. The characteristics of the springs which result from each of these flow paths are also given in Figure 4-5.

Figures 4-1 and 4-2 are anomaly maps for zinc and copper in the drill hole and surface waters, showing the apparent recharge areas for those samples which were analyzed for Na^+. The anomalous drill holes will be discussed individually later. The surface waters have essentially three anomalous zones and

Figure 4-5. Idealized diagram indicating types of flow paths that water might travel in a mineralized area. Values of various parameters are calculated assuming a coefficient of permeability of 49 meters per ~~day~~. Spring 1: $SO_4^{2-} \approx 10^{-2.3}$ molar, $H_4SiO_4/Na^+ < 2$, $C \approx 10^{6.7}$ presence of zinc and iron. Spring 2: $SO_4^{2-} \approx 10^{-3.54}$ molar, $H_4SiO_4/Na^+ = 2$, $C \approx 10^{7.4}$, presence of zinc, minor iron. Spring 3: $SO_4^{2-} \approx 10^{-3.3}$ molar $H_4SiO_4/Na^+ > 2$, $C \approx 10^{7.6}$, presence of copper, zinc and iron.


WATER TABLE
MINERALIZED ZONE
SPRINGS
(3)
(2)
(1)
100m
100m
SCALE

these are labled A, B and C.

Anomaly A

Anomaly A is a strong zinc anomaly with no anomalous copper values. It is probable that the high zinc concentrations are due to contaminating waters from the Albert Mine shaft. The evidence for this is as follows. Sample site 39 is an emergent spring which only emerges during periods of abundant water supply. During periods of maximum flow the water from this spring becomes an intermittent stream flowing through sample sites 40, 41 and 51 and is anomalous the entire distance, some 750 feet. Sample site 38 is a seep with abundant iron oxides at the base of a ridge which lies between sites 38 and 39. This ridge is approximately 100 feet higher than site 38 and 25 feet higher than site 39. On the side of the ridge about 100 feet upslope from sample site 38 is a small gossan zone approximately 10 feet in diameter. The source of the iron appears to be seepage of ground water.

From Figure 4-1 it is seen that there is no possibility of surface contamination from the oxidizing mine dumps because the drainage is away from the anomalous area. If this were not the case, spring samples 50 and 49 would also be anomalous. A map accompanying a report by Holyk (1953) indicates a drill hole at the approximate location of the above mentioned gossan zone. This drill hole may have intercepted the lateral extension of the Albert Mine shaft in a similar manner to drill holes 71 and 72. The shaft water probably came up the drill hole, mixed with the ground water, then escaped out fracture zones in the bedrock,

causing the anomaly A. An estimate as to the amount the shaft water was diluted by ground water to form sample 51i can be made by assuming that the water from drill hole 72 represents the shaft water and that no sulfate, other than from precipitation, is added or removed from either water. This will be a lower limit because there probably will be some sulfate picked up in the soil zone by the dilute ground water. This calculation shows that only 3% of the water in sample 51i is mine shaft water. It must be concluded that anomaly A is caused by contamination from the mine shaft water and that only a small portion of the water seepage in this zone is mine shaft water.

Anomaly B

Anomaly B is located just south of an old mining road. The anomaly in all cases exists on the downslope side of this road. This area is anomalous in both zinc and copper. Copper is not as mobile as zinc, therefore the source of this anomaly must be relatively close (Goleva, 1968). Only sample 30 was analyzed completely. The H_4SiO_4/Na^+ molar ratio indicates an appreciable amount of soil water but the recharge area is indicated as the top of the hill. Apparently deeper water mixes with soil water, which contains the heavy metals. The distance of oxidation, 2 meters, indicates very little surface oxidation, if any. An inspection of the old mining road indicated a few pieces of mineralized rock. Most of the road is constructed with clean gravel. The road may have contributed metals to the waters but it seems unlikely that all the metals are from contamination.

Anomaly C

Unfortunately no complete chemical analyses were performed on the samples which constitute anomaly C. The geologic map indicates a large area of disseminated mineralization 153-214 meters to the northwest upslope. Apparently this is the source of the mineralized waters.

Interpretation of drill hole waters anomalous in zinc or copper

Drill holes 71 and 72 have been discussed previously (Chapter III) and their anomalous behavior is due to contamination by the Albert Mine workings. Drill hole 69 and perhaps drill hole 62 are also probably anomalous for this reason.

Drill holes 64 and 65 are located near the Victoria Mine shaft but do not appear to have been affected by contamination since the mine was not more than 17 meters deep. Drill hole 64 intersects a 6" inch band of massive pyrite at 21 meters with 1.7% Cu and .11% Zn. Drill hole 65 intersects only minor disseminated pyrite at 48 meters. The sulfate content indicates that the anomalies are caused by subsurface oxidation. The constant C and the H_4SiO_4/Na^+ ratio indicate that most of the water is from a deep source with no surface water. Drill hole 65 may indicate more extensive mineralization laterally, and should be investigated. The anomaly in drill hole 64 might be caused by the intersected mineralization.

Drill holes 70 and 67 intersect sericite schist with up to 20% disseminated pyrite in many places. The extent of this mineralization is sufficient to produce these anomalies but the sulfate concentration indicates some surface oxidation, which

is not explained.

Drill holes 66 and 68 intersect considerable mineralization. Drill hole 66 cuts through sulfides which assayed up to 7% zinc, at 174 to 181 meters and drill hole 68 intersect zones up to 30% chalcopyrite. The constant C and the H_4SiO_4/Na^+ ratio indicates that the water in drill hole 66 comes from a fairly deep source, but apparently not from the zone of mineralization. Although drill hole 67, which is 61 meters to the southwest of drill hole 66, is anomalous, it is not flowing, whereas drill hole 66, which is at a higher elevation, is flowing. The total depth of drill hole 67 is 114 meters and of drill hole 66, 247 meters. Therefore, allowing for a difference in elevation between the two holes of 23 meters, the water-bearing zone is at a depth in drill hole 66 of between 137 meters to 247 meters. Apparently drill hole 67 is anomalous because the water is sitting in contact with the sulfides, with no circulation taking place. The iron content of drill hole 66 indicates some dissolution of sulfides, but as indicated by the sulfate, under subsurface conditions. The lack of Zn^{2+} in solution cannot be explained. Drill hole 68 is also not flowing and the constant C and the H_4SiO_4/Na^+ ratio indicates that its water is mostly soil water. Actually this sample should be discounted since there was abundant organic matter in it, and it appeared to be blocked up at depth, with its stagnant water coming from the soil zone.

CONCLUSIONS

Techniques have been developed which use chemical and hydrologic theory and data for estimating the travel distance, extent of contact with oxidizing sulfides and the approximate source area of a water. Equation (4-8), $L_2 = \left[.832\ k_2(\rho/\mu)\Delta H(m_i - m_i^o)/k_1\right]^{\frac{1}{2}}$ is used to determine the travel distance of a water. A simplified version of equation (4-8), equation (4-14), $L_2 = \left[C\Delta H(m_i - m_i^o)\right]^{\frac{1}{2}}$ could be used with little increase in error. Several appropriate values of ΔH were substituted into this equation to arrive at values of L_2. These values of L_2 and ΔH were then used to graphically determine a travel time line on the map. The intersection of the flow line with the travel time line is the approximate source area of the water. The recharge location of a water is considered an area because the recharge of a water actually takes place all along a flow path. Variations in permeability, temperature, rock composition and pH may also influence the calculated recharge area. In the waters of this study it has been determined that these influences are probably minor. A major source of error is the simplification of the flow path distance to the horizontal plane. It has been shown that most of the drill hole waters had a deep semi-confined flow path, whereas all the springs had a shallow flow path.

The extent of contact between a water and oxidizing sulfides is estimated by using the sulfate content. Any water in this area with a sulfate content greater than 0.29 millimoles per liter (28 ppm) must have some surface oxidation taking place. Values less than this could be caused by subsurface oxidation

and atmospheric contributions, but minor surface oxidation cannot be ruled out.

The following equation was derived for the estimation of the distance a water has traveled through the zone of oxidation:

$$L_{ox} = K_2 (SO_4^{2-})(P_{CO_2})/10^{-4.42}$$

The results determined with this equation appear to be consistent and within limits imposed by overburden depth and other physical factors except for two drill holes which have a high sulfate content produced by bacterial oxidation of mine dump sulfides at the surface.

Anomalous drill hole and surface waters are partly explained by contamination from mine workings, partly by known mineralization and partly by unknown causes.

CHAPTER V FINAL SUMMARY AND CONCLUSIONS

The spring and drill hole waters in this area gain most of their total dissolved solids from the dissolution of vein and disseminated carbonates. The influence of these minerals is so strong that the water composition is similar to one from a carbonate bedrock. The major influence of dissolution of the silicate minerals is to release Na^+ and H_4SiO_4 to within fairly narrow concentration limits. Precipitation and snow melt react quickly with the soil zone, dissolving more H_4SiO_4 than Na^+. Continued reaction through the overburden and bedrock results in a steady increase in Na^+, but a slow increase and leveling off of H_4SiO_4 concentration. Consequently the H_4SiO_4/Na^+ ratio becomes less as the contact time increases. For this reason the H_4SiO_4/Na^+ ratio is a useful parameter for distinguishing waters from a shallow source from those from a deep source.

Precipitation and evapotranspiration do not have a drastic effect on the variations of the dissolved constituents, in that variations are well within one order of magnitude. This lack of variability has been attributed to chemical buffering by the soil zone. There is evidence that evapotranspiration causes concentration of dissolved solids in the soil water and formation of silica-rich clay minerals in the soil zone.

Decaying vegetation contributes distinguishable amounts of K^+ anc Cl^- into dilute near-surface waters in the fall of the year. Upon filtration through the overburden these effects are no longer distinguishable due to adsorption in the overburden.

Many of the waters are affected by contamination of mine dump waters. These waters are distinguished by their high sulfate content, which indicates extensive surface oxidation. An estimate as to the quantity of zinc, copper and iron leached from the Albert Mine dump is made by comparing the composition of drill hole water 72 with an analysis of the surface water. Approximately 220 tons of copper, 160 tons of zinc and 840 tons of iron have been leached from the mine dump, with most of it having been reprecipitated in the bedrock at depth.

Techniques have been developed which use chemical and hydrologic theory and data for estimating the travel distance, extent of contact with oxidizing sulfides and the approximate source area of a water. The equation, $L_2 = \left[C\Delta H(m_i - m_i^o)\right]^{\frac{1}{2}}$ is used to determine the travel distance of a water. Several appropriate values of ΔH were substituted into this equation to arrive at values of L_2. These values of L_2 and ΔH were then used to graphically determine a travel time line on the map. The intersection of the flow line with the travel time line is the approximate source area of the water.

The sulfate concentration is used to estimate the extent of contact between a water and oxidizing sulfides. Any water

in this area with a sulfate concentration greater than 28 ppm must have some surface oxidation taking place.

The following equation was derived for the estimation of the distance a water has traveled through the zone of oxidation:

$$L_{ox} = K_2(SO_4^{2-})(P_{CO_2})/10^{-4.42}$$

The results determined with this equation appear consistent and within limits imposed by overburden depth and other physical factors.

PROPOSED FUTURE WORK

Location areas of alteration and gangue mineralization

It has been demonstrated that analysis of ground waters is an effective method of locating zones of carbonatization. The extensive carbonatization in the Eustis Mine area is not locally indicative of sulfide mineralization. The possibility of it being an indicator on a regional scale has not been investigated to my knowledge in the Ascot volcanic belt. An investigation into the spatial relationship of carbonatization and sulfide mineralization in the Ascot volcanic belt would be an excellent research project. The best method of performing this task would be by chemical analysis of ground waters. A logical extension of this study would be to test this method of exploration in an area where carbonatization is indicative of known mineralization. Types of mineralization which might be found by this method are massive base metal

sulfides, gold-quartz veins, carbonatites and perhaps some porphyry copper deposits.

This type of study need not be restricted to just carbonate mineralization but zones rich in other accessory minerals could be located as well. Such minerals as barite, celestite, fluorite and gypsum would dissolve sufficiently in circulating waters to be used as an ore guide. Some types of alteration, such as albitization or anthophyllization might also be located by this method. The advantage of this method of geochemical exploration is that the release of the diagnostic constituents does not require oxygen, therefore deep zones of mineralization and zones of mineralization located under extensive glacial cover could be located.

Analysis of carbonates as a rock geochemistry technique

The most important reactions which affect the mobility and precipitation of Zn^{2+}, Cu^{2+}, Fe^{2+} and Mn^{2+} in the Eustis Mine area are the various carbonate reactions. In waters most highly concentrated with these constituents it was found that the waters were close to saturation with respect to the various carbonate minerals. Analysis of drill hole waters 71 and 72 indicates that the observed loss in Cu^{2+} and Zn^{2+} may in part be due to precipitation of carbonate minerals. It is likely that similar reactions occur during the ore-forming process, as well as during weathering of mineralized rocks. Carbonate minerals have a large capacity

for foreign ions, therefore they would be good minerals to analyze for trace constituents for defining a metal halo around an ore deposit.

Many minerals have been used in this respect but the carbonate minerals have been grossly neglected. Partial dissolution of a whole rock sample with fairly dilute acids would be a quick, easy method of dissolving disseminated carbonate minerals. Vein carbonates could also be sampled and analyzed but should be kept separate from the disseminated samples. Analysis should be made for calcium, magnesium, manganese, iron, copper and zinc in order that the percentage of carbonates in the rock may be estimated and used to normalize the data. Certain relationships will probably develop between these constituents which may make interpretation easier. An example might be high magnesium content of carbonates near mineralization due to the common magnesium enrichment associated with many deposits.

Analysis of drill core might locate offshoots which would have been missed by other methods of exploration. This method holds much promise of being an effective technique for locating ore deposits.

Control of acid mine waters

The geochemical investigations of drill hole waters indicate that the vein and disseminated carbonates are effective in neutralizing and removing most of the metals from acid mine

waters. This beneficial phenomenon might be used toward man's advantage in areas where acid mine drainage is a problem. Drainage from leaching mine dumps could be diverted into old mine shafts. Drill holes could be drilled in such a manner that water from the shaft would percolate through bedrock, ridding itself of the unwanted constituents.

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APPENDIX I THERMODYNAMIC CALCULATIONS

CALCULATION OF THE EQUILIBRIUM CONSTANT OF A REACTION AT ANY TEMPERATURE

The most important parameter to determine for the calculation of a saturation index is the value of the equilibrium constant of the reaction at the temperature of interest. The following discussion describes the general framework employed to determine the change of the equilibrium constant with temperature.

The standard state adopted for the aqueous phase is an hypothetical 1 molal solution at 1 atmosphere and any specified temperature. The pressure effect on solutions below 300° C is slight compared to the effect of temperature and is considered constant for this discussion (Helgeson, 1969). The change of the Gibbs free energy of reaction with temperature is expressed by reaction (I-1).

$$(\Delta G_r^o)_T = (\Delta H_r^o)_{298.} - T(\Delta S_r^o)_{298.} + \int_{298.}^{T} (\Delta C_p)dT$$

$$-\int_{298.}^{T} (\Delta C_p)/T \; dT \qquad \text{(I-1)}$$

Where (ΔG_r^o) = standard free energy of reaction

(ΔS_r^o) = standard entropy of reaction

(ΔH_r^o) = standard enthalpy of reaction

ΔC_p = heat capacity change of reaction

298. = reference temperature in °Kelvin and is simplified from 298.15°K

T = any temperature

Equation (I-1) can only be used if the substances taking part in the reaction under consideration do not undergo any change of state in the temperature interval 298. to T.

The change of heat capacity, C_p, with temperature of solids is usually expressed in power functions as given by equation (I-2) (Kelly, 1960).

$$C_p = a + bT + cT^{-2} \qquad \text{(I-2)}$$

The enthalpy of formation from the elements of a species at temperature T is:

$$(\Delta H_i^o)_T = (\Delta H_i^o)_{298.} + a(T-298.) + b/2(T^2 - (298.)^2) - c/2(1/T^2 - 1/(298.)^2)$$

where ΔH_i^o = enthalpy of formation from the elements of species i. The entropy of formation of a species at any temperature is given by:

$$(S_i^o)_T = (S_i^o)_{298.} + a\ln(T/298.) + b(T-298.) - c/2(1/T^2 - 1/(298.)^2)$$

where S_i^o = entropy of formation from the elements of species i.

Usually only average heat capacities are known or estimated for dissolved constituents. Standard enthalpy is given by:

$$(\Delta H_i^o)_T = (\Delta H_i^o)_{298.} + C_{p,i}^o \Big]_{298.}^{T} (T-298.)$$

where $C_{p,i}^o \Big]_{298.}^{T}$ is the average heat capacity of an ion from 298. ^oK to temperature T.

Standard entropy is given by:

$$(S_i^o)_T = (S_i^o)_{298.} + C_{p,i}^o \Big]_{298.}^{T} (\ln(T/298.))$$

Equilibrium constants at any temperature can then be calculated from equation (I-3) (Helgeson, 1969).

$$\log K_T = \left[T(\Sigma_j(S_j^o)_T - \Sigma_l(S_l^o)_T - \Sigma_j(\Delta H_j^o)_T + \Sigma_l(\Delta H_l^o)_T\right] /2.303RT \quad \text{(I-3)}$$

j and l refer to the products and reactants respectively.

CALCULATION OF THE AVERAGE HEAT CAPACITIES

The average heat capacities of the ions between two temperatures can be calculated from absolute entropies by evaluating equation (I-4) (Criss and Cobble, 1964b).

$$C_{p,i}^o \Big]_{298.}^{T} = (S_i^o)_T^{(abs)} - (S_i^o)_{298.}^{(abs)} \Big/ \ln(T/298.) \quad \text{(I-4)}$$

where $(S_i^o)^{(abs)}$ is the absolute entropy of the i th species. The absolute entropy is related to the conventional entropy $(S_i^o)^{(conv)}$ by Criss and Cobble (1964b):

$$(S_i^o)_T^{(abs)} = (S_i^o)_T^{(conv)} + Z_i(S_{H+}^o)_T^{(abs)}$$

Z_i = charge of the i th species

$(S_{H+}^o)_T^{(abs)}$ = absolute entropy of H^+ at temperature, T

at 298. °K; $(S_i^o)_{298.}^{(abs)} = (S_i^o)_{298.}^{(conv)} - 5.0Z_i$

Criss and Cobble (1964a) have shown that the absolute entropies of ions at high temperatures can be calculated from:

$$(S_i^o)_T^{(abs)} = a_T + b_T(S_i^o)_{298.}^{(abs)} \qquad (I\text{-}5)$$

where a and b are temperature dependent coefficients characteristic of simple cations, simple anions, oxy-anions or acid oxy-anions.

By combining equations (I-4) and (I-5) a similar equation can be found for heat capacity (Criss and Cobble, 1964b).

$$C_{p,i}^o\Big]_{298.}^{T} = \alpha_T + \beta_T (S_i^o)_{298.}^{(abs)}$$

where $\alpha_T = a_T/\ln(T/298.)$ and $\beta_T = (b_T - 1)/\ln(T/298.)$

Values of a, b, α , and β have been computed by Criss and Cobble (1964a,b) for 25°, 60°, 100°, 150°, 250° and 300°C. They also give a list of the ionic partial molal heat capacities, which have been used in this study except for the certain ions which were recalculated using new values for the conventional entropy (Table I-1).

DERIVATION OF AN EQUATION WHICH ACCURATELY DESCRIBES THE CHANGE OF THE EQUILIBRIUM CONSTANT WITH TEMPERATURE

This technique assumes that the change in heat capacity of dissolved constituents with temperature is described by equation (I-2). The change with temperature of the partial molal heat capacity of ions has been described accurately with equations similar to (I-2) (Khodakovskiy et al., 1968). The change of the heat capacity of reaction, ΔC_p, with temperature can therefore be expressed in the form:

$$\Delta C_p = a + bT + cT^{-2} \qquad \text{(I-6)}$$

Substitution of equation (I-6) into equation (I-1) and integration yields:

$$(\Delta G^o_r)_T - (\Delta H^o_r)_{298.} - T(\Delta S^o_r)_{298.} + a(T-298.) + b/2(T^2 - (298.)^2) - c(1/T - 1/298.) - T\left[a\ln(T/298.) + b(T-298.) - c/2(1/T^2 - 1/(298.)^2)\right]$$

TABLE I-1.

Partial molal heat capacities calculated using the method of Criss and Cobble (1964b). The source of $(S_i^o)_{298.}^{(conv)}$ is also given.

Ion	$C_{p,i}^o]_{298.}^{333.}$	$C_{p,i}^o]_{298.}^{373.}$	$C_{p,i}^o]_{298.}^{423.}$	$C_{p,i}^o]_{298.}^{473.}$	$(S_i^o)_{298.}^{(abs)}$	$(S_i^o)_{298.}^{(conv)}$	Reference
Fe^{2+}	49.6	64.5	67.0	72.4	-35.6	-25.6	a
Fe^{3+}	67.6	91.1	94.4	101.7	-82.	-67.	a
Cu^{2+}	48.8	64.5	65.8	71.2	-33.6	-23.6	a
Zn^{2+}	50.1	66.3	67.8	73.2	-36.9	-26.9	a
Mn^{2+}	45.7	60.4	61.5	66.5	-26.2	-16.2	b

[a] Larson, J.W. et al. (1968)
[b] Gedansky and Hepler (1969)

Regrouping:

$$(\Delta G_r^o)_T - (\Delta H_r^o)_{298.} + T(\Delta S_r^o)_{298.} = a\left[T(1-\ln T + \ln 298.) - 298. \right] + b\left[T(298.) - T^2/2 - (298.)^2/2 \right] - c\left[1/2T + T/2(298.)^2 - 1/298. \right] \quad (I\text{-}7)$$

If one knows $(\Delta G_r^o)_T$ at several temperatures in a certain temperature range, and $(\Delta H_r^o)_{298.}$ and $(\Delta S_r^o)_{298.}$ are also known, then the coefficients a, b, and c can be calculated.

Set:

$$X_1 = T(1-\ln T + \ln 298.) - 298.$$

$$X_2 = T(298.) - T^2/2 - (298.)^2/2$$

$$X_3 = 1/2T + T/2(298.)^2 - 1/298.$$

$$Y = (\Delta G_r^o)_T - (\Delta H_r^o)_{298.} + T(\Delta S_r^o)_{298.}$$

Then combining the above equations with equation (I-7) yields:

$$Y = aX_1 + bX_2 - cX_3$$

The heat capacity coefficients can be evaluated by generating three equations for least square regression:

$$\Sigma X_1 Y = a\Sigma X_1^2 + b\Sigma X_1 X_2 - c\Sigma X_1 X_3$$

$$\Sigma X_2 Y = a\Sigma X_1 X_2 + b\Sigma X_2^2 - c\Sigma X_2 X_3$$

$$\Sigma X_3 Y = a\Sigma X_1 X_3 + b\Sigma X_2 X_3 - c\Sigma X_3^2$$

The simultaneous solution of these three equations results in values for a, b, and c.

The equation of best fit for describing the change of the equilibrium constant with temperature can be found in the following way:

Divide equation (I-7) by 2.303 RT where R is the gas content to yield:

$A^* = a/2.303R \quad B^* = b/2.303R \quad C^* = -c/2.303R \quad -\log K = \Delta G/2.303RT$

Thus,

$$-\log K = (\Delta H^o_r)_{298.}/2.303RT - (\Delta S^o_r)_{298.}/2.303R + A^*/T \left[T(-\ln T + 1 + \ln 298.) - 298. \right] + B^*/T \left[-T^2/2 + T(298.) - (298.)^2/2 \right] + C^*/T \left[1/2T + T/2(298.)^2 - 1/298. \right]$$

Multiplying and grouping like functions of T:

$$-\log K = \ln T \left[-A^* \right] + T \left[-B^*/2 \right] + 1/T \left[-A^*(298.) - B^*/2(298.)^2 - C^*/298. + (\Delta H^o_r)_{298.}/2.303R \right] + 1/T^2 \left[C^*/2 \right] + \left[A^* + A^*298. + B^*(298.) + C^*/2(298.)^2 - (\Delta S^o_r)_{298.}/2.303R \right]$$

After multiplying by -1 so the equation calculates log K, the final equation is:

$$\log K = A\ln T + BT + C/T + D/T^2 + K \qquad \text{(I-8)}$$

Where:

$A = A^*$

$B = B^*/2$

$C = A^*(298.) + B^*/2(298.)^2 + C^*/298. - (\Delta H^o_r)_{298.}/2.303R$

$D = -C^*/2$

$K = -A^* - A^* 298. + B^*(298.) - C^*/2(298.)^2 + (\Delta S^o_r)_{298.}/2.303R$

CALCULATION OF THE DISSOCIATION CONSTANTS OF COMPLEX IONS AT DIFFERENT TEMPERATURES

When the $(\Delta S^o_r)_{298.}$ and $(\Delta H^o_r)_{298.}$ of dissociation is known for a complex ion the dissociation constant in aqueous solution at temperatures up to 200° can be estimated by applying the following equation (Helgeson, 1969).

$$\log K = (\Delta S^o_r)_{298.}/2.303RT \left[79.85 \left| 1 - \exp \left[\exp(-12.741 + .01875T) - 7.84 \times 10^{-4} + (T-298.15)/219.0 \right] \right| \right] - (\Delta H^o_r)_{298.}/2.303RT$$

This equation was used, when no laboratory measurements were available, to calculate the dissociation constants at several temperatures. These dissociation constants were then used to calculate the coefficients of equation (I-8) by the method described earlier.

OXIDATION-REDUCTION REACTIONS OF ELEVATED TEMPERATURES

The oxidation potential, Eh, is the potential of a half cell measured against the standard hydrogen electrode (e.g., Garrels and Christ, 1965). The oxidation of pyrite is a convenient reaction to use as an example equation (I-9).

$$14e^- + 16H^+ + 2SO_4^{2-} + Fe^{2+} = 8H_2O + FeS_2 \qquad (I\text{-}9)$$

It is more convenient to use the term pe, which is the relative electron activity (Stumm and Morgan, 1970). pe is related to Eh by the following relationships:

$$pe = pe^o + 1/n \log\left[(ox) / (red) \right]$$

Where:

pe^o = $-(\Delta G_r^o)_{298.}/2.303RT$

(ox) = activity of the oxidized species

(red) = activity of the reduced species

n = number of electrons transferred

$(\Delta G_r^o)_{298.}$ = standard free energy change of reaction at 298. ^oK

R = gas constant

pe = Eh x F/2.303RT

where F equals Faraday's constant.

For these relations to hold true the redox reaction must be written with the electrons on the left.

$$(ox) + ne^- = (red)$$

It is the convention to assume a (ΔG_r^o) of zero at all temperatures for the standard hydrogen electrode equation (I-10) (e.g., Denbigh, 1966).

$$\tfrac{1}{2}H_2(g) = H^+ + e^- \qquad \text{(I-10)}$$

It is also a convention to assign a value of zero to the (ΔG_f^o), (ΔH_f^o) and (S_f^o) of H^+ at 298.°K, where (ΔG_f^o), (ΔH_f^o) and (S_f^o) are respectively the free energy, enthalpy and entropy of formation from the elements.

Hydrogen gas has a definite enthalpy and entropy at different temperatures. For example at 298.° the values for H_2 are: $(\Delta H_f^o) = 0$; $(S_f^o) = 31.21$ calories/mole-degree. At 333°K, $(\Delta H_f^o) = 241$ calories/mole and $(S_f^o) = 31.97$ calories/mole-degree (Helgeson, 1969). The (ΔH_f^o) and (S_f^o) of H^+ at temperatures other than 298.°K are calculated using the heat capacity parameters of Criss and Cobble (1964b).

Since the (ΔG_r^o) is zero at all temperatures then the (ΔH_r^o) and (ΔS_r^o) are also zero at all temperatures (equations I-11 and I-12) (Denbigh, 1966).

$$\partial((\Delta G_r^o)/T)/\partial T = -(\Delta H_r^o)/T^2 \qquad \text{(I-11)}$$

$$\partial(\Delta G_r^o)/\partial T = -(\Delta S_r^o) \qquad \text{(I-12)}$$

It then follows from equation (I-10):

$$(\Delta H_f^o)(e^-) + (\Delta H_f^o)(H^+) = (\Delta H_f^o)(\tfrac{1}{2}H_{2(g)})$$

and

$$(S_f^o)(e^-) + (S_f^o)(H^+) = (S_f^o)(\tfrac{1}{2}H_{2(g)})$$

at all temperatures. Values of $(\Delta H_f^o)_T$ and $(S_f^o)_T$ for H^+ and H_2 are known, therefore values for an electron can be calculated. Table I-2 summarizes the thermodynamic values for an electron. These values for an electron are not absolute values, but are values based on the convention used for the hydrogen half-reaction.

An example will suffice why this discussion has been necessary. Combining equation (I-9) and equation (I-10) results in equation (I-13).

$$7H_2 + 2H^+ + 2SO_4^{2-} + Fe^{2+} = FeS_2 + 8H_2O \qquad \text{(I-13)}$$

The (ΔG_r^o) of equation (I-10) is zero at all temperatures, therefore the free energy of reaction of equations (I-9 and I-13) are identical.

$$(\Delta G_r^o)_T = \Sigma\Delta H^o_{Prod} - \Sigma\Delta H^o_{Reac} - T\left[\Sigma S^o_{Prod} - \Sigma S^o_{Reac}\right] \qquad \text{(I-14)}$$

The right hand side of equation (I-14) should be the same for reactions (I-9 and I-13). If no value is given for an e^- then the $(\Delta G_r^o)_{298.}$ of reactions (I-9 and I-13) are not the same (Table I-3). The difference in (ΔG_r^o) at 298.^oK between these two reactions is 65,119 calories. This amounts to a calculated

TABLE I-2.

Thermodyanmic values for the reaction $\frac{1}{2}H_2 = H^+ + e^-$.

Temp.	(S_f^o)				(ΔH_f^o)				(ΔG_r^o)
°C	e^-	H^+	$\frac{1}{2}H_2$	Σ	e^-	H^+	$\frac{1}{2}H_2$	Σ	
25	15.6		15.6	0	0	0	0	0	0
60	13.4	2.6	16.0	0	-684.	805.	121.	0	0
100	9.4	7.0	16.4	0	-2066.	2325.	259.	0	0
150	5.2	11.6	16.8	0	-3694.	4125.	431.	0	0
200	1.0	16.2	17.2	0	-5521.	6125.	604.	0	0

TABLE I-3.

Comparison of reaction I-11 to reaction I-16, neglecting the (ΔH_f^o) and (S_f^o) of an electron, at 298.°K.

Reaction	$14e^- + 16H^+ + 2SO_4^{2-} + Fe^{2+} = 8H_2O + FeS_2$						
	Products		Reactants				Products − Reactants
	FeS_2	$8H_2O$	Fe^{2+}	$2SO_4^{2-}$	$16H^+$	$14e^-$	
(S_f^o)	12.65	133.68	-25.6	+9.6	0	0	+162.33
(ΔH_f^o)	-41,000.	-546,520.	-22,000.	-434,640.	0	0	+130,880.
(ΔG_r^o)	179,179 cal/mole						

Reaction	$7H_2 + 2H^+ + 2SO_4^{2-} + Fe^{2+} = 8H_2O + FeS_2$						
	Products		Reactants				Products − Reactants
	FeS_2	$8H_2O$	Fe^{2+}	$2SO_4^{2-}$	$2H^+$	$7H_2$	
(S_f^o)	12.65	133.68	-25.6	+9.6	0	218.5	-56.14
(ΔH_f^o)	-41,000.	-546,520.	-22,000.	-434,640.	0	0	+130,880.
(ΔG_r^o)	114,060 cal/mole						

pe^{o} of 3.41 units too negative or an E^{o} of .201 volts too negative. Paces (1969) made this mistake in calculating the saturation indices of ground waters for the pyrite-water reaction. This problem is easily corrected by assigning thermodynamic values of an electron equal to those given in Table I-2. This is the procedure followed in this study.

The pe^{o} at different temperatures of a reaction were calculated in the same manner as the values for the equilibrium constant at different temperatures. The coefficients of equation (I-8) were then determined by the method described earlier.

SUMMARY OF THE THERMODYNAMIC DATA NECESSARY FOR THE CALCULATION OF THE EQUILIBRIUM CONSTANT FROM $0^{o}C$ to $200^{o}C$

The mineral-water reactions used in this study are given in Table I-4. Tables I-5, I-6, I-7 and I-8 give the necessary thermodynamic constants for the calculations. The sources of these values are also given. The tabulated values were checked for internal consistency, and where necessary, the least reliable variable was altered to maintain internal consistency. The coefficients of reaction (I-8) for the mineral-water equilibria are given in Table I-9. The equations for calcite and gypsum are those recommended by Jacobson and Langmuir (1974) and Wigley (1971) respectively.

Table I-10 gives the coefficients of equation (I-8) for the dissociational equilibria used in this study.

TABLE I-4.

Mineral-water reactions considered in the saturation index program.

Reaction Number	Reaction
1	$CaCO_3 = Ca^{2+} + CO_3^{2-}$
2	$FeCO_3 = Fe^{2+} + CO_3^{2-}$
3	$MgCO_3 = Mg^{2+} + CO_3^{2-}$
4	$CaMg(CO_3)_2 = Ca^{2+} + Mg^{2+} + 2CO_3^{2-}$
5	$ZnCO_3 = Zn^{2+} + CO_3^{2-}$
6	$MnCO_3 = Mn^{2+} + CO_3^{2-}$
7	$CaSO_4 \cdot H_2O = Ca^{2+} + SO_4^{2-} + H_2O$
8	$Cu_2(OH)_2CO_3 + 2H^+ = 2Cu^{2+} + CO_3^{2-} + 2H_2O$
9	$Cu_3(OH)_2(CO_3)_2 + 2H^+ = 3Cu^{2+} + 2CO_3^{2-} + 2H_2O$
10	$2H^+ + Mg(OH)_2 = Mg^{2+} + 2H_2O$

TABLE I-4 (continued)

Reaction Number	Reaction
11	$e^- + 3H^+ + Fe(OH)_3 = 3H_2O + Fe^{2+}$
12	$e^- + 3H^+ + .5Fe_2O_3 = Fe^{2+} + 1.5H_2O$
13	$14e^- + 16H^+ + 2SO_4^{2-} + fe^{2+} = 8H_2O + FeS_2$
14	$8e^- + 8H^+ + SO_4^{2-} + Zn^{2+} = ZnS + 4H_2O$
15	$16e^- + 16H^+ + 2SO_4^{2-} + Cu^{2+} + Fe^{2+} = CuFeS_2 + H_2O$
16	$KAlSi_3O_8 + H^+ + 4.5H_2O = .5Al_2Si_2O_5(OH)_4 + K^+ + 2H_4SiO_4$
17	$CaAl_2Si_2O_8 + 2H^+ + H_2O = Ca^{2+} + Al_2Si_2O_5(OH)_4$
18	$NaAlSi_3O_8 + 4.5H_2O + H^+ = Na^+ + 2H_4SiO_4 + .5Al_2Si_2O_5(OH)_4$
19	$Mg_5Al_2Si_3O_{10}(OH)_8 + 10H^+ = Al_2Si_2O_5(OH)_4 + 5Mg^{2+} + 4H_4SiO_4 + 5H_2O$
20	$KAl_3Si_3O_{10}(OH)_2 + H^+ + 1.5H_2O = K^+ + 1.5Al_2Si_2O_5(OH)_4$

TABLE I-4 (continued)

Reaction Number	Reaction
21	$3Na_{.33}Al_{2.33}Si_{3.67}O_{10}(OH)_2 + H^+ + 11.5H_2O = Na^+ + 4H_4SiO_4 + 3.5Al_2Si_2O_5(OH)_4$
22	$6Ca_{.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2 + 23H_2O + 2H^+ = 7Al_2Si_2O_5(OH)_4 + Ca^{2+} + 8H_4SiO_4$
23	$6Mg_{.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2 + 23H_2O + 2H^+ = 8H_4SiO_4 + 7Al_2Si_2O_5(OH)_4 + Mg^{2+}$
24	$K_{.6}Mg_{.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2 + 1.1H^+ + 3.15H_2) = .6K^+ + 1.2H_4SiO_4 + .25Mg^{2+} + 1.15Al_2Si_2O_5(OH)_4$

TABLE I-5.

Thermodynamic data for species in aqueous solution at 25°C and 1 atmosphere.

Species	(ΔH_f^o) (cal mole^{-1})	(S_f^o) (cal mole^{-1} deg^{-1})	(ΔG_f^o) (cal mole^{-1})	Average heat capacity (cal mole^{-1} deg^{-1}) 60°C	100°C	150°C	200°C
Ca^{2+}	-129,770.[a]	-13.2[a]	-132,180.[g]	45.[d]	59.	60.	66.
Mg^{2+}	-110,410.[a]	-28.2[a]	-108,900.[g]	51.[d]	67.	69.	75.
HCO_3^-	-165,390.[f]	21.8[f]	-140,260.[f]	-27.[d]	-25.	-34.	-35.
SO_4^{2-}	-217,320.[a]	4.8[a]	-177,970.[h]	-99.[d]	-108.	-105.	-114.
Na^+	-57,279.[a]	14.4[a]	-62,539.[g]	35.[d]	41.	41.	45.
K^+	-60,040[a]	24.5[a]	-67,700.[g]	27.[d]	35.	35.	39.
Cl^-	-39,950.[a]	13.5[a]	-31,350.[g]	-51.[d]	-58.	-62.	-66.
Fe^{2+}	-22,100.[b]	-25.6[b]	-21,800.[b]	49.6[e]	64.5	67.	72.4
Cu^{2+}	15,700[b]	-23.6[b]	15,900.[b]	48.8[e]	64.5	65.8	71.2
Zn^{2+}	-36,900[b]	-26.9[b]	-35,200.[b]	50.1[e]	66.3	67.8	73.2
Mn^{2+}	-52,900.[c]	-16.2[c]	-55,100.[c]	45.7[e]	60.4	61.5	66.5

TABLE I-5 (continued)

Species	$(\bar{\Delta} H_f^o)$ (cal mole^{-1})	(S_f^o) (cal mole^{-1} deg^{-1})	(ΔG_f^o) (cal mole^{-1})	Average heat capacity (cal mole^{-1} deg^{-1}) 60°C	100°C	150°C	200°C
H_4SiO_4	-348,060.[a]	45.8[a]	-312,500.[g]	49.[a]	49.	46.	46.
H^+	0[a]	0[a]	0[g]	23.[d]	31.	33.	35.
CO_3^{2-}	-161,736.[f]	-13.6[f]	-126,170.[f]	-132.[d]	-146.	-138.	-151.
OH^-	-54,970.[a]	-2.57[a]	-37,594.[g]	-47.[d]	-58.	-61.	-65.
H_2O	-68,315.[g]	16.71[g]	-56,688.[g]	18.[a]	18.	18.	18.

[a]Helgeson(1969). [b]Larson et al.(1968). [c]Gedansky and Hepler(1969). [d]Criss and Cobble (1964b). [e]Calculated from (S_f^o) by the correspondence principle. [f]Langmuir(1968). [g]Robie and Waldbaun(1968). [h]Wagman et al.(1966).

TABLE I-6.

Thermodynamic data of minerals necessary for the calculation of equilibrium constants in Table I-7. $C_p = a + bT + c/T^2$

Mineral	C_p a	C_p bx10^3	C_p cx10^{-5}	$(\Delta G_f^o)_{298.}$	$(\Delta H_f^o)_{298.}$	$(S_f^o)_{298.}$
$CaCO_3$	18.49[e]	15.84	-2.82	-259,840.[a]	-288,921.[a]	20.6[a]
$FeCO_3$	11.63[j]	26.80	0	-162,360.[c]	-177,812.[b]	29.26[c]
$MgCO_3$	18.62[f]	13.80	-4.16	-246,712.[d]	-266,081.[d]	15.7[d]
Dolomite	33.3[g]	36.2	-5.3	-470,232.[i]	-554,372.[i]	40.3[i]
$ZnCO_3$	9.30[j]	33.	0	-176,068.[k]	-195,386.[k]	19.7[j]
$MnCO_3$	21.99[j]	9.3	-4.69	-195,465.[m]	-212,820.[m]	23.9[l]
$CaSO_4 \cdot 2H_2O$				-429,807.[n]	-483,060.[l]	48.31[o]
$Cu_2(OH)_2CO_3$				-158,096.[p]		
$Cu_3(OH)_2(CO_3)_2$				-214,798.[p]		
$Mg(OH)_2$	13.04[q]	15.8	0	-199,460.[l]	-221,100.[q]	15.09[q]
$Fe(OH)_3$	14.3[r]	33.7	.474	-167,460.[s]	-197,835.[t]	25.[r]
Fe_2O_3	14.8[r]	33.7	.474	-177,719.[r]	-197,300.[r]	20.89[r]
FeS_2	17.88[u]	1.32	-3.05	-38,296.[w]	-41,000.[l]	12.65[l]
ZnS	11.77[u]	1.26	-1.16	-48,623.[w]	-49,750.[l]	13.77[l]

TABLE I-6 (continued)

Mineral	C_p a	C_p $bx10^3$	$cx10^{-5}$	(ΔG_f^o) 298.	(ΔH_f^o) 298.	(S_f^o) 298.
$CuFeS_2$	24.92[v]	6.39	-3.51	-45,000[q]	-44,550[q]	31.2[q]
$KAlSi_3O_8$	63.83[q]	12.90	-17.05	-892,817.[l]	-946,000[q]	52.47[q]
$CaAl_2Si_2O_8$	64.42[q]	13.70	-16.89	-955,626.[l]	-1,009,300[q]	48.45[q]
$NaAlSi_3O_8$	61.70[q]	13.90	-15.01	-883,988.[l]	-937,300[q]	50.2[q]
$Mg_5Al_2Si_3O_{10}(OH)_8$	96.8[q]	36.1	-23.9	-1,954,800.[l]	-2,109,840[q]	112[q]
$KAl_3Si_3O_{10}(OH)_2$	97.56[q]	26.38	-25.44	-1,330,103.[l]	-1,420,900[q]	69[q]
$Na_{.33}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	84.9[q]	34.3	-19.7	-1,277,790.[q]	-1,366,840[q]	62.8[q]
$Ca_{.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	84.2[q]	33.6	-20.	-1,279,240.[q]	-1,367,980[q]	61.2[q]
$Mg_{.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2$	84[q]	33.7	-19.9	-1,275,340.[q]	-1,364,140[q]	61.2[q]
$K_{.6}Mg_{.25}Al_{2.36}Si_{3.5}(OH)_2$	87.9[q]	35.	-19.5	-1,300,980.[q]	-1,390,820[q]	66.4[q]
$Al_2Si_2O_5(OH)_4$	67.93[q]	19.22	-13.78	-902,868.[q]	-980,020[q]	48.53[q]
CO_2	10.57[q]	2.10	-2.06	-94,257.[l]	-94,050[q]	51.06[q]

TABLE I-6 (continued)

[a]Calculated from data in Tables I-5 and I-7. [b]Langmuir (1969). [c]Calculated from data in Tables I-5 and I-7 and $(\Delta H_f^o)_{298.}$ [d]Christ and Hostetler (1970). [e]The C_p of Stavely and Linford (1969) and that of Kelly (1960) were combined and a new equation valid for 250°-500°K was derived. [f]Anderson (1934). [g]The heat capacities for calcite and magnesite were summed for temperatures above 300°K. The data of Stout and Robie (1963) was used from 250°-300°K and a new equation was derived valid from 250°-500°K. [h]Calculated from data in Tables I-5 and I-7. [i]Calculated from log K, dolomite, Langmuir (1971b) and data in Tables I-5 and I-7. [j]Kelly (1960). [k]Calculated from data in Table I-5 and log K in Schindler et al. (1969). [l]Robie and Waldbaum (1968). [m]Calculated from data in Table I-5 and log K by Morgan (1967). [n]Calculated from data in Table I-5 and log K from Wigley (1971). [o]Calculated from the $(\Delta G_f^o)_{298.}$ log K, data in Table I-5 and $(\Delta H_f^o)_{298.}$ of gypsum from Robie and Waldbaum (1968). [p]Calculated from data in Table I-5 and log K given in Schindler et al. (1968). [q]Helgeson (1969). [r]JANAF Tables (1971) C_p coefficients good up to 500°K. [s]Langmuir (1969) for freshly precipitated material. [t]Calculated from data in Table I-5 and $(\Delta G_f^o)_{298.}$ and $(S_f^o)_{298.}$ of $Fe(OH)_3$. [u]Pankratz and King (1965). [v]Pankratz and King (1970). [w]Calculated from $(S_f^o)_{298.}$ and $(\Delta H_f^o)_{298.}$ and data in Table I-5.

TABLE I-7.

Equilibrium constants for the dissolution of various minerals in aqueous solutions, at elevated temperatures and a pressure of 1 bar. All data calculated from that in Tables I-5 and I-6 except where noted otherwise.

Reaction Number (Table I-4)	$(\Delta H^\circ_r)_{298.}$ (cal/mole)	$(\Delta S^\circ_r)_{298.}$ (cal/mole-deg)	Log K(T) 25°C	50°C	60°C	100°C	150°C	200°C
1	-2585.[a]	-47.4[a]	-8.475[a]	-8.700[a]				
2	-6024.[e]	-68.57	-10.55[e]		-11.18	-11.98	-12.96	-14.22
3[c]	-6102.	-57.5	-8.09	-8.51	-8.69	-9.50	-10.48	-11.70
4	-9280.[d]	-108.93[d]	-17.0[d]		-17.99	-19.38	-21.35	-23.63
5	-3250.	-60.2	-10.78[e]		-11.17	-11.77	-12.56	-13.63
6	-1816.	-53.7	-10.41[f]		-10.70	-11.23	-11.96	-13.02
7	-665.	-23.28	-4.60[g]		-4.72[g]	-5.00[g]		
8			-5.16[h]					
9			-16.89[h]					
10[i]	-25,820.	-9.81	16.78		14.84	13.10	11.41	10.09
11	-29,210.	-16.07	-17.90		-15.58	-14.07	-12.69	-11.92
12	-25,923.	-26.58	-13.196		-11.28	-9.77	-8.52	-8.05

TABLE I-7 (continued)

Reaction Number (Table I-4)	$(\Delta H^{\circ}_r)_{298.}$ (cal/mole)	$(\Delta S^{\circ}_r)_{298.}$ (cal/mole-deg)	Log K(T) 25°C	50°C	60°C	100°C	150°C	200°C
13	-130,880.	-56.07	-83.65		-73.79	-65.30	-57.51	-52.06
14	-68,790.	-22.09	-45.58		-40.51	-36.00	-31.9	-28.92
15	-150,030.	-45.20	-100.08		-88.83	-78.96	-69.87	-63.35
16[i]	7248.	12.78	-2.53		-1.96	-1.46	-1.08	-.71
17[i]	-32,175.	-29.83	-17.06		-14.57	-12.26	-9.91	-8.16
18[i]	1307.5	4.95	.125		.235	.345	.370	.45
19[i]	-111,865.	-75.08	65.57		57.15	49.81	42.86	37.95
20[i]	-6697.5	3.179	-5.61		-5.09	-4.57	-3.98	-3.51
21[i]	6552.5	-12.95	-7.65		-7.15	-6.77	-6.61	-6.54
22[i]	4735.	-58.74	-16.31		-15.91	-16.00	-16.16	-16.64
23[i]	1055.	-73.37	-16.81		-16.76	-16.85	-17.41	-18.05
24[i]	-2309.	-.569	1.57		1.39	1.21	.95	.75

TABLE I-7 (continued)

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[a]Jacobson and Langmuir (1974) assuming ion pairing of $CaCO_3^o$ and $CaHCO_3^+$. [b]Langmuir (1969). [c]All data from Christ and Hostetler (1970). [d]Langmuir (1971b). [e]Schindler et al. (1969). [f]Morgan (1967). [g]Wigley (1971). [h]Schindler et al. (1968). [i]All data from Helgeson (1969).

TABLE I-8.

Thermodynamic data for dissociational equilibria used in this study.

Reaction	$(\Delta H_r^o)_{298.}$ (cal/mole)	$(\Delta S_r^o)_{298.}$ (cal/mole^{-1}deg^{-1})	Log K_T 0°C	25°C	50°C	60°C	100°C	150°C	200°C
$CaHCO_3^+ = Ca^{2+} + HCO_3^-$	-5405.[a]	-22.66[b]	-.7[a]	-.99[a]	-1.5[a]				
$MgHCO_3^+ = Mg^{2+} + HCO_3^-$				-1.23[c]					
$NaSO_4^- = Na^+ + SO_4^{2-}$	-490.[d]	-1.3[d]		-.643[e]		-.608[e]	-.582[e]	-.568[e]	-.571[e]
$MnHCO_3^+ = Mn^{2+} + HCO_3^-$				-1.95[f]					
$MnOH^+ = Mn^{2+} + OH^-$				-3.41[f]					
$KSO_4^- = K^+ + SO_4^{2-}$			-.64[g]	-.85[g]		-1.084[g]	-1.301[g]	-1.514[h]	-1.682[h]
$NaCO_3^- = Na^+ + CO_3^{2-}$				-1.27[i]					
$FeOH^+ = Fe^{2+} + OH^-$				-5.7[j]					
$CuOH^+ = Cu^{2+} + OH^-$				-6.0[k]					
$ZnOH^+ = Zn^{2+} + OH^-$				-5.04[l]					
$NaHCO_3 = Na^+ + HCO_3^-$				.25[i]					
$MgCO_3^o = Mg^{2+} + CO_3^{2-}$	-3230.[m]	-24.[m]	-2.76[m]	-2.88[m]	-3.1[m]	-3.29 [h]			

TABLE I-8 (continued)

Reaction	$(\Delta H^o_r)_{298.}$ (cal/mole)	$(\Delta S^o_r)_{298.}$ (cal/mole^{-1}deg^{-1})	Log K_T 0°C	25°C	50°C	60°C	100°C	150°C	200°C
$FeSO_4^o = Fe^{2+} + SO_4^{2-}$	-560.[d]	-12.[d]	-2.18[e]	-2.21[d]		-2.28[e]	-2.40[e]	-2.62[e]	-2.92[e]
$ZnSO_4^o = Zn^{2+} + SO_4^{2-}$	-1360.[n]	-15.8[n]	-2.25[e]	-2.32[n]		-2.46[e]	-2.66[e]	-2.98[e]	-3.40[e]
$CuSO_4^o = Cu^{2+} + SO_4^{2-}$	-1720.[d]	-16.6[d]	-2.27[e]	-2.37[d]		-2.53[e]	-2.76[e]	-3.13[e]	-3.61[e]
$MnSO_4^o = Mn^{2+} + SO_4^{2-}$	-610.[d]	-15.2[d]	-2.85[e]	-2.87[d]		-2.95[e]	-3.10[e]	-3.30[e]	-3.75[e]
$CaSO_4^o = Ca^{2+} + SO_4^{2-}$	-1500.[n]	-15.6[n]	-2.22[e]	-2.31[n]		-2.46[e]	-2.67[e]	-3.00[e]	-3.44[e]
$MgSO_4^o = Mg^{2+} + SO_4^{2-}$	-4010.[o]	-24.4[o]	-2.13[o]	-2.40[o]	-2.63[o]		-3.06[o]	-3.50[o]	-4.00[o]
$MnCO_3^o = Mn^{2+} + CO_3^{2-}$				.75[p]					
$Fe(OH)_2 = Fe^{2+} + 2OH^-$				-10.4[j]					
$CaCO_3^o = Ca^{2+} + CO_3^{2-}$	-4025.[m]	-27.9[m]	-3.01[m]	-3.15[m]	-3.49[m]	-3.67[h]			
$CuCO_3^o = Cu^{2+} + CO_3$				-6.77[k]					
$H_2O = H^+ + OH^-$	13,335.[q]	-19.31[q]	-14.94[s]	-13.997[s]	-13.262[s]	-13.017[s]	-12.254[t]	-11.634[t]	-11.254[t]
$HCO_3^- = H^+ + CO_3^{2-}$	-3600.[q]	-35.16[q]	10.63[r]	10.329[r]	10.17[r]	10.15[q]	10.16[q]	10.29[q]	10.68[q]
$CO_2 + H_2O = H^+ + HCO_3^-$	-2810.[q]	-45.2[q]		-7.81[q]	-8.01[q]	-8.10[q]	-8.42[q]	-8.80[q]	-9.14[q]

TABLE I-8 (continued)

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[a]Jacobson and Langmuir (1974). [b]Calculated from $(\Delta H_r^o)_{298.}$ and log K from Jacobson and Langmuir (1974). [c]Nakayama (1971). [d]Izatt et al. (1969). [e]Calculated from equation 16 in Helgeson (1969). [f]Morgan (1967). [g]Truesdall and Hostetler (1968). [h]Extrapolated. [i]Garrels and Christ (1965). [j]Langmuir (1969). [k]Schindler (1967). [l]Perrin (1962). [m]Reardon and Langmuir (1974). [n]Larson (1970). [o]Marshall (1967). [p]Calculated from $(\Delta G_f^o)_{298.}$ of $MnCO_3^o$ given in Rossini et al. (1952). [q]Helgeson (1969). [r]Harned and Scholes (1941). [s]Harned and Robinson (1940). [t]Fisher (1969).

TABLE I-9.

Coefficients from the general equation $\log K = A\ln T + BT + C/T + D/T^2 + E$ which describes the variation of the equilibrium constant with temperature.

	Coefficients				
Equation	A	B	C	D	E
C1[a]		-.0401	-3000.		13.543
C2	+822.6087	-.786562	+293257.5	-17382225.	-5250.997
C3	-144.0448	.099332	-54016.1	3165222.	928.565
C4	497.5967	-.513326	+177314.4	-10816790.	-3172.089
C5	719.7140	-.689067	256724.0	-15307840.	-4594.822
C6	716.2077	-.687730	255068.0	-15245845.	-4570.017
C7		.00249		(-.0000952)[b]	-4.641
C8					-5.17
C9					-16.89
C10	-122.8952	.105668	-42403.5	3100355.	792.826
C11	30.9372	-.023053	17207.3	-544141.	-203.092
C12	-23.8387	.026065	-2334.2	478232.	143.692
C13	-13.6399	.016862	-2444.4	286117.	83.642
C14	-55.4125	.051759	-18734.1	1295875.	354.240
C15	-33.4926	.033724	-9923.2	743007.	211.951
C16	59.4441	-.054909	20267.0	-1342917.	-377.705
C17	29.2675	-.032082	16718.7	-568579.	-189.805
C18	48.3227	-.045058	16875.1	-1007557.	-307.031
C19	-1369.5290	1.287843	-466758.7	29421070.	8719.176
C20	-22.4010	.016037	-7026.2	482453.	146.592
C21	45.1842	-.053364	13235.0	-885330.	-283.594
C22	150.5456	-.164688	50008.4	-3100394.	-957.801
C23	16.8890	-.046920	528.0	158 2.	-100.990
C24	9.2165	-.012076	3286.2	-165074.	-56.508
B1	205.4062	-.185866	753343.5	-4999629.	-1325.358
B2	-28.612	.03129	-5336.5	30029.	163.43

[a]Equation from Jacobson and Langmuir (1974). [b]Coefficient is times T^2 not D/T^2, equation from Wigley (1971).

TABLE I-10.

Coefficients for the general equation, $A\ln T + BT + C/T + D/T^2 + K$, which describes the variation of the dissociation constant with temperature.

	Coefficients				
	A	B	C	D	K
$CaHCO_3^+$		.0133			-2.95
$MgHCO_3^+$					-1.23
$NaSO_4^-$	1.572	-.00318	76.3	390.2	-8.910
$MnHCO_3^+$					-1.95
$MnOH^+$					-3.41
KSO_4^-			673.6		-3.106
$NaCO_3^-$					-1.27
$FeOH^+$					-5.7
$CuOH^+$					-6.0
$ZnOH^+$					-5.04
CO_3^{2-} [a]		-.01261	296.09	-328532.	-3.8662
$NaHCO_3^o$					.25
$MgCO_3$		-.04467	-3265.		21.39
$FeSO_4$	14.366	-.02926	1740.6	9583.	-81.286
$ZnSO_4$	17.945	-.03671	2300.	12486.	-101.479
$CuSO_4$	19.647	-.04017	2571.	13672.	-111.11
$MnSO_4$	17.98	-.03676	2143.	12439.	-101.687
$CaSO_4$	18.018	-.03708	2315.	13188.	-101.826
$MgSO_4$	23.702	-.04215	4077.	17765.	-138.75
$MnCO_3$					.748
$Fe(OH)_2$					-10.4
$CaCO_3$		-.05617	-4114.		27.393
$CuCO_3$					-6.77
H_2O [b]	-28.612	.03129	-5336.5	30029.	163.43
CO_2 [c]	205.4062	-.185866	75343.5	-4999629.	-1325.358

TABLE I-10 (continued)

$^{a}HCO_3^- = CO_3^{2-} + H^+$

$^{b}H_2O = OH^- + H^+$

$^{c}CO_2 + H_2O = HCO_3^- + H^+$

DESCRIPTION OF THE COMPUTER PROGRAM WHICH CALCULATES THE COEFFICIENTS OF EQUATION (I-8)

A computer program was written for the I.B.M. 360 computer at McGill University. The program is written in Fortram IV for a WATFIV compiler. The input is as follows:

Card 1 is the number of reactions to be run. Every reaction consists of the following cards. Card 2 is the Title of the reaction, and is labled NREAC in the program and must not have over 8 numbers or letters. Card 3 is the number of equilibrium constants which are entered and is labled N in the program. Card 4 consists of $(\Delta H^{o}_{r})_{298.}$, $(\Delta S^{o}_{r})_{298.}$, XN which is the number of electrons transferred. If the reaction is not a redox reaction then 1 must be entered for XN. Cards 5, 6, etc. contain the temperatures in degrees Centigrade and log K. There is one card for each temperature. There must be a total of N such cards.

Table I-11 is a listing of the program. The output consists of the coefficients for the general equation, $\log K = A\ln T + BT + C/T + D/T^2 + K$, and the coefficients for the change in heat capacity of the reaction of the type $C_{p,r} = a + BT + C/T^2$.

TABLE I-11.

Computer listing of the computer program which calculates the coefficients of equation (1-8).

```
(1)   $WATFIV 706652 -700 ' -NOAG,PAGES=25
 1          DIMENSION XLOGK(50),CLOGK(50),PE(50),PE1(50)
 2          DOUBLE PRECISION XA,XB,XC,XD,XE,XF,XG,XH,XI,XJ,XK,XM,A,B,D,A1,B1,
           1D1,A2,B2,C2,D2,K2,X1,X2,X3,T(50),TT(50),Y,NREAC
 3          READ,M
 4          DO 20 J=1,M
 5          READ(5,24)NREAC
 6       24 FORMAT(A8)
 7          READ,N
 8          READ,DH,DS,XN
 9          XA=0.
10          XB=0.
11          XC=0.
12          XD=0.
13          XE=0.
14          XF=0.
15          XG=0.
16          XH=0.
17          XI=0.
18          XJ=0.
19          XK=0.
20          XM=0.
21          DO 1 I=1,N
22          READ,T(I),XLOGK(I)
23          TT(I)=T(I)+273.15
24          PE(I)=XLOGK(I)/XN
25          X1=TT(I)-TT(I)*DLOG(TT(I))+TT(I)*ALOG(298.15)-298.15
26          X2=(TT(I)*298.15-(TT(I)**2)/2.-44446.71125)
27          X3=(.5/TT(I)+TT(I)/177796.845-.003354016435)
28          Y=(XLOGK(I)*2.303*.0019872*TT(I)-DH+TT(I)*DS)
29          XA=XA+X1*X1
30          XB=XB+X1*X2
31          XC=XC+X1*X3
32          XD=XD+X1*Y
33          XE=XE+X1*X2
34          XF=XF+X2*X2
35          XG=XG+X2*X3
36          XH=XH+X2*Y
37          XI=XI+X1*X3
38          XJ=XJ+X2*X3
39          XK=XK+X3*X3
40          XM=XM+X3*Y
41        1 CONTINUE
42          D=((XH/XE-XM/XI)*(XF/XE-XB/XA)-(XH/XE-XD/XA)*(XF/XE-XJ/XI))/
           1((XB/XE-XJ/XI)*(XC/XA-XG/XE)-(XK/XI-XG/XE)*(XF/XE-XB/XA))
43          B=(D*(XC/XA-XG/XE)+XH/XE-XD/XA)/(XF/XE-XB/XA)
44          A=(-XB/XA)*B-(XC/XA)*D+XD/XA
45          D1=(D/.0045765)
46          B1=(B/.0045765)
47          A1=(A/.0045765)
48          A2=-A1/XN
49          B2=(-B1/2.)/XN
50          C2=(-A1*(298.15)-(B1/2.)*(298.15**2.)-(D1/298.15)+DH/(2.303*.00198
           172))/XN
51          D2=(D1/2.)/XN
52          K2=(A1+A1*ALOG(298.15)+B1*298.15+D1/(2*(298.15**2))
           1-DS/(2.303*.0019872))/XN
53          DO 16 I=1,N
54          PE1(I)=A2*DLOG(TT(I))+B2*TT(I)+C2/TT(I)+D2/(TT(I)**2.)+K2
55          CLOGK(I)=PE1(I)*XN
```

TABLE I-11 (continued)

```
     56          CLOGK(I)=-CLOGK(I)
     57          XLOGK(I)=-XLOGK(I)
     58          PE1(I)=-PE1(I)
     59          PE(I)=-PE(I)
     60       16 CONTINUE
     61          WRITE(6,25) NREAC
     62          IF(XN.GT.1.) GO TO 3
     63          WRITE(6,6)
     64          WRITE(6,2)(T(I),XLOGK(I),CLOGK(I),I=1,N)
     65          GO TO 5
     66        3 WRITE(6,7)
     67          WRITE(6,4)(T(I),XLOGK(I),CLOGK(I),PE(I),PE1(I),I=1,N)
     68        5 CONTINUE
     69          IF(XN.EQ.1.) GO TO 11
     70          WRITE(6,9)
     71          WRITE(6,10)
     72          WRITE(6,8)-A2,-B2,-C2,-D2,-K2
*EXTENSION*    IO-3
*EXTENSION*    IO-3
*EXTENSION*    IO-3
*EXTENSION*    IO-3
*EXTENSION*    IO-3
     73          GO TO 12
     74       11 WRITE(6,13)
     75          WRITE(6,10)
     76          WRITE(6,8)-A2,-B2,-C2,-D2,-K2
*EXTENSION*    IO-3
*EXTENSION*    IO-3
*EXTENSION*    IO-3
*EXTENSION*    IO-3
*EXTENSION*    IO-3
     77       12 CONTINUE
     78        6 FORMAT('0',18X,'TEMP-C      LOGK(OBS)      LOGK(CALC)'//)
     79        2 FORMAT(10X,3F14.3)
     80        4 FORMAT(10X,5F14.3)
     81       25 FORMAT('1',10X,A8)
     82        7 FORMAT('0',18X,'TEMP-C      LOGK(OBS)      LOGK(CALC)      PE(OBS)
               1     PE(CALC)'//)
     83        9 FORMAT('0',10X,'COEFFICIENTS FOR THIS EQUATION PE =A(LNT)+BT+C/T+D
               1/T**2+K')
     84        8 FORMAT(10X,F16.4,F16.6,F18.1,F17.0,F18.3//)
     85       13 FORMAT('0',10X,'COEFFICIENTS FOR THIS EQUATION  LOGK=A(LNT)+BT+C/T
               1+D/T**2+K')
     86       10 FORMAT('0',21X,'A',16X,'B',16X,'C',15X,'D',17X,'K'//)
     87          WRITE(6,17)
     88          WRITE(6,18)
     89       17 FORMAT('0',10X,'COEFFICIENTS FOR THE CHANGE IN HEAT CAPACITY WITH
               1TEMPERATURE')
     90       18 FORMAT('0',10X,'CP(REAC) = A+B*T-D/T**2 = A+B*T+C/T**2')
     91          WRITE(6,14)
     92          WRITE(6,15) A,B,D
     93       14 FORMAT('0',20X,'A',15X,'B',16X,'D'//)
     94       15 FORMAT(10X,F16.7,F16.8,F16.2)
     95       20 CONTINUE
     96       19 FORMAT('1')
     97          WRITE(6,19)
     98          STOP
     99          END
```

APPENDIX II DESCRIPTION OF THE PROGRAM WHICH CALCULATES THE SATURATION INDEX OF MINERAL-WATER REACTIONS

The degree of saturation of a mineral in aqueous solution is determined by comparing the products of the activities of the dissolved solids with the equilibrium constant at the temperature of the water. This degree of saturation is expressed in the form of a saturation index which has been used by various authors (e.g., Wigley, 1971, 1973; Langmuir, 1971; Paces, 1969, 1972, 1973).

The activities of the constituents have been found using Debye-Hückel theory, assuming ion pairing and using a method of successive approximations to calculate ionic strength and activities (Garrels and Thompson, 1962). This program is based on one by Wigley (1972) but extended to include silicates and sulfides.

THEORETICAL BACKGROUND

The degree of saturation of the 24 mineral-water systems can be expressed in the form of a saturation index (SI). The definition of saturation index for this study is somewhat different than other studies but similar to Langmuir (1971b). In reactions which can be written to consume or produce H^+, the SI is defined as the Log(AP/K) divided by the number of hydrogen ions transferred, where AP is the ion activity product and K is the equilibrium constant of the reaction of interest. This is equivalent to writing the reaction and calculating the equilibrium constant to conform with the

transfer of one hydrogen ion. The saturation index when calculated in this manner is equivalent to the amount the pH must be changed for the solution to be in a state of equilibrium with respect to the mineral of interest. For example a saturation index of -.2 for the dissociation of calcite means the pH must be increased by .2 before saturation of the solution with respect to calcite occurs assuming all other constituents remain constant. The saturation index of one reaction can be directly compared to another, thereby indicating which reaction is closer to equilibrium. If a saturation index is positive the water is supersaturated; if it is negative, the water is unsaturated with respect to the compound on the left hand side of the equation. The reactions considered are given in Table I-4.

In the case of a redox reaction, the saturation index is equal to the equilibrium pe (pe_{eq}) minus the measured pe (pe_m), divided by the number of hydrogen ions transferred. The equilibrium pe is defined here as the pe of the solution in which the reaction of interest is at equilibrium. A good example is the pyrite reaction.

$$Fe^{2+} + 2SO_4^{2-} + 16H^+ + 14e^- = 8H_2O + FeS_2 \qquad (II-1)$$

pe^o is equal to $1/n \log K$, where n is the number of electrons transferred and K is the equilibrium constant (Stumm and Morgan, 1970). The reaction must be written with the electrons

on the left, pe^o is the electron activity when all species other than electrons are at unit activity and it is related to the standard electrode potential by:

$$pe^o = E^o/2.303RTF^{-1}$$

where R is the gas constant, F is Faraday's constant and T is temperature in ^oK.

The $\log_{10}$ activity product of equation (II-1) is:

$$\log(AP) = -\log\left[Fe^{2+}\right] - 2\log\left[SO_4^{2-}\right] + 16pH + 14pe_m$$

where $pe_m = -\log\left[e^-\right]$

At equilibrium the activity product is numerically equal to the equilibrium constant. Therefore,

$$\log K = -\log\left[Fe^{2+}\right] - 2\log\left[SO_4^{2-}\right] + 16pH + 14pe_m$$

Since $pe^o = 1/n \log K$ and $n = 14$ then,

$$pe^o = -1/14 \log\left[Fe^{2+}\right] - 2/14 \log\left[SO_4^{2-}\right] + 16/14pH + pe_m$$

rearranging,

$$pe_{eq} - pe^o + 1/14 \log\left[Fe^{2+}\right] + 2/14 \log\left[SO_4^{2-}\right] - 16/14pH$$

where at equilibrium $pe_{eq} - pe_m$

Therefore at equilibrium this reaction should have a pe_m equal to pe_{eq}. If the pe_m is less than the pe_{eq} then the reaction will proceed to the right, i.e., the solution is supersaturated with respect to pyrite. Consequently the saturation index is defined as $(pe_{eq} - pe_m)$ divided by the number of hydrogen ions transferred. The reaction is written backwards in relation to the hydrolysis and dissociation reactions and a positive index indicates supersaturation and a negative index indicates undersaturation with respect to the compound on the right (the mineral being oxidized).

Activity coefficients for the charged species were calculated using the Debye-Hückel relation which is valid for ionic strengths less than 0.1, a value not exceeded in this study. The activity coefficients of uncharged species were taken to be unity.

The Debye-Hückel relation is:

$$-\log\gamma_i = AZ_i^2 I^{\frac{1}{2}} \left[1 + a_i B I^{\frac{1}{2}} \right]^{-1}$$

where γ_i is the activity coefficient, Z_i is the charge for species i, a_i is the effective ion radius for species i, I is the ionic strength and A and B are temperature dependent constants.

The values for a_i are from Garrels and Christ (1965). Ionic strength I is defined as,

$$I = \tfrac{1}{2}\Sigma m_i Z_i^2$$

where m_i is the molarity of species i. Temperature dependent equations for A and B are from Helgeson (1969) and are:

$$A = (1.8246 \times 10^6 \rho^{\frac{1}{2}})/(\epsilon T)^{3/2}$$

$$B = (50.29 \times 10^8 \rho^{\frac{1}{2}})/(\epsilon T)^{\frac{1}{2}}$$

where ρ is equal to the density of water and ϵ is the dielectric constant of water, and both are temperature dependent. The equations which describe the variation of these parameters with temperature are the following (Anderson, 1973):

$$\rho = 1.4579 - .0031654 * T + 7.9018 \times 10^{-6} T^2 - 8.1461 * 10^{-9} T^3$$

$$\epsilon = 283.49 - 1.1001 * T + 1.6714 \times 10^{-3} T^2 - 9.6878 \times 10^{-7} T^3$$

Ion pairs were considered in this study and are given on Table I-10. The coefficients of the temperature dependent equation which gives the dissociation constant at any temperature up to 473°K is also given on this table. Most of those ion pairs which occur outside of the pH range of this study (pH 6-8) are not included. The method of calculating the molarities of the individual and complexed ions is from Garrels and Thompson (1962). The following is an example of this calculation for Ca^{2+} and its complex ions.

$$mCa_{(total)} = mCa^{2+} + mCaHCO_3^{+} + mCaCO_3^{o} + mCaSO_4^{o} \qquad (II-2)$$

where $mCa_{(total)}$ is the total analysed Ca in solution. mCa^{2+},

$mCaHCO_3^+$, etc. are the molarities of the Ca^{2+} ion and the complex ions.

The components of equation (II-2) are related to each other by the equilibrium constants for the various reactions which can occur in solution.

$$aH^+ \, aCO_3^{2-} / aHCO_3^- = K_{HCO_3}$$

$$aCa^{2+} \, aHCO_3^- / aCaHCO_3^+ = K_{CaHCO_3}$$

$$aCa^{2+} \, aCO_3^{2-} / aCaCO_3^o = K_{CaCO_3}{}^o$$

$$aCa^{2+} \, aSO_4^{2-} / aCaSO_4^o = K_{CaSO_4}{}^o$$

where K_{HCO_3}, etc. are equilibrium constants and aH^+, etc. are activities of the species. Substitution of these equations into equation (II-2), setting activity equal to activity coefficient (γ) times molarity (m) and rearranging yields:

$$mCa^{2+} = mCa_{(total)} \left[1 + \left(\gamma Ca \gamma HCO_3 mHCO_3^- / \gamma CaHCO_3 K_{CaHCO_3} \right) + \left(\gamma Ca \gamma HCO_3 mHCO_3^- K_{HCO_3} / \gamma CaCO_3{}^o aH^+ K_{CaCO_3}{}^o \right) + \left(\gamma Ca \gamma SO_4 mSO_4^{2-} / \gamma CaSO_4{}^o K_{CaSO_4}{}^o \right) \right]^{-1}$$

Similar equations are derived for all the species in

solution. The ionic strength was then corrected for ion pairing and a new activity coefficient was calculated. A method of successive approximations (Garrels and Thompson, 1962) is used to determine the true ionic strength and distribution of species. The approximation is terminated when the difference between two successive values of the ionic molarity of Ca^{2+} each divided by the second ionic molarity of Ca^{2+} is less than a designated error level, in this case .0001.

INPUT AND OUTPUT DETAILS OF THE COMPUTER PROGRAM

The program was developed for the I.B.M. 360 computer at McGill University. It is written in Fortran IV for use with a WATFIV compiler. The input cards are as follows:

Card 1 contains the number of samples in free format. Card 2 has the sample name, sample date, temperature in ^{o}C, pH, Eh (with reference to the H_2 electrode), and chemical constituents in ppm in this order: Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, Na^+, K^+, Cl^-, Fe^{2+}, Cu^{2+}, Zn^{2+}, Mn^{2+}, H_4SiO_4. These are all entered in free format. The following constituents must have analyses entered: pH, Ca^{2+}, Mg^{2+}, HCO_3^-, SO_4^{2-}, Na^+, K^+, Cl^- and H_4SiO_4. If no analysis is made or the result is zero for Eh, Fe^{2+}, Cu^{2+}, Zn^{2+} and Mn^{2+} then zero must be entered on Card 2. Temperature, pH, Eh and constituents must have a decimal point. The sample label may have letters or numbers, but is must be entered in the form of a Hollarith statement, e.g.,'DS-1'. The sample date must be entered in numbers only since the output is in I format.

Only 4 spaces are allowed for sample name and 6 spaces for the date.

The output contains the sample label and date for every sample on every output page. In order that all information is given on one page, only 23 samples should be run at once. The addition of an extra do-loop would make it possible to do as many batches of 23 samples as need be. The output is 19 pages long. The reactions which were considered are written out by comment statements in the main body of the program as indicated by the listings (Table II-2). The output for total molarity, ionic molarity, activity, activity product, total dissolved solids, and partial pressure of CO_2 are in $\log_{10}$ form, and this is indicated on the output. Also, codes are given for data which were entered as zero, or in the case of Eh, no measurement performed. If a measured Eh were by accident zero, then .001 should be entered. The last page of the output includes the equilibrium pe which was discussed earlier. A flow chart and listing of the program are given in Tables II-1 and II-2. Examples of the output are given in Appendix VI.

TABLE T1-1.

Main Program SATIND

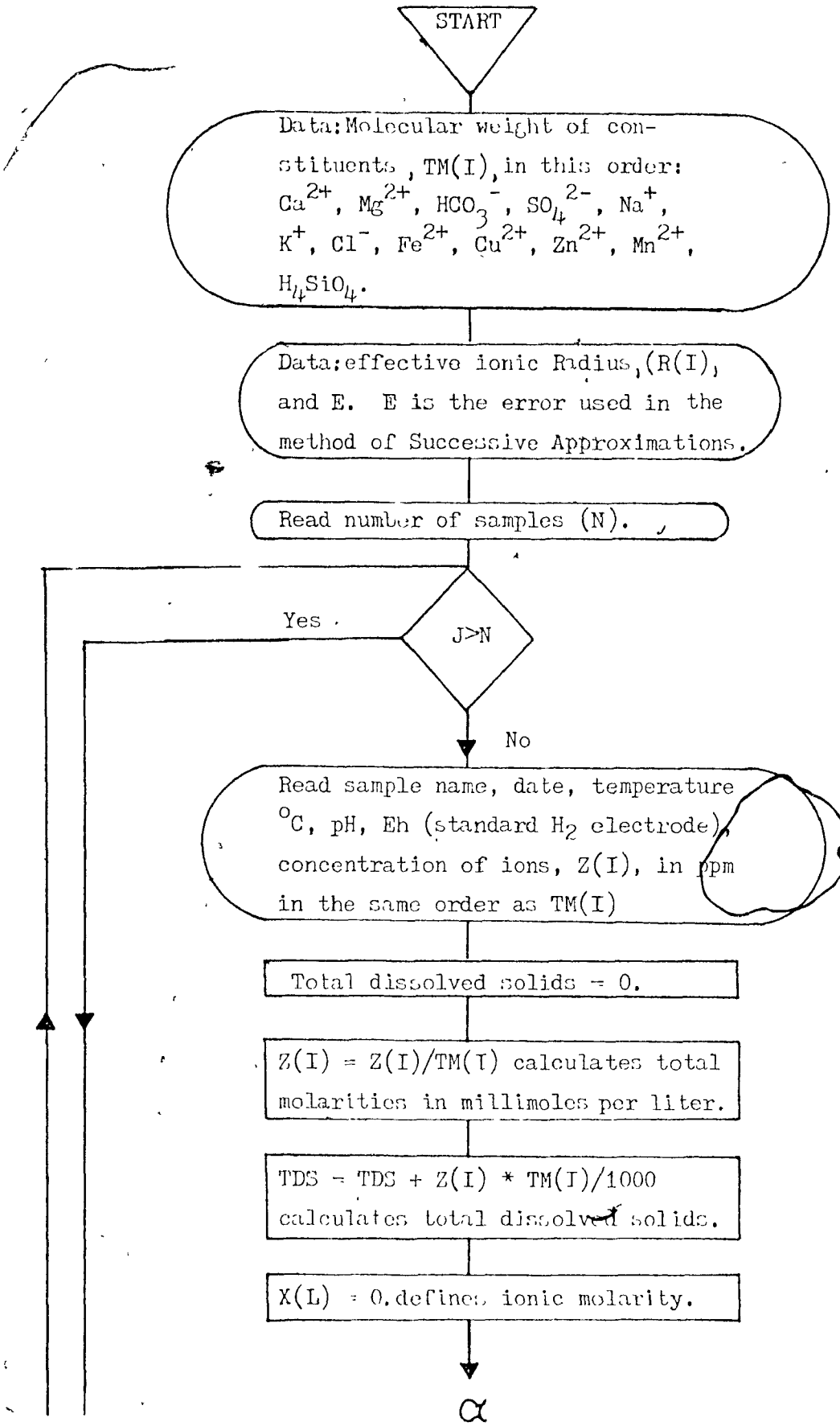


TABLE II-1 (continued)

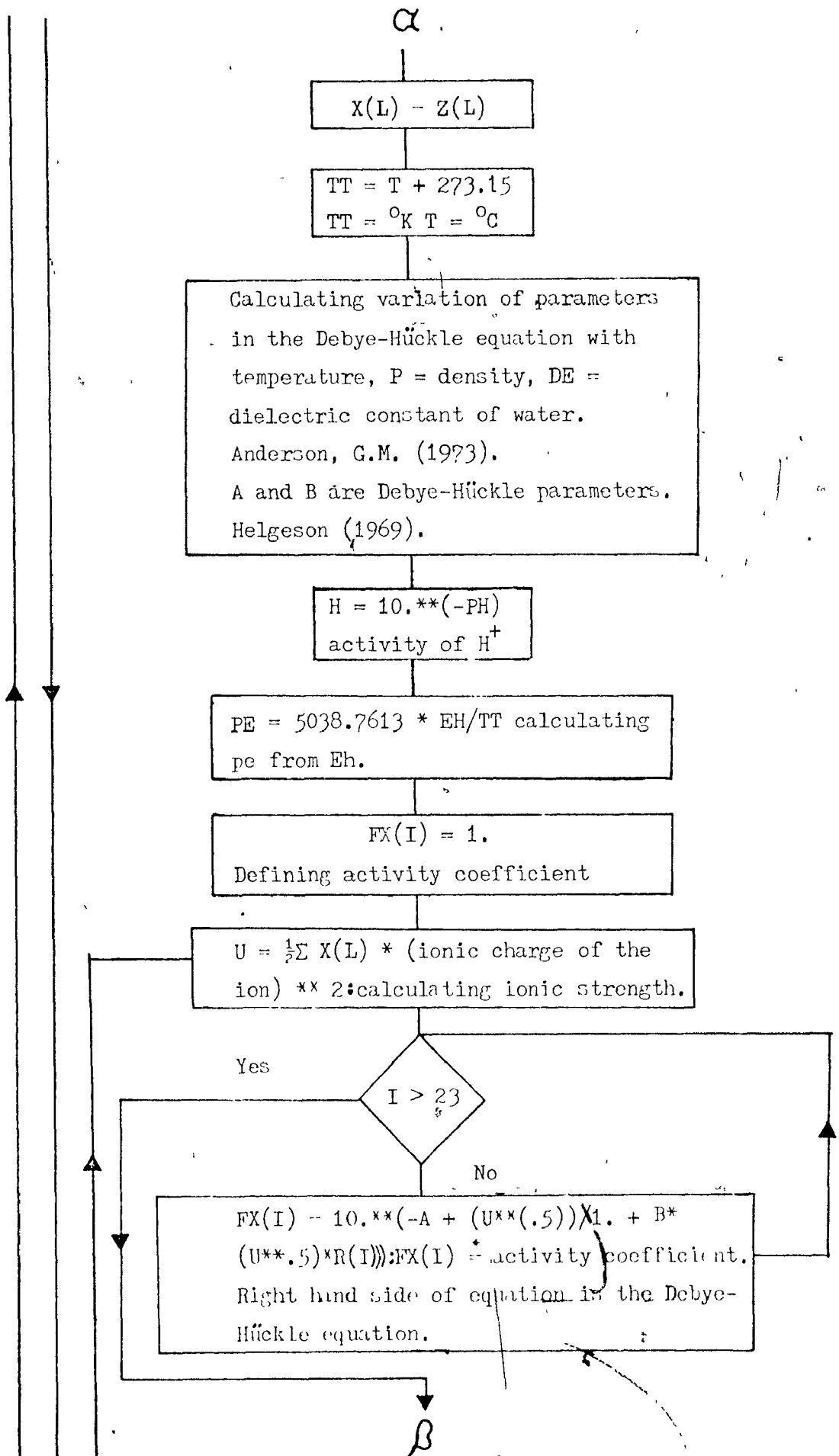


TABLE II-1 (continued)

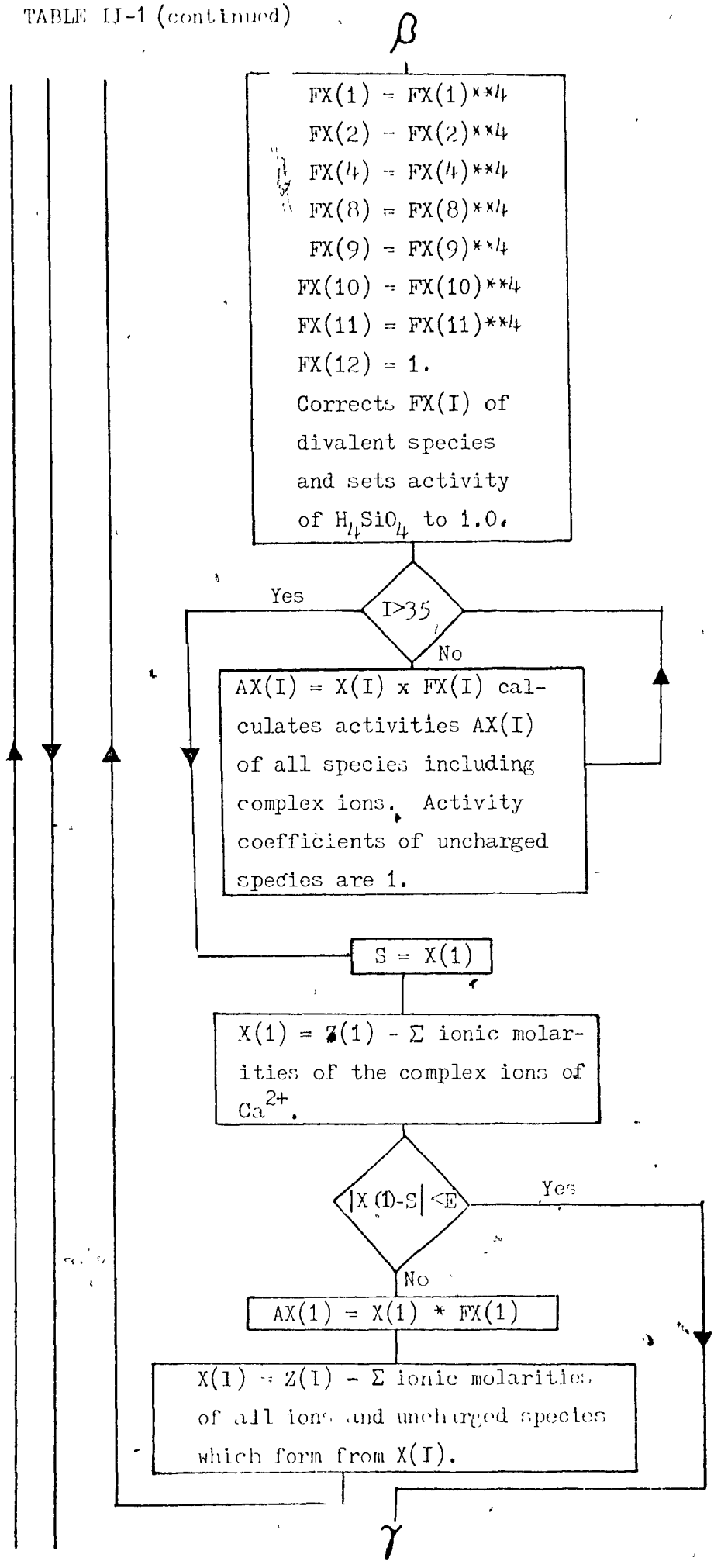


TABLE II-1 (continued)

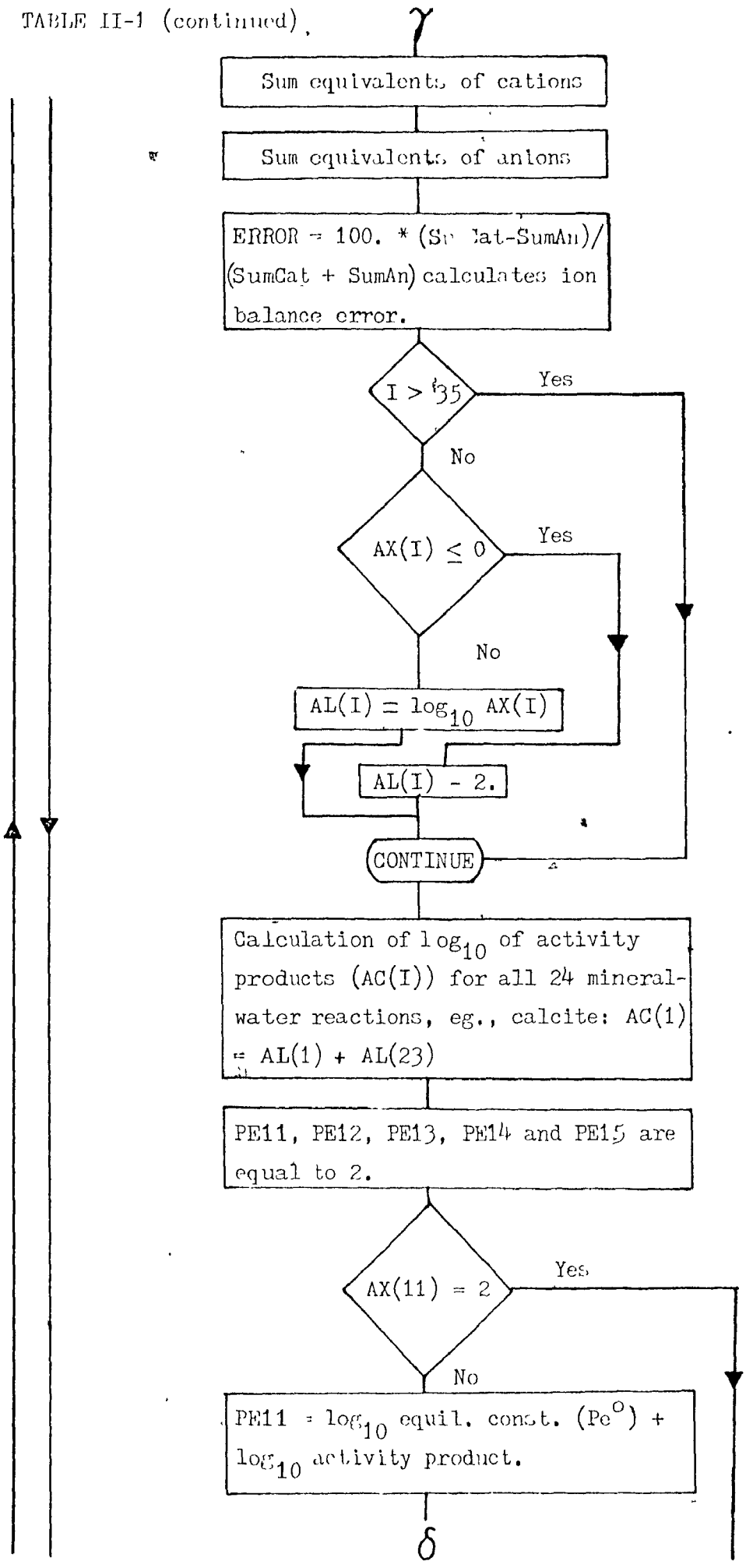


TABLE II-1 (continued)

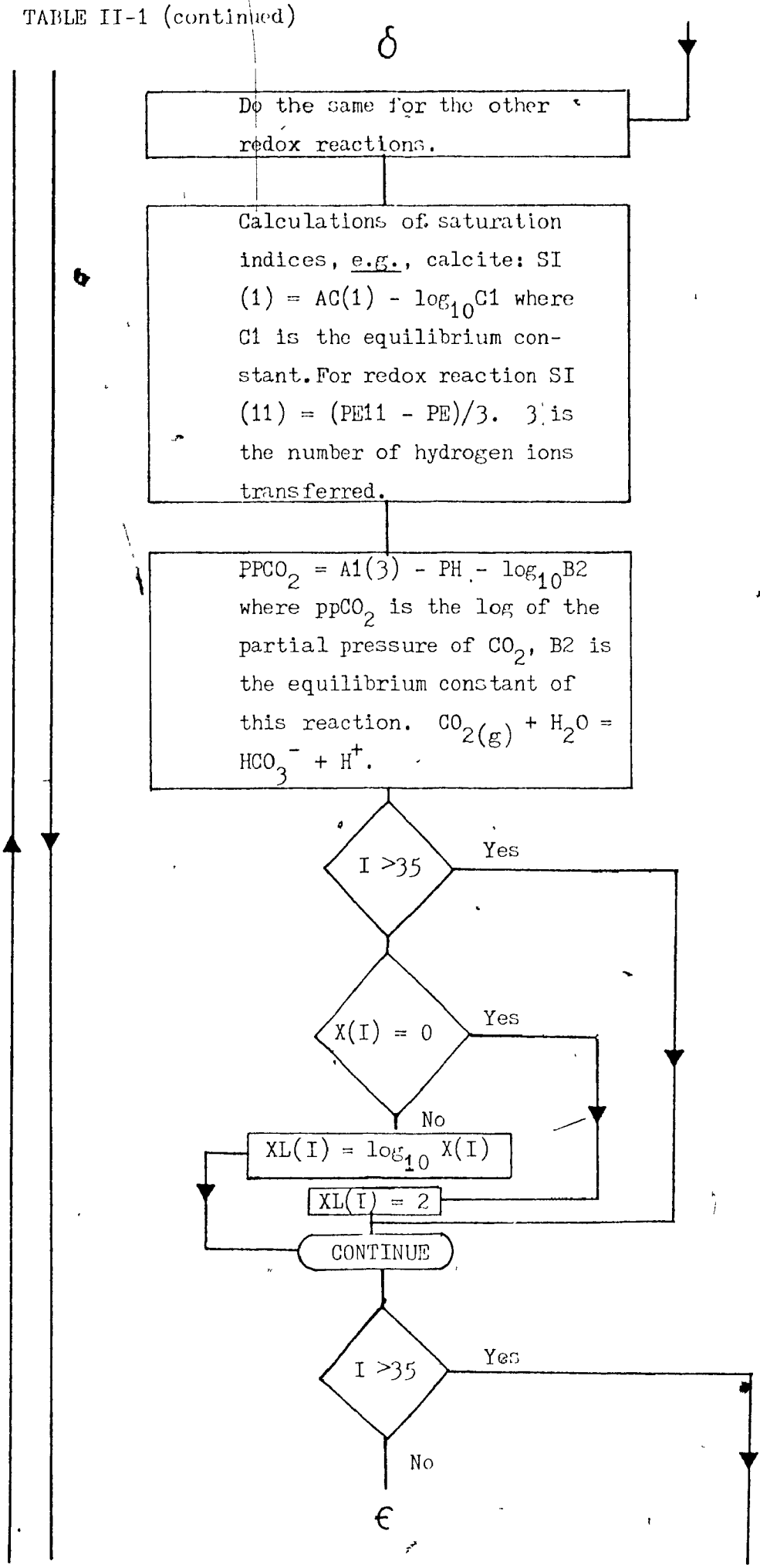


TABLE II-1 (continued)

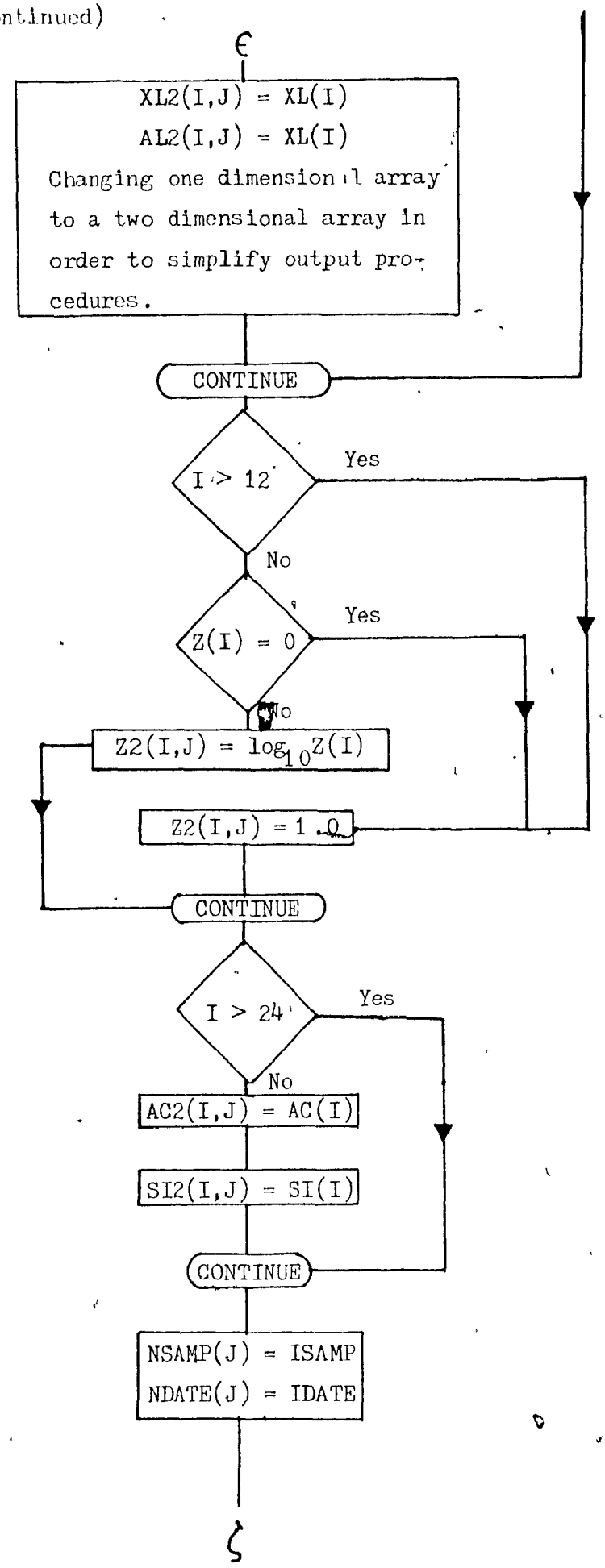
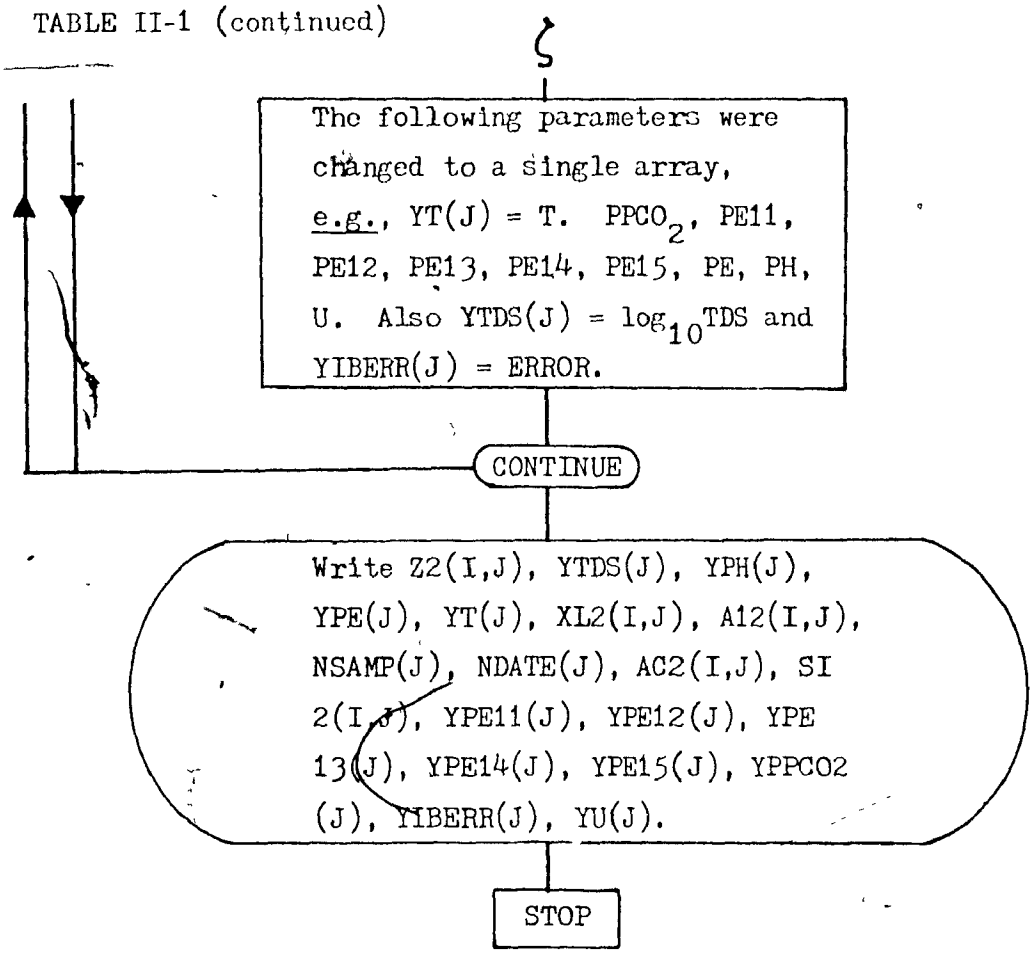


TABLE II-1 (continued)



Subroutine EQUON

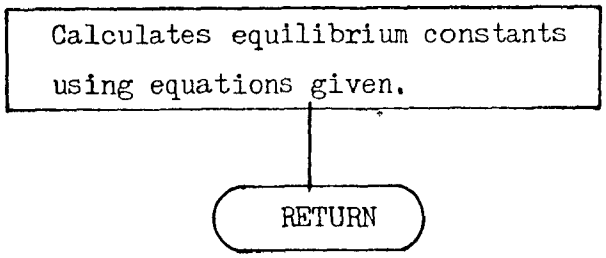


TABLE II-2.

Listing of the saturation index program.

```
(1)  $WATSBIG,PAGES=300,TIME=200
     C
     C
     C INTRODUCTION
     C
     C       THE DEGREE OF SATURATION OF A MINERAL IN AQUEOUS SOLUTION IS
     C DETERMINED BY COMPARING THE ACTIVITY PRODUCT WITH THE EQUILIBRIUM
     C CONSTANT AT THE TEMPERATURE OF THE WATER. THIS DEGREE OF SATURATION
     C IS EXPRESSED IN THE FORM OF A SATURATION INDEX. SATURATION INDEX IS
     C DEFINED AS THE LOG10(ACTIVITY PRODUCT/EQUILIBRIUM CONSTANT). THIS
     C INDEX IS DIVIDED BY THE NUMBER OF HYDROGEN IONS TAKING PLACE IN THE
     C REACTION. PH IS THE MOST VARIABLE PARAMETER IN MOST NATURAL WATERS.
     C BY DIVIDING BY THE NUMBER OF HYDROGEN IONS TRANSFERED. THE VARIABILITY
     C OF SATURATION INDICES CAN BE COMPARED TO ONE ANOTHER WITHOUT BEING
     C INFLUENCED BY VARIABLE NUMBERS OF HYDROGEN IONS. THE ACTIVITY COEFFICIENTS
     C OF THE CONSTITUENTS HAVE BEEN FOUND USING DEBYE-HUCKLE THEORY. ASSUMING
     C ION PAIRING AND USING A METHOD OF SUCCESSIVE APPROXIMATIONS TO
     C CALCULATE IONIC STRENGTHS AND ACTIVITIES (GARRELS AND THOMPSON, 1962).
     C THIS PROGRAM IS BASED ON ONE BY WIGLEY(1972) BUT EXTENDED TO INCLUDE
     C SILICATES AND SULFIDES.
     C
     C
   1          DIMENSION R(23),FX(35),AX(35),X(35),Z(12),XL2(35, 80),AL2(35, 80)
             1,Z2(12, 80),AC2(24, 80),SI2(24, 80),NSAMP( 80),NDATE( 80),YT( 80),
             2YPPCO2( 80),YPE11( 80),YPE12( 80),YPE13( 80),YPE14( 80),YPE15( 80)
             3,YPE( 80),YPH( 80),YTDS( 80),AL(35),AC(24),SI(24),XL(35),TM(12)
   2          DIMENSION YIBERR(80),YU(80)
   3          COMMON B1,B2,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,
             1C16,C17,C18,C19,C20,C21,C22,C23,C24,D1,D2,D3,D4,D5,D6,D7,D8,D9,D10
             2,D11,D12,D13,D14,D15,D16,D17,D18,D19,D20,D21,D22,D23,T,TT
     C  MOLUCULAR WEIGHT IN GRAMS*1000  FOR CA MG HCO3 SO4 NA K  CL FE CU ZN MN
     C  H4SIO4 IN THAT ORDER
   4          DATA (TM(I),I=1,12)/40084.,24312.,61017.3,96062.,22989.8,39102.,
             135453.,55847.,63540.,65370.,54938.,100094./
     C  EFFECTIVE IONIC RADIUS IN SAME ORDER AS MOLECULAR WEIGHT- E IS ERROR LEVEL
     C   IN THE ITERATION
*EXTENSION*  OTHER COMPILERS MAY NOT ALLOW IMPLIED DO-LOOPS IN DATA STATEMENTS
*EXTENSION*  OTHER COMPILERS MAY NOT ALLOW NON-CONSTANT SUBSCRIPTS IN DATA STATEMENTS
   5          DATA (R(I),I=1,23)/6.,.8,.3*4.25,2*3.,.4*6.,.0,.10*4.25,4.5/,E/.0001/
     C  N IS NUMBER OF SAMPLES
*EXTENSION*  OTHER COMPILERS MAY NOT ALLOW IMPLIED DO-LOOPS IN DATA STATEMENTS
*EXTENSION*  OTHER COMPILERS MAY NOT ALLOW NON-CONSTANT SUBSCRIPTS IN DATA STATEMENTS
   6          READ,N
   7          DO 4 J=1,N
     C  EH IN VOLTS, T IN DEGREES CENT... Z(I) ARE SAMPLE ANALYSES IN PPM IN SAME
     C  ORDER AS MOLECULAR WEIGHT
   8          READ,ISAMP,IDATE,T,PH,EH,(Z(I),I=1,12)
   9          TDS=0
  10          DO 1 I=1,12
     C  Z(I) BECOMES MOLARITY
     C  CALCULATING TOTAL DISSOLVED SOLIDS
  11          Z(I)=Z(I)/TM(I)
  12        1 TDS=TDS+Z(I)*TM(I)/1000.
     C  RECALCULATING TOTAL MOLARITIES TAKING IN CONSIDERATION THE TOTAL DISSOLVED
     C  SOLIDS
  13          DO 2 I=1,12
  14        2 Z(I)=Z(I)*1000./(1000.+TDS)
  15          DO 9 L=1,35
     C  X(L) ARE IONIC MOLARITIES
  16        9 X(L)=0.
```

TABLE II-2 (continued)

```
17          DO 7 L=1,12
18        7 X(L)=Z(L)
      C   CALCULATION OF DEBEYE HUCKLEL PARAMETERS, A AND B, USING EQUATIONS FOR
      C   VARIATION OF DENSITY(P) AND DIELECTRIC CONSTANT OF WATER GIVEN BY ANDERSON
      C   G.M.(1973), ECON. GEOL. VOL.68, P. 490 AND EQUATIONS FOR A AND B FROM
      C   HELGESON (1969), AM. JOUR. OF SCIENCE, VOL 267,P.748
19          TT=T+273.15
20          P=1.4579-.0031654*TT+7.9018E-6*TT**2-8.1461E-9*TT**3
21          DE=283.49-1.1002*TT+1.6714E-3*TT**2-9.6878E-7*TT**3
22          A=1.8246E6*P**.5/(DE*TT)**(3./2.)
23          B=50.29*P**.5/(DE*TT)**.5
24          H=10.**(-PH)
25          PE=5038.7613*EH/TT
26          DO 44 I=1,35
27        44 FX(I)=1.
28          CALL EQUCON
      C   U IS IONIC STRENGTH-THE FOLLOWING STEPS CALCULATE THE IONIC STRENGTH THEN
      C   ACTIVITY COEF. AND ACTIVITIES. IF THE PREVIOUS ACTIVITY OF CALCIUM MINUS
      C   THE FOLLOWING ACTIVITY IS NOT LESS THAN E THE WHOLE PROCEEDURE IS REPEATED
      C   UNTIL THE ERROR IS LESS THAN E.
29        5 U=(4.*(X(1)+X(2)+X(4)+X(8)+X(9)+X(10)+X(11)+X(23))+(X(3)+X(5)+X(6)
           1+X(7)+X(13)+X(14)+X(15)+X(16)+X(17)+X(18)+X(19)+X(20)+X(21)
           2+X(22)))/2.
30          DO 3 I=1,23
      C   FX(I) ARE ACTIVITY COEF. CALCULATED FROM THE DEBYE-HUCKEL EQUATION, AND ARE
      C   IN THE SAME ORDER AS THE Z(I)
31        3 FX(I)=10.**(-A*(U**(.5))/(1.+B*(U**(.5))*R(I)))
32          FX(1)=FX(1)**4.
33          FX(2)=FX(2)**4.
34          FX(4)=FX(4)**4.
35          FX(8)=FX(8)**4.
36          FX(9)=FX(9)**4.
37          FX(10)=FX(10)**4.
38          FX(11)=FX(11)**4.
39          FX(12)=1.
      C   AX(I) ARE THE ACTIVITIES.
40          DO 17 I=1,35
41        17 AX(I)=X(I)*FX(I)
      C   X(I)=CA++
42          S=X(1)
43          X(1)=Z(1)/(1.+FX(1)*AX(3)/(FX(13)*D1)+FX(1)*AX(3)*D11/(H*D22)+
           1 FX(1)*AX(4)/D18)
44          IF(ABS((X(1)-S)/X(1)).LT.E) GO TO 6
45          AX(1)=X(1)*FX(1)
      C   X(2)=MG++
46          X(2)=Z(2)/(1.+FX(2)*AX(3)/(FX(14)*D2)+FX(2)*AX(3)*D11/(H*D13)+
           1FX(2)*AX(4)/D19)
47          AX(2)=X(2)*FX(2)
      C   X(3)=HCO3-
48          X(3)=(Z(3)-FX(9)*X(9)/(H*FX(21)*D9)-FX(10)*X(10)/(H*FX(22)*D10)
           1-2.*FX(8)*X(8)/(D21*(H**2))-FX(8)*X(8)/(H*FX(20)*D8)-FX(11)*X(11)/
           2(H*FX(17)*D5))/(1.+2.*FX(3)*D11/(H*FX(23))+FX(1)*X(1)*FX(3)/(FX(13
           3)*D1)+FX(2)*X(2)*FX(3)/(FX(14)*D2)+FX(11)*X(11)*FX(3)/(FX(16)*D4)+
           42.*FX(5)*X(5)*FX(3)*D11/(FX(19)*H*D7)+FX(5)*X(5)*FX(3)/D12+2.*FX(2
           5)*X(2)*FX(3)*D11/(H*D13)+2.*FX(11)*X(11)*FX(3)*D11/(H*D20)+2.*FX(1
           6)*X(1)*FX(3)*D11/(H*D22)+2.*FX(9)*X(9)*FX(3)*D11/(H*D23))
49          AX(3)=X(3)*FX(3)
      C   X(4)=SO4--
50          X(4)=Z(4)/(1.+FX(1)*X(1)*FX(4)/D18+FX(2)*X(2)*FX(4)/D19+FX(5)*X(5)
           1*FX(4)/(FX(15)*D3)+FX(6)*X(6)*FX(4)/(FX(18)*D6)+FX(11)*X(11)*FX(4)
```

TABLE II-2 (continued)

```
     2/D17+FX(8)*X(8)*FX(4)/D14+FX(10)*X(10)*FX(4)/D15+FX(9)*X(9)*FX(4)/
     3D16)
51       AX(4)=X(4)*FX(4)
C    X(5)=NA+
52       X(5)=Z(5)/(1.+FX(5)*AX(3)/D12+FX(5)*AX(3)*D11/(FX(19)*H*D7)+FX(5)*
     1AX(4)/(FX(15)*D3))
53       AX(5)=X(5)*FX(5)
C    X(6)=K+
54       X(6)=Z(6)/(1.+FX(6)*AX(4)/(FX(18)*D6))
55       AX(6)=X(6)*FX(6)
C    X(7)=CL--NO COMPLEXING
C    X(8)=FE++
56       X(8)=Z(8)/(1.+FX(8)*AX(4)/D14+FX(8)/(H*FX(20)*D8)+FX(8)/(D21*
     1(H**2)))
57       AX(8)=X(8)*FX(8)
C    X(9)=CU++
58       X(9)=Z(9)/(1.+FX(9)*AX(4)/D16+FX(9)*AX(3)*D11/(H*D23)+FX(9)/(H*
     1FX(21)*D9))
59       AX(9)=X(9)*FX(9)
C    X(10)=ZN++
60       X(10)=Z(10)/(1.+FX(10)*X(4)/D15+FX(10)/(H*FX(22)*D10))
61       AX(10)=X(10)*FX(10)
C    X(11)=MN++
62       X(11)=Z(11)/(1.+FX(11)*AX(3)/(FX(16)*D4)+FX(11)*AX(3)*D11/(H*D20)
     1+FX(11)*AX(4)/D17+FX(11)/(H*FX(17)*D5))
C    X(12)=H4SIO4-NO COMPLEXING
C    X(13)=CAHCO3+
63       X(13)=AX(1)*AX(3)/(FX(13)*D1)
C    X(14)=MGHCO3+
64       X(14)=AX(2)*AX(3)/(FX(14)*D2)
C    X(15)=NASO4-
65       X(15)=AX(5)*AX(4)/(FX(15)*D3)
C    X(16)=MNHCO3+
66       X(16)=AX(11)*AX(3)/(FX(16)*D4)
C    X(17)=MNOH+
67       X(17)=AX(11)/(FX(17)*H*D5)
C    X(18)=KSO4-
68       X(18)=AX(6)*AX(4)/(FX(18)*D6)
C    X(23)=CO3--
69       X(23)=D11*AX(3)/(H*FX(23))
70       AX(23)=X(23)*FX(23)
C    X(19)=NACO3-
71       X(19)=AX(5)*AX(23)/D7
C    X(20)=FEOH+
72       X(20)=AX(8)/(FX(20)*H*D8)
C    X(21)=CUOH+
73       X(21)=AX(9)/(FX(21)*H*D9)
C    X(22)=ZNOH+
74       X(22)=AX(10)/(FX(22)*H*D10)
C    X(24)=NAHCO3
75       X(24)=AX(5)*AX(3)/D12
C    X(25)=MGCO3
76       X(25)=AX(2)*AX(23)/D13
C    X(26)=FESO4
77       X(26)=AX(8)*AX(4)/D14
C    X(27)=ZNSO4
78       X(27)=AX(4)*AX(10)/D15
C    X(28)=CUSO4
79       X(28)=AX(9)*AX(4)/D16
C    X(29)=MNSO4
```

TABLE II-2 (continued)

```
80          X(29)=AX(11)*AX(4)/D17
      C  X(30)=CASO4
81          X(30)=AX(1)*AX(4)/D18
      C  X(31)=MGSO4
82          X(31)=AX(2)*AX(4)/D19
      C  X(32)=MNCO3
83          X(32)=AX(11)*AX(23)/D20
      C  X(33)=FE(OH)2
84          X(33)=AX(8)/(D21*(H**2))
      C  X(34)=CACO3
85          X(34)=AX(1)*AX(23)/D22
      C  X(35)=CUCO3
86          X(35)=AX(9)*AX(23)/D23
87          GO TO 5
      C  ION BALANCE
88        6 SUMCAT=2.*(X(1)+X(2)+X(8)+X(9)+X(10)+X(11))+X(5)+X(6)+X(13)+X(14)
         1+X(15)+X(16)+X(20)*X(21)+X(22)
89          SUMAN=2.*(X(4)+X(23))+X(3)+X(7)+X(15)+X(18)+X(19)
90          ERROR=100.*(SUMCAT-SUMAN)/(SUMCAT+SUMAN)
      C  CALCULATES LOG 10 OF ACTIVITIES
91          DO 10 I=1,35
92          IF(AX(I).LE.0.) GO TO 12
93          AL(I)=ALOG10(AX(I))
94          GO TO 10
95        12 AL(I)=200.
96        10 CONTINUE
      C  CALCULATION OF ACTIVITY PRODUCTS. IF AC(1)= 2   ONE OR MORE OF THE CONST.
      C  WERE NOT DETECTED BY THE METHODS USED.
      C  THE REACTIONS CONSIDERED ARE THE FOLLOWING.
97          DO 47 I=1,24
98        47 AC(I)=200.
      C  AC(1)   CACO3 = CA++ + CO3--
99          AC(1)=AL(1)+AL(23)
      C  AC(2)   FECO3 = FE++ + CO3--
100         IF(X(8).NE.0.) AC(2)=AL(8)+AL(23)
      C  AC(3)   MGCO3 = MG++ + CO3--
101         AC(3)=AL(2)+AL(23)
      C  AC(4)   CAMG(CO3)2 = CA++ + MG++ + 2CO3--
102         AC(4)=AL(2)+AL(1)+2.*AL(23)
      C  AC(5)   ZNCO3 = ZN++ + CO3--
103         IF(X(10).NE.0.) AC(5)=AL(10)+AL(23)
      C  AC(6)   MNCO3 = MN++ + CO3--
104         IF(X(11).NE.0.) AC(6)=AL(11)+AL(23)
      C  AC(7)   CASO4.2H2O = CA++ + SO4-- + 2H2O
105         AC(7)=AL(1)+AL(4)
      C  AC(8)   CU2(OH)2CO3 + 2H+ = 2CU++ + CO3-- + 2H2O
106         IF(X(9).NE.0.) AC(8)=AL(9)*2+AL(23)+2*PH
      C  AC(9)   CU3(OH)2(CO3)2 + 2H+ = 3CU++ + 2CO3-- + 2H2O
107         IF(X(9).NE.0.) AC(9)=AL(9)*3+AL(23)*2+2*PH
      C  AC(10)   2H+ + MG(OH)2 = MG++ + H2O
108         AC(10)=AL(2)+2*PH
      C  AC(11)   E- +3H+ + FE(OH)2 = 3H2O + FE++
109         IF(X(8).NE.0.) AC(11)=+AL(8)+3*PH
      C  AC(12)   E- + 3H+ + .5FE2O3 = 1.5H2O + FE++
110         IF(X(8).NE.0.) AC(12)=+AL(8)+3*PH
      C  AC(13)   14E- + 16H+ + SO4 + FE++ = H2O + FES2
111         IF(X(8).NE.0.) AC(13)=(-AL(8)+16*PH-2*AL(4))/14.
      C  AC(14)   8E- + 8H+ + SO4-- + ZN++ = H2O + ZNS
112         IF(X(10).NE.0.) AC(14)=(-AL(10)-AL(4)+8*PH)/8.
113         IF(X(8).EQ.0.) GO TO 13
```

TABLE II-2 (continued)

```
      C  AC(15)   16E- + 16H+ + 2SO4-- + FE++ + CU++ = CUFES2 + 8H2O
114         IF(X(9).NE.0.) AC(15)=(-AL(9)-AL(8)-2.*AL(4)+16.*PH)/16.
115      13 CONTINUE
      C  AC(16)   KALSI3O8 + H+ + 4.5H2O = 0.5AL2SI2O5(OH)4 + K+  2H4SIO4
116         AC(16)=AL(6)+2.*AL(12)+PH
      C  AC(17)   CAAL2SI2O8 + 2H+ + H2O = CA++ + AL2SI2O5(OH)4
117         AC(17)=AL(1)+2.*PH
      C  AC(18)   NAALSI3O8 + 4.5H2O + H+ = NA+ + 2H4SIO4 + .5AL2SI2O5(OH)4
118         AC(18)=AL(5)+2.*AL(12)+PH
      C  AC(19)   MG5AL2SI3O10(OH)8 + 10H+ = AL2SI2O5(OH)4 + 5MG++ + H4SIO4 + 5H2O
119         AC(19)=5.*AL(2)+AL(12)+10.*PH
      C  AC(20)   KAL3SI3O10(OH)2 + H+ + 1.5H2O = K+ + 1.5AL2SI2O5(OH)4
120         AC(20)=AL(6)+PH
      C  AC(21) . 3NA.33 AL2.33 SI3.67 O10 (OH)2 + H+ + 11.5H2O = NA++ + 4H4 SIO4 +
      C  3.5AL2 SI2 O5(OH)4
121         AC(21)=AL(5)+4.*AL(12)+PH
      C  AC(22)   6CA.167 AL2.33 SI3.67 O10 (OH)2 + 23H2O + 2H+ = 7AL2 SI2 O5 (OH)4 +
      C  CA++ + 8H4 SIO4
122         AC(22)=AL(1)+8.*AL(12)+2.*PH
      C  AC(23)   6MG.167 AL2.33 SI3.67 O10 (OH)2 + 23H2O + 2H+ = 8H4SIO4 +
      C       7AL2SI2O5(OH)4 + MG++
123         AC(23)=AL(2)+8.*AL(12)+2.*PH
      C  AC(24)   K.6 MG.25 AL2.3 SI3.5 O10 (OH)2 + 1.1H+ + 3.15H2O = 0.6K+ +
      C       1.2H4SIO4 + .25MG++ + 1.15AL2SI2O5(OH)4
124         AC(24)=.6*AL(6)+1.2*AL(12)+.25*AL(2)+1.1*PH
      C  CALCULATION OF EQUILIBRIUM P.E.
125         PE11=200.
126         PE12=200.
127         PE13=200.
128         PE14=200.
129         PE15=200.
130         IF(X(8).NE.0.) PE11=ALOG10(C11)-AC(11)
131         IF(X(8).NE.0.) PE12=ALOG10(C12)-AC(12)
132         IF(X(8).NE.0.) PE13=ALOG10(C13)-AC(13)
133         IF(X(10).NE.0.) PE14=ALOG10(C14)-AC(14)
134         IF(X(9).EQ.0.) GO TO 49
135         IF(X(8).NE.0.) PE15=ALOG10(C15)-AC(15)
136      49 CONTINUE
      C  CALCULATION OF SATURATION INDICES SI(I)=LOG(AP/K)/# OF H+ IONS TRANSFERRED
      C  IF SI=2 ONE OR MORE CONSTITUENTS WAS 0.
137         DO 48 I=1,24
138      48 SI(I)=200.
139         SI(1)=AC(1)-ALOG10(C1)
140         IF(X(8).NE.0.) SI(2)=AC(2)-ALOG10(C2)
141         SI(3)=AC(3)-ALOG10(C3)
142         SI(4)=(AC(4)-ALOG10(C4))/2
143         IF(X(10).NE.0.) SI(5)=AC(5)-ALOG10(C5)
144         IF(X(11).NE.0.) SI(6)=AC(6)-ALOG10(C6)
145         SI(7)=AC(7)-ALOG10(C7)
146         IF(X(9).NE.0.) SI(8)=(AC(8)-ALOG10(C8))/2
147         IF(X(9).NE.0.) SI(9)=(AC(9)-ALOG10(C9))/2
148         SI(10)=(AC(10)-ALOG10(C10))/2
149         IF(PE.EQ.0.) GO TO 14
150         IF(X(8).NE.0.) SI(11)=(PE11-PE)/3
151         IF(X(8).NE.0.) SI(12)=(PE12-PE)/3
152         IF(X(8).NE.0.) SI(13)=(PE13-PE)/(16/14)
153         IF(X(10).NE.0.) SI(14)=PE14-PE
154         IF(X(8).EQ.0.) GO TO 14
155         IF(X(9).NE.0.) SI(15)=PE15-PE
156      14 CONTINUE
```

TABLE II-2 (continued)

```
157         SI(16)=AC(16)-ALOG10(C16)
158         SI(17)=(AC(17)-ALOG10(C17))/2
159         SI(18)=AC(18)-ALOG10(C18)
160         SI(19)=(AC(19)-ALOG10(C19))/10
161         SI(20)=AC(20)-ALOG10(C20)
162         SI(21)=AC(21)-ALOG10(C21)
163         SI(22)=(AC(22)-ALOG10(C22))/2
164         SI(23)=(AC(23)-ALOG10(C23))/2
165         SI(24)=(AC(24)-ALOG10(C24))/1.1
      C  PARTIAL PRESSURE OF CO2.
      C  CO2 + H2O = H+ + HCO3-
166         PPCO2=AL(3)-PH-ALOG10(B2)
167         IF(PE.EQ.0.) PE=300.
168         DO 16 I=1,35
169         IF(X(I).EQ.0.) GO TO 15
170         XL(I)=ALOG10(X(I))
171         GO TO 16
172      15 XL(I)=200.
173      16 CONTINUE
174         DO 18 I=1,35
      C  CHANGING IONIC ACTIVITIES AND MOLARITIES FROM ONE DIMENSION TO 2 DIMENSIONS.
175         XL2(I,J)=XL(I)
176         AL2(I,J)=AL(I)
177      18 CONTINUE
      C  CHANGING TOTAL MOLARITY TO A TWO DIMENSIONAL ARRAY.
178         DO 19 I=1,12
179         IF(Z(I).EQ.0.) GO TO 60
180         Z2(I,J)=ALOG10(Z(I))
181         GO TO 19
182      60 Z2(I,J)=100.
183      19 CONTINUE
184         DO 20 I=1,24
      C  CHANGING SATURATION INDEX AND ACTIVITY PRODUCT INTO TWO DIMENSIONAL ARRAYS.
185         AC2(I,J)=AC(I)
186         SI2(I,J)=SI(I)
187      20 CONTINUE
188         NSAMP(J)=ISAMP
189         NDATE(J)=IDATE
190         YT(J)=T
191         YPPCO2(J)=PPCO2
192         YPE11(J)=PE11
193         YPE12(J)=PE12
194         YPE13(J)=PE13
195         YPE14(J)=PE14
196         YPE15(J)=PE15
197         YPE(J)=PE
198         YPH(J)=PH
199         YTDS(J)=ALOG10(TDS)
200         YIBERR(J)=ERROR
201         YU(J)=U
202       4 CONTINUE
      C  FORMAT STATEMENTS FOR OUTPUT.
203      23 FORMAT(10X,A4,3X,I6,8F9.3/)
204      24 FORMAT(10X,'SAMP    DATE      CA++      MG++      HCO3-     SO4--
        1NA+       K+        CL-      FE++'///)
205      25 FORMAT(10X,'SAMP    DATE       CU        ZN        MN       H4SIO4
        1TDS       PH        PE      TEMP C'///)
206      26 FORMAT(10X,'SAMP    DATE      CU++      ZN++      MN++      H4SIO4   CAH
        1CO3+   MGHCO3+    NASO4-   MNHCO3+'///)
207      27 FORMAT(10X,'SAMP    DATE      MNOH+     KSO4-     NACO3-     FEOH+     C
```

TABLE II-2 (continued)

```
     1UOH+     ZNOH+     CO3--    NAHCO3*///)
208  28 FORMAT(10X,*SAMP     DATE      MGCO3     FESO4     ZNSO4     CUSO4     M
     1NSO4     CASO4     MGSO4     MNCO3*///)
209  29 FORMAT(10X,*SAMP     DATE    FE(OH)2     CACO3     CUCO3*///)
210  30 FORMAT(10X,*SAMP     DATE      CACO3     FECO3     MGCO3    DOLOMITE  Z
     1NCO3     MNCO3     CASO4   MALACHITE*///)
211  31 FORMAT(10X,*SAMP     DATE    AZURITE  MG(OH)2  FE(OH)3     FE2O3     F
     1ES2       ZNS      CUFES2     KF-K*///)
212  32 FORMAT(10X,*SAMP     DATE      AN-K      AB-K      CHL-K     KMI-K     N
     1AM-K     CAM-K     MGM-K     ILL-K*///)
213  33 FORMAT(10X,*SAMP     DATE    FE(OH)3     FE2O3     FES2       ZNS      CU
     1FES2     PPCO2     ERROR    I.STR.*///)
214  34 FORMAT(10X,*SAMP     DATE        CA        MG        ALK         S
     1NA         K         CL         FE*///)
215  35 FORMAT('1'/'0',43X,'TOTAL MOLARITY*'/)
216  36 FORMAT('1'/'0',43X,'IONIC MOLARITY*'/)
217  37 FORMAT('1'/'0',43X,'IONIC ACTIVITY*'/)
218  38 FORMAT('1'/'0',42X,'ACTIVITY PRODUCT*'/)
219  39 FORMAT('1'/'0',44X,'SATURATION INDEX'/)
220  40 FORMAT('1'/'0',43X,'EQUILIBRIUM PE'/)
221  41 FORMAT('0',40X,'*LOG TO THE BASE 10')
222  42 FORMAT(10X,A4,3X,I6,3F9.3/)
223  46 FORMAT(10X,A4,3X,I6,7F9.3,F9.5/)
224  51 FORMAT(' ',10X,'100 = NOT DETECTED BY THE METHOD USED')
225  52 FORMAT(' ',10X,'200 = INCOMPLETE INFORMATION TO PERFORM THE CALCUL
     1ATION')
226  53 FORMAT(' ',10X,'300 = NO MEASURMENT PERFORMED')
227  54 FORMAT(' ',10X,'200 = INCOMPLETE INFORMATION TO PERFORM THE CALCUL
     1ATION')
     C  BEGIN OUT-PUT  PRINT TOTAL MOLARITY.
228       WRITE(6,35)
229       WRITE(6,34)
230       WRITE(6,23)(NSAMP(J),NDATE(J),(Z2(I,J),I=1,8),J=1,N)
231       WRITE(6,41)
232       WRITE(6,51)
233       WRITE(6,35)
234       WRITE(6,25)
235       WRITE(6,23)(NSAMP(J),NDATE(J),(Z2(I,J),I=9,12),YTDS(J),YPH(J),YPE(
          1J),YT(J),J=1,N)
236       WRITE(6,41)
237       WRITE(6,51)
238       WRITE(6,53)
     C  PRINT IONIC MOLARITY.
239       WRITE(6,36)
240       WRITE(6,24)
241       WRITE(6,23)(NSAMP(J),NDATE(J),(XL2(I,J),I=1,8),J=1,N)
242       WRITE(6,41)
243       WRITE(6,52)
244       WRITE(6,36)
245       WRITE(6,26)
246       WRITE(6,23)(NSAMP(J),NDATE(J),(XL2(I,J),I=9,16),J=1,N)
247       WRITE(6,41)
248       WRITE(6,52)
249       WRITE(6,36)
250       WRITE(6,27)
251       WRITE(6,23)(NSAMP(J),NDATE(J),(XL2(I,J),I=17,24),J=1,N)
252       WRITE(6,41)
253       WRITE(6,52)
254       WRITE(6,36)
255       WRITE(6,28)
```

TABLE II-2 (continued)

```
256           WRITE(6,23)(NSAMP(J),NDATE(J),(XL2(I,J),I=25,32),J=1,N)
257           WRITE(6,41)
258           WRITE(6,52)
259           WRITE(6,36)
260           WRITE(6,29)
261           WRITE(6,42)(NSAMP(J),NDATE(J),(XL2(I,J),I=33,35),J=1,N)
262           WRITE(6,41)
263           WRITE(6,52)
      C   PRINT IONIC ACTIVITY.
264           WRITE(6,37)
265           WRITE(6,24)
266           WRITE(6,23)(NSAMP(J),NDATE(J),(AL2(I,J),I=1,8),J=1,N)
267           WRITE(6,41)
268           WRITE(6,52)
269           WRITE(6,37)
270           WRITE(6,26)
271           WRITE(6,23)(NSAMP(J),NDATE(J),(AL2(I,J),I=9,16),J=1,N)
272           WRITE(6,41)
273           WRITE(6,52)
274           WRITE(6,37)
275           WRITE(6,27)
276           WRITE(6,23)(NSAMP(J),NDATE(J),(AL2(I,J),I=17,24),J=1,N)
277           WRITE(6,41)
278           WRITE(6,52)
279           WRITE(6,37)
280           WRITE(6,28)
281           WRITE(6,23)(NSAMP(J),NDATE(J),(AL2(I,J),I=25,32),J=1,N)
282           WRITE(6,41)
283           WRITE(6,52)
284           WRITE(6,37)
285           WRITE(6,29)
286           WRITE(6,42)(NSAMP(J),NDATE(J),(AL2(I,J),I=33,35),J=1,N)
287           WRITE(6,41)
288           WRITE(6,52)
      C   PRINT ACTIVITY PRODUCT.
289           WRITE(6,38)
290           WRITE(6,30)
291           WRITE(6,23)(NSAMP(J),NDATE(J),(AC2(I,J),I=1,8),J=1,N)
292           WRITE(6,41)
293           WRITE(6,52)
294           WRITE(6,38)
295           WRITE(6,31)
296           WRITE(6,23)(NSAMP(J),NDATE(J),(AC2(I,J),I=9,16),J=1,N)
297           WRITE(6,41)
298           WRITE(6,52)
299           WRITE(6,38)
300           WRITE(6,32)
301           WRITE(6,23)(NSAMP(J),NDATE(J),(AC2(I,J),I=17,24),J=1,N)
302           WRITE(6,41)
303           WRITE(6,52)
      C   PRINT SATURATION INDEX.
304           WRITE(6,39)
305           WRITE(6,30)
306           WRITE(6,23)(NSAMP(J),NDATE(J),(SI2(I,J),I=1,8),J=1,N)
307           WRITE(6,54)
308           WRITE(6,39)
309           WRITE(6,31)
310           WRITE(6,23)(NSAMP(J),NDATE(J),(SI2(I,J),I=9,16),J=1,N)
311           WRITE(6,54)
312           WRITE(6,39)
```

TABLE II-2 (continued)

```
313           WRITE(6,32)
314           WRITE(6,23)(NSAMP(J),NDATE(J),(SI2(I,J),I=17,24),J=1,N)
315           WRITE(6,54)
      C  PRINT EQUILIBRIUM PE.
316           WRITE(6,40)
317           WRITE(6,33)
318           WRITE(6,46)(NSAMP(J),NDATE(J),YPE11(J),YPE12(J),YPE13(J),YPE14(J),
             1YPE15(J),YPPCO2(J),YIBERR(J),YU(J),J=1,N)
319           WRITE(6,54)
320        45 FORMAT('1')
321           WRITE(6,45)
      C  PUNCHING DATA ON CARDS.
322        43 FORMAT(A4,I6,6F8.3,F9.5/(10F8.3))
323           DO 50 J=1,N
324           WRITE(7,43)NSAMP(J),NDATE(J),YTDS(J),YPH(J),YPE(J),YT(J),YPPCO2(J
             1),YIBERR(J),YU(J),(Z2(I,J),I=1,12),(XL2(I,J),I=1,35),(AL2(I,J),I=1
             2,35),(AC2(I,J),I=1,24),(SI2(I,J),I=1,24),YPE11(J),YPE12(J),YPE13(J
             3),YPE14(J),YPE15(J)
325        50 CONTINUE
326           STOP
327           END

328           SUBROUTINE EQUCON
329           COMMON B1,B2,C1,C2,C3,C4,C5,C6,C7,C8,C9,C10,C11,C12,C13,C14,C15,
             1C16,C17,C18,C19,C20,C21,C22,C23,C24,D1,D2,D3,D4,D5,D6,D7,D8,D9,D10
             2,D11,D12,D13,D14,D15,D16,D17,D18,D19,D20,D21,D22,D23,T,TT
      C
      C    B1   CO2 + H2O = HCO3- + H+
330           B1=10.**(205.4062*ALOG(TT)-.185866*TT+7534.5/TT
             1-4999629./(TT**2)-1325.358)
      C
      C    B2   H2O = H+ + OH-
331           B2=10.**(-28.612*ALOG(TT)+.03129*TT-5336.5/TT+30029./TT**2+163.43)
      C
      C    C1      CACO3 = CA++ + CO3--
332           C1=10.**(13.543-3000./TT-.0401*TT)
      C
      C    C2      FECO3 = FE++ + CO3--
333           C2=10.**(822.6087*ALOG(TT)-.786562*TT+293257.5/TT-17382225./
             1(TT**2)-5250.997)
      C
      C    C3      MGCO3 = MG++ + CO3--
334           C3=10.**(-144.0448*ALOG(TT)+.0993319*TT-5401.6.11/TT
             1+3165222./(TT**2)+928.5653)
      C
      C    C4      CAMG(CO3)2 = CA++ + MG++ + 2CO3--
335           C4=10.**(497.5967*ALOG(TT)-.513326*TT+177314.4/TT-10816790./(TT**2
             1)-3172.089)
      C
      C    C5      ZNCO3 = ZN++ + CO3--
336           C5=10.**(719.714*ALOG(TT)-.6890669*TT+256724./TT-1.53078E
             17/(TT**2)-4594.822)
      C
      C    C6      MNCO3 = MN++ + CO3--
337           C6=10.**(716.2077*ALOG(TT)-.6877297*TT+255068./TT
             1-1.524585E7/(TT**2)-4570.017)
      C
      C    C7      CASO4.2H2O = CA++ + SO4-- + 2H2O
338           C7=10.**(-4.641+.00249*T-.0000592*T**2.)
```

TABLE II-2 (continued)

```
      C
      C   C8      CU2(OH)2CO3 + 2H+ = 2CU++ + CO3-- + 2H2O
339           C8=10.**(-5.17)
      C
      C   C9      CU3(OH)2(CO3)2 + 2H+ = 3CU++ + 2CO3-- + 2H2O
340           C9=10.**(-16.89)
      C
      C   C10     2H+ + MG(OH)2 = MG++ + H2O
341           C10=10.**(-122.8952*ALOG(TT)+.1056675*TT-42403.49/TT
             1+3100355./(TT**2)+792.8263)
      C
      C   C11     E- +3H+ + FE(OH)2 = 3H2O + FE++
342           C11=10.**(30.93723*ALOG(TT)-.0230533*TT+17207.34/TT-54414
             10.6/(TT**2)-203.0921)
      C
      C   C12     E- + 3H+ + .5FE2O3 = 1.5H2O + FE++
343           C12=10.**(-23.83873*ALOG(TT)+.0260645*TT-2334.203/TT
             1+478231.6/(TT**2)+143.6918)
      C
      C   C13     14E- + 16H+ + SO4 + FE++ = H2O + FES2
344           C13=10.**(-13.63987*ALOG(TT)+.0168619*TT-2444.372/TT+2861
             117.3/(TT**2)+83.64202)
      C
      C   C14     8E- + 8H+ + SO4-- + ZN++ = H2O + ZNS
345           C14=10.**(-55.41252*ALOG(TT)+.0517585*TT-18734.14/TT+1295
             1875./(TT**2)+354.2405)
      C
      C   C15     16E- + 16H+ + 2SO4-- + FE++ + CU++ = CUFES2 + 8H2O
346           C15=10.**(-33.49253*ALOG(TT)+.0337241*TT-9923.163/TT
             1+743006.9/(TT**2)+211.9511)
      C
      C   C16     KALSI3O8 + H+ + 4.5H2O = 0.5AL2SI2O5(OH)4 + K+  2H4SIO4
347           C16=10.**(59.4441*ALOG(TT)-.0549088*TT+20267.04/TT
             1-1342917./(TT**2)-377.70498)
      C
      C   C17     CAAL2SI2O8 + 2H+ + H2O = CA++ + AL2SI2O5(OH)4
348           C17=10.**(29.26747*ALOG(TT)-.0320822*TT+16718.69/TT
             1-568578.6/(TT**2)-189.8053)
      C
      C   C18     NAALSI3O8 + 4.5H2O + H+ = NA+ + 2H4SIO4 + .5AL2SI2O5(OH)4
349           C18=10.**(48.32266*ALOG(TT)-.0450578*TT+16875.09/TT
             1-1007557./(TT**2)-307.0305)
      C
      C   C19     MG5AL2SI3O10(OH)8 + 10H+ = AL2SI2O5(OH)4 + 5MG++ + H4SIO4 + 5H2O
350           C19=10.**(-1369.529*ALOG(TT)+1.287843*TT-466758.7/TT
             1+2.942107E7/(TT**2)+8719.176)
      C
      C   C20     KAL3SI3O10(OH)2 + H+ + 1.5H2O = K+ + 1.5AL2SI2O5(OH)4
351           C20=10.**(-22.40102*ALOG(TT)+.0160368*TT-7026.157/TT
             1+482453.3/(TT**2)+146.5921)
      C
      C   C21     3NA.33 AL2.33 SI3.67 O10 (OH)2 + H+ + 11.5H2O = NA++ + 4H4 SIO4 +
      C  3.5AL2 SI2 O5(OH)4
352           C21=10.**(45.18421*ALOG(TT)-.0533644*TT+13234.99/TT
             1-885329.9/(TT**2)-283.5935)
      C
      C   C22     6CA.167 AL2.33 SI3.67 O10 (OH)2 + 23H2O + 2H+ = 7AL2 SI2 O5 (OH)4 +
      C  CA++ + 8H4 SIO4
353           C22=10.**(150.5456*ALOG(TT)-.1646881*TT+50008.4/TT
             1-3100394./(TT**2)-957.8015)
```

TABLE II-2 (continued)

```
      C
      C   C23     6MG.167 AL2.33 SI3.67 O10 (OH)2 + 23H2O + 2H+ = 8H4SIO4 +
      C       7AL2SI2O5(OH)4 + MG++
354           C23=10.**(16.88901*ALOG(TT)-.0469202*TT+528.0407/TT
     1+15802.07/(TT**2)-100.9903)
      C
      C   C24     K.6 MG.25 AL2.3 SI3.5 O10 (OH)2 + 1.1H+ + 3.15H2O = 0.6K+ +
      C       1.2H4SIO4 + .25MG++ + 1.15AL2SI2O5(OH)4
359           C24=10.**(9.21646*ALOG(TT)-.0120764*TT+3286.232/TT
     1-165073.8/(TT**2)-56.50831)
      C
      C   D1    CAHCO3+
356           D1=10.**(-2.95+.0133*TT)
      C
      C   D2    MGHCO3+
357           D2=10.**(-1.23)
      C
      C   D3    NASO4-
358           D3=10.**(1.572*ALOG(TT)-.00318*TT+76.3/TT+390.2/TT**2-8.910)
      C
      C   D4    MNHCO3+
359           D4=10.**(-1.95)
      C
      C   D5    MNOH+
360           D5=10.**(-3.41)/B1
      C
      C   D6    KSO4-
361           D6=10.**(-3.106+673.6/TT)
      C
      C   D7    NACO3-
362           D7=10.**(-1.27)
      C
      C   D8    FEOH+
363           D8=10.**(-5.7)/B1
      C
      C   D9    CUOH+
364           D9=10.**(-6.0)/B1
      C
      C   D10   ZNOH+
365           D10=10.**(-5.04)/B1
      C
      C   D11   CO3--
366           D11=10.**(-.01261*TT+296.09/TT-328532./TT**2-3.8662)
      C
      C   D12   NAHCO3
367           D12=10.**(.25)
      C
      C   D13   MGCO3
368           D13=10.**(21.39-3265./TT-.04457*TT)
      C
      C   D14   FESO4
369           D14=10.**(14.366*ALOG(TT)-.02926*TT+1740.6/TT+9583./TT**2-81.286)
      C
      C   D15   ZNSO4
370           D15=10.**(17.945*ALOG(TT)-.03671*TT+2300./TT+12486./TT**2-101.479)
      C
      C   D16   CUSO4
371           D16=10.**(19.647*ALOG(TT)-.04017*TT+2571./TT+13672./TT**2-111.11)
      C
      C   D17   MNSO4
```

TABLE II-2 (continued)

```
372         D17=10.**(17.98*ALOG(TT)-.03676*TT+2143./TT+12439./TT**2-101.687)
      C
      C   D18  CASO4
373         D18=10.**(18.018*ALOG(TT)-.03708*TT+2315./TT+13188./TT**2-101.826)
      C
      C   D19  MGSO4
374         D19=10.**(23.702*ALOG(TT)-.04215*TT+4077./TT+17765./TT**2-138.75)
      C
      C   D20  MNCO3
375         D20=10.**(.748)
      C
      C   D21  FE(OH)2
376         D21=10.**(-10.4)/(B1**2)
      C
      C   D22  CACO3
377         D22=10.**(27.393-4114./TT-.05617*TT)
      C
      C   D23  CUCO3
378         D23=10.**(-6.77)
379         RETURN
380         END

      $DATA
```

APPENDIX III DESCRIPTION OF THE SAMPLE SITES AND CHEMICAL COMPOSITION OF THE WATERS

TABLE III-1.

Sampling techniques and descriptions of sampling locations.

SAMPLE NUMBER	DATE	CONDUCTIVITY	SAMPLING TECHNIQUE	DESCRIPTION OF SAMPLE LOCATION AND SOURCE
1	3-6-72	210	a	Spring issuing from a hillside; flow 1 gal/min. 7.5°C.
2	3-6-72	128	a	Seepage; very low flow. 7.5°C.
3	3-6-72	220	a	Seepage area; very low flow, no outlet. 13°C.
4	3-6-72	112	a	Spring near an old shaft. 11°C.
5	3-6-72	120	a	Sample from old prospect pit. 12°C.
6	3-6-72	112	a	Spring; good flow, from side of hill, 2-5 gal/min. 7°C.
7	3-6-72	132	a	Spring; good flow, 5-7 gal/min. 9°C.
8	3-6-72	114	a	Wet area with a puddle 2' x 4'. 14.5°C.
9	3-6-72	162	a	Spring in middle of an old drill road. Part of same spring area as 10. 9°C.
10	3-6-72	170	a	Large springy area 100' x 200'. 18°C.
11	3-6-72	148	a	Swampy area in a pasture. 16°C.
12	3-6-72	122	a	Horizontal pipe from a spring a few feet to the N.W. Probably was a water supply in past. 7.5°C.
13	3-6-72	130	a	Old well in pasture. 13°C.
14	4-6-72	60	a	Small pond, extending 100' x 50', water colored, much humic matter. 17°C.
15	4-6-72	80	a	Seepy area on side of a hill, not too much flow, a well developed channel. 14°C.
16	4-6-72	82	a	Spring; wet area, very little flow. 14°C.
17	4-6-72	152	a	Wet spot with very low flow. 15°C.

TABLE III-1 (continued)

SAMPLE NUMBER	DATE	CONDUCTIVITY	SAMPLING TECHNIQUE	DESCRIPTION OF SAMPLE LOCATION AND SOURCE
18	5-6-72	140	a	Small stream from a spring beside a new drill road. 10.5°C.
19	5-6-72	354	a	Brook drains a small swampy area; some sediment in sample. 17.5°C.
20	5-6-72	-	a	Spring on hillside, grassy, no trees, somewhat swampy. No temp. taken ≈ 15-18°C.
21	5-6-72	-	a	Spring; good flow, 5 gal/min. Excellent source.
22	20-7-72	-	a	Small intermittent stream comes from spring on side of hill.
23	20-7-72	-	a	Intermittent stream. Same stream as 22.
24	20-7-72	-	a	Intermittent stream. Same as 22.
25	20-7-72	-	a	Emergent spring on side of hill.
26	20-7-72	-	a	Intermittent stream, very low flow.
27	20-7-72	-	a	Same intermittent stream as 26.
28	20-7-72	-	a	Same intermittent stream as 26.
29	20-7-72	-	a	Same intermittent stream as 26. 190' further on is a flowing drill hole, probably causes contamination.
30	20-7-72	-	a	Emergent spring; some silt.
31	20-7-72	-	a	Intermittent stream downstream from 30; good flow.
32	20-7-72	-	a	Downstream from 31; good flowing river.
33	20-7-72	-	a	Emergent spring; fair flow.
34	20-7-72	-	a	Sample from intermittent stream which starts at 33.
35	20-7-72	-	a	Stream; 3 gal/min.

TABLE III-1 (continued)

SAMPLE NUMBER	DATE	CONDUCTIVITY	SAMPLING TECHNIQUE	DESCRIPTION OF SAMPLE LOCATION AND SOURCE
36	20-7-72	-	a	Sample from same stream as 35.
37	20-7-72	-	a	Upstream from 37.
38	20-7-72	-	a	Water from a puddle with abundant rust around.
39	20-7-72	-	a	Emerging spring with some rust.
40	20-7-72	-	a	Intermittent stream below 39.
41	20-7-72	-	a	Intermittent stream below 40.
42	23-7-72	-	a	Intermittent stream.
43	23-7-72	-	a	Same intermittent stream as 42.
44	23-7-72	-	a	Same intermittent stream as 42.
45	23-7-72	-	a	Intermittent stream; good flow.
46	23-7-72	-	a	Same intermittent stream as 45.
47	23-7-72	-	a	Flat, wet area; very low flow, 1 gal/min.
48	23-7-72	-	a	Emerging spring; does not form a channel; flat, muddy area.
49	23-7-72	-	a	Spring; encased in a wooden box; probably used as a water supply.
50	23-7-72	-	a	Spring; encased by an old barrel.
51	Periodically	-	a	Intermittent stream below 41.
52	Periodically	-	a	Old cement-lined well.
53	3-6-72	408	b	Cased, flowing drill hole. 9°C.
54	3-6-72	344	b	Cased, flowing drill hole. 9°C.
55	3-6-72	204	b	Cased, flowing drill hole. 9°C.

TABLE III-1 (continued)

SAMPLE NUMBER	DATE	CONDUCTIVITY	SAMPLING TECHNIQUE	DESCRIPTION OF SAMPLE LOCATION AND SOURCE
56	3-6-72	264	a	Uncased, flowing drill hole. 8°C.
57	3-6-72	208	b	Cased, flowing drill hole. 8°C.
58	4-6-72	254	b	Cased, flowing drill hole. 8°C.
59	18-7-72	-	d	Cased drill hole but not flowing out of casing, flowing around casing. Slow flow.
60	18-7-72	-	d	Cased drill hole, not flowing out of casing but around casing; slow flow, casing plugged up.
61	18-7-72	-	d	Cased drill hole flowing very slightly.
62	18-7-72	-	c	Cased drill hole, not flowing, water level at 15'3".
63	18-7-72	-	b	Cased drill hole flowing very slightly.
64	18-7-72	-	b	Cased, flowing drill hole; good flow.
65	18-7-72	-	b	Cased, flowing drill hole; minor iron around, good flow.
66	20-7-72	-	b	Flowing, cased drill hole; flow less than 500 ml/min, but appears there is leakage around casing.
67	21-7-72	-	c	Cased drill hole; not flowing but water level near surface.
68	23-7-72	-	c	Cased drill hole; not flowing, water level at 15'.
69	20-8-72	-	b	Cased, flowing drill hole with bent casing.
70	21-8-72	-	c	Cased drill hole; not flowing.

TABLE III-1 (continued)

SAMPLE NUMBER	DATE	CONDUCTIVITY	SAMPLING TECHNIQUE	DESCRIPTION OF SAMPLE LOCATION AND SOURCE
71	Periodically	-	b	Cased, flowing drill hole abundant iron hydroxide around hole. 50' x 40' gossan developed.
72	Periodically	-	d	Drill hole; no casing but flowing. A very large gossan developed 70' x 50'.

[a]Sample bottle dipped into source.

[b]Sample bottle filled from overflow of drill hole.

[c]Water sampled by pumping.

[d]Sampled with syringe.

TABLE III-2.
Zn^{2+} and Cu^{2+} concentrations for springs and drill holes.

SAMPLE NUMBER	SPRINGS Zn (ppb)	Cu (ppb)
1	10	0
2	0	4
3	5	10
4	0	1
5	0	7
6	5	11
7	20	56
8	0	11
9	0	3
10	0	5
11	0	3
12	0	8
13	0	4
14	15	19
15	0	2
16	0	0
17	0	6
18	30	29
19	0	3
20	0	0
21	0	0
22	10	6
23	5	2
24	10	9
25	10	6
26	30	15
27	30	7
28	40	5
29	35	9
30	260	150

TABLE III-2 (continued)

SAMPLE NUMBER	SPRINGS Zn (ppb)	Cu (ppb)
31	40	30
32	40	16
33	25	13
34	30	17
35	15	13
36	25	15
37	45	19
38	250	0
39	690	2
40	270	10
41	50	15
42	20	24
43	5	23
44	0	8
45	5	17
46	0	13
47	5	8
48	5	7
49	5	15
50	5	8
51	80	1
52	80	2

TABLE III-2 (continued)

DRILL HOLES

SAMPLE NUMBER	Zn (ppb)	Cu (ppb)
53	5	18
54	5	18
55	5	10
56	0	3
57	0	2
58	0	10
59	5	0
60	5	0
61	10	0
62	30	28
63	5	0
64	110	47
65	130	28
66	5	3
67	60	43
68	10	0
69	60	0
70	155	70
71	3200	30
72	470	40
73	3500	0

TABLE III-3.*

RAW DATA IN PARTS PER MILLION

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
1	210872	24.0	17.2	132.0	24.0	1.1	0.30	0.80	0.00	0.005	0.005	0.00	10.2	7.20	0.000	11.0
6	30672	15.4	3.1	60.2	9.0	1.2	0.18	0.55	0.00	0.011	0.005	0.00	10.9	6.60	0.487	7.0
7	30672	18.4	3.2	72.0	9.0	1.4	0.19	0.60	0.00	0.056	0.034	0.00	13.8	6.60	0.444	9.0
12	30672	14.8	5.2	69.0	9.0	1.1	0.18	0.60	0.00	0.008	0.000	0.00	9.6	6.79	0.445	7.5
14	40672	8.5	1.4	31.0	9.0	0.3	0.97	0.30	0.00	0.020	0.015	0.14	5.4	6.41	0.436	17.0
30	210872	11.4	3.5	38.0	13.5	1.3	0.18	0.50	0.25	0.014	0.026	0.01	13.0	7.10	0.000	16.0
41	200772	26.0	8.8	75.0	38.0	1.7	0.41	0.35	0.00	0.015	0.050	0.01	12.0	7.30	0.000	16.0
51	290672	25.5	10.2	76.0	40.0	1.6	0.30	0.23	0.00	0.000	0.030	0.00	13.0	7.58	0.452	15.6
52	290672	15.6	7.4	42.6	38.5	2.2	0.22	0.46	0.00	0.000	0.040	0.00	14.1	6.80	0.507	7.5
53	30672	26.2	26.5	264.0	24.0	10.8	0.70	0.90	0.00	0.020	0.000	0.01	18.1	7.80	0.273	9.0
54	30672	26.1	19.0	185.0	29.0	1.9	0.33	0.50	0.00	0.020	0.005	0.00	8.6	7.46	0.340	9.0
55	30672	37.0	12.9	189.0	15.0	1.7	0.22	0.55	0.00	0.010	0.005	0.02	11.4	7.78	0.432	9.0
58	40672	22.2	15.3	145.0	40.0	4.4	0.52	0.50	0.00	0.010	0.000	0.02	15.7	7.33	0.359	8.0
64	180772	43.0	14.5	176.0	27.0	2.6	0.38	0.40	1.80	0.050	0.110	0.04	15.7	7.40	0.000	9.0
65	180772	31.8	4.9	96.0	26.0	1.8	0.25	0.35	0.00	0.030	0.130	0.02	13.0	7.20	0.000	9.0
66	200772	26.0	23.0	170.0	29.0	4.5	1.33	0.40	0.32	0.003	0.005	0.04	25.0	7.70	0.000	9.0
68	230772	15.6	3.5	56.0	8.0	1.5	0.31	0.65	0.00	0.000	0.010	0.04	12.0	6.60	0.000	9.0
70	210872	26.0	9.3	99.0	48.0	2.8	0.51	0.40	3.10	0.070	0.155	0.21	22.6	7.00	0.000	9.0
71	290672	201.0	63.2	304.0	603.0	5.9	2.60	2.50	2.60	0.030	2.900	5.70	27.5	6.60	0.256	7.8
72	290672	345.0	84.0	378.0	1230.0	11.6	5.40	0.89	71.00	0.084	0.470	6.50	23.0	6.40	0.178	7.9

*Chemical composition of the areal samples.

TABLE III-4.*

RAW DATA IN PARTS PER MILLION

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
51A	290672	25.5	10.2	76.0	40.0	1.6	0.26	0.23	0.00	0.000	0.060	0.00	13.0	7.96	0.452	15.6
51B	130772	26.6	10.5	85.0	44.0	1.7	0.23	0.25	0.00	0.000	0.060	0.00	13.3	7.70	0.453	17.2
51C	240772	25.9	10.2	83.0	42.0	1.6	0.23	0.34	0.00	0.000	0.060	0.00	13.6	7.50	0.390	16.2
51D	60872	27.1	10.7	83.0	39.0	1.6	0.21	0.41	0.00	0.000	0.160	0.00	14.2	7.50	0.000	14.6
51E	200872	27.5	11.5	85.0	46.0	1.6	0.18	0.34	0.00	0.000	0.070	0.00	13.6	7.65	0.000	14.0
51F	290872	29.8	12.0	90.0	46.0	1.8	0.20	0.64	0.00	0.000	0.080	0.00	14.3	7.65	0.000	16.3
51G	70972	32.0	13.4	97.0	53.0	1.9	0.19	0.50	0.00	0.000	0.080	0.00	13.9	7.60	0.000	14.4
51H	180972	32.7	13.9	86.0	53.0	1.9	0.22	0.58	0.00	0.000	0.160	0.00	14.5	7.30	0.000	13.0
51I	250972	33.6	14.2	87.0	64.0	2.0	0.31	0.46	0.00	0.000	0.100	0.00	14.2	7.65	0.000	13.1
51J	101072	30.8	13.7	74.0	65.0	2.0	0.59	0.95	0.00	0.000	0.410	0.00	14.6	7.25	0.000	6.8
51K	271072	24.9	10.7	53.0	52.0	1.5	0.52	2.47	0.00	0.000	0.090	0.00	11.4	7.45	0.000	8.2
51L	131172	21.5	9.0	47.0	43.0	1.3	0.21	1.80	0.00	0.000	0.070	0.00	9.7	7.20	0.000	6.6
51M	271172	20.4	8.3	39.0	45.0	1.3	0.19	1.12	0.00	0.000	0.060	0.00	8.1	7.10	0.000	3.6
51N	180173	25.7	10.7	37.0	66.0	1.4	0.09	0.66	0.00	0.000	0.090	0.00	8.3	7.04	0.000	1.8
51O	180373	13.4	5.5	24.0	28.0	1.0	0.13	1.13	0.00	0.000	0.050	0.00	7.4	6.90	0.000	3.5
51P	40473	15.5	6.3	31.5	38.0	1.1	0.09	0.63	0.00	0.000	0.060	0.00	8.2	7.06	0.000	5.1
51Q	230473	17.4	7.4	41.3	38.0	1.4	0.10	3.65	0.00	0.000	0.050	0.00	9.7	7.17	0.000	10.4
51R	70573	19.0	7.9	42.4	46.0	1.3	0.12	0.52	0.00	0.000	0.080	0.00	9.9	7.24	0.000	11.1
51S	240573	17.4	6.8	45.0	40.0	1.3	0.14	0.45	0.00	0.000	0.038	0.00	9.1	7.45	0.000	10.4
51T	70673	18.2	6.9	55.0	31.0	1.3	0.13	0.39	0.00	0.000	0.051	0.00	9.5	7.38	0.000	13.0
51U	250673	21.1	7.9	69.0	28.0	1.4	0.10	0.27	0.00	0.000	0.065	0.00	11.6	7.30	0.000	14.8
51V	20873	26.1	10.3	86.0	40.0	1.7	0.12	0.36	0.00	0.000	0.061	0.00	13.4	7.23	0.000	17.7

*Chemical composition of the periodical samples from spring 51.

TABLE III-5.*

RAW DATA IN PARTS PER MILLION

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
52A	290672	15.6	7.4	42.6	38.5	2.2	0.22	0.46	0.00	0.000	0.040	0.00	14.1	6.40	0.507	7.5
52B	130772	16.0	7.3	40.0	38.0	1.4	0.24	0.23	0.00	0.001	0.080	0.00	9.9	6.60	0.538	7.3
52C	240772	14.5	5.9	43.0	33.0	1.5	0.36	0.36	0.00	0.003	0.020	0.00	12.3	6.95	0.407	12.0
52D	60872	15.8	5.7	40.0	32.0	1.6	0.33	0.41	0.00	0.000	0.015	0.00	12.3	7.20	0.000	9.8
52E	200872	16.6	5.6	43.0	35.0	1.6	0.34	0.36	0.00	0.000	0.015	0.00	13.0	7.15	0.000	9.0
52F	290872	15.6	5.8	43.0	36.0	1.6	0.35	0.56	0.00	0.000	0.010	0.00	12.6	7.10	0.000	10.5
52G	70972	15.9	5.8	38.0	31.0	1.5	0.35	0.46	0.00	0.000	0.010	0.00	12.3	6.90	0.000	10.6
52H	160972	15.1	6.4	37.0	33.0	1.4	0.28	0.36	0.00	0.000	0.045	0.00	12.0	6.90	0.000	8.7
52I	250972	15.5	6.5	37.0	33.0	1.6	0.30	0.41	0.00	0.000	0.035	0.00	12.3	6.95	0.000	9.4
52J	101072	12.5	7.0	38.0	29.0	1.7	0.26	0.50	0.00	0.000	0.040	0.00	12.6	6.92	0.000	8.1
52K	271072	13.5	8.7	38.0	43.0	1.8	0.26	0.48	0.00	0.000	0.050	0.00	14.6	6.72	0.000	7.8
52L	131172	14.2	8.2	35.0	43.0	1.8	0.27	0.86	0.00	0.000	0.035	0.00	15.8	6.65	0.000	7.4
52M	271172	14.3	8.5	37.0	45.0	1.8	0.27	0.43	0.00	0.000	0.035	0.00	18.1	6.62	0.000	6.5
52N	180173	18.6	9.5	35.0	47.0	1.4	0.26	0.86	0.00	0.000	0.035	0.00	13.6	6.60	0.000	6.2
52O	160373	13.9	7.6	32.6	35.0	1.2	0.26	0.63	0.00	0.000	0.031	0.00	12.3	6.70	0.000	6.2
52P	40473	11.5	6.5	29.0	27.0	1.1	0.20	0.50	0.00	0.000	0.031	0.00	11.5	6.74	0.000	5.6
52Q	230473	10.2	6.1	31.5	21.0	1.3	0.29	0.59	0.00	0.000	0.008	0.00	13.4	6.75	0.000	5.9
52R	70573	10.7	6.4	29.4	27.0	1.3	0.22	0.51	0.00	0.000	0.008	0.00	13.4	6.76	0.000	7.2
52S	240573	13.7	6.9	29.0	38.0	1.2	0.16	0.52	0.00	0.000	0.006	0.00	9.9	6.81	0.000	5.0
52T	70673	13.2	6.6	38.0	36.0	1.3	0.23	0.52	0.00	0.000	0.024	0.00	11.9	6.68	0.000	6.0
52U	250673	11.9	5.6	40.0	18.0	1.2	0.16	0.45	0.00	0.000	0.002	0.00	13.3	7.30	0.000	9.5
52V	20873	12.6	5.6	40.0	25.0	1.4	0.19	0.47	0.00	0.000	0.000	0.00	13.8	7.02	0.000	12.2

*Chemical corposition of the periodical samples from well 52.

TABLE III-6.*

RAW DATA IN PARTS PER MILLION

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
71A	290672	201.0	63.2	304.0	603.0	5.9	2.10	2.50	2.60	0.030	2.920	5.70	27.5	6.50	0.256	7.8
71B	130772	202.0	63.3	310.0	613.0	6.0	2.10	2.40	4.05	0.040	3.080	5.80	27.9	6.80	0.252	7.7
71C	240772	199.0	59.7	311.0	613.0	5.9	1.90	2.80	2.40	0.020	2.860	5.60	27.5	6.70	0.236	7.6
71D	60872	202.0	63.3	308.0	613.0	5.9	1.90	2.75	2.50	0.030	2.970	5.70	27.5	6.70	0.000	7.8
71E	200872	202.0	62.9	306.0	620.0	6.0	1.90	2.80	2.60	0.030	3.060	5.90	31.0	6.40	0.000	7.8
71F	290872	207.0	64.1	308.0	641.0	6.5	2.10	2.80	2.65	0.040	3.200	5.90	28.4	6.70	0.000	7.8
71G	70972	211.0	64.9	310.0	636.0	6.3	1.90	2.75	2.80	0.040	3.290	6.00	28.6	6.60	0.000	7.8
71H	160972	214.0	66.1	273.0	671.0	6.8	2.30	2.90	2.60	0.040	3.450	6.20	28.7	6.70	0.000	7.8
71I	250972	219.0	67.3	280.0	674.0	6.3	2.00	2.70	3.05	0.000	3.620	6.50	29.2	6.70	0.000	7.9
71J	101072	243.0	69.1	284.0	667.0	6.5	2.10	2.50	3.60	0.000	3.910	6.80	29.5	6.72	0.000	7.7
71K	271072	236.0	72.3	289.0	740.0	6.5	2.00	2.70	2.00	0.000	3.870	6.90	29.5	6.70	0.000	7.7
71L	131172	241.0	74.7	296.0	757.0	6.5	2.17	3.00	3.00	0.000	3.390	6.13	30.3	6.62	0.000	7.8
71M	271172	239.0	73.7	298.0	739.0	6.4	2.00	3.20	2.93	0.000	3.440	6.13	30.4	6.64	0.000	7.8
71N	180173	234.0	72.8	294.0	684.0	6.3	2.11	3.20	3.00	0.000	3.710	6.00	30.2	6.53	0.000	7.8
71O	160373	227.0	64.8	276.0	643.0	5.6	2.00	3.00	2.70	0.000	2.910	5.48	27.8	6.48	0.000	7.8
71P	40473	215.0	62.8	275.0	627.0	5.5	1.93	2.80	2.70	0.000	3.040	5.34	27.8	6.78	0.000	7.4
71Q	230473	197.0	68.8	267.0	570.0	5.6	1.63	2.70	2.70	0.000	2.860	5.50	27.7	6.65	0.000	7.4
71R	70573	197.0	68.5	269.0	577.0	5.6	1.70	2.80	2.77	0.000	2.880	5.40	27.5	6.73	0.000	7.4
71S	240573	191.0	58.4	265.0	599.0	5.4	1.60	2.40	2.60	0.000	2.720	5.30	24.0	7.30	0.000	7.5
71T	70673	205.0	63.3	296.0	605.0	5.4	1.60	2.70	2.60	0.000	2.720	5.30	26.9	6.74	0.000	7.5
71U	250673	207.0	63.2	298.0	541.0	5.4	1.60	2.90	2.73	0.000	2.860	5.30	26.6	6.73	0.000	7.5
71V	20873	206.0	67.6	304.0	591.0	5.8	2.00	3.00	3.10	0.020	3.720	5.80	27.6	6.75	0.247	7.6

*Chemical composition of the periodical samples from drill hole 71.

TABLE III-7.*

RAW DATA IN PARTS PER MILLION

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
72A	290672	345.0	94.0	378.0	1230.0	11.6	4.40	0.89	71.00	0.084	0.470	6.50	23.0	6.40	0.178	7.9
72B	130772	340.0	96.0	376.0	1120.0	11.7	4.10	0.70	66.50	0.010	0.510	6.70	24.6	6.50	0.186	7.9
72C	240772	343.0	95.0	376.0	1190.0	11.5	4.20	0.62	54.00	0.040	0.470	6.50	24.3	6.40	0.155	7.9
72D	60872	346.0	85.5	365.0	1125.0	12.3	4.40	0.58	74.50	0.050	0.580	6.70	24.3	6.30	0.000	7.8
72E	200872	344.0	95.5	341.0	1070.0	12.3	4.10	0.94	73.50	0.110	0.780	6.70	23.7	6.40	0.000	7.9
72F	290872	330.0	85.5	362.0	1110.0	11.2	4.00	0.88	74.00	0.020	0.480	6.70	22.2	6.40	0.000	7.9
72G	70972	340.0	83.2	361.0	1160.0	11.0	4.00	0.92	75.00	0.020	0.480	6.70	23.7	6.30	0.000	8.0
72H	160972	344.0	87.0	332.0	1090.0	11.5	4.50	0.75	76.00	0.020	0.480	6.70	18.9	6.40	0.000	8.1
72I	250972	358.0	89.0	324.0	1260.0	11.9	4.50	0.75	79.00	0.000	0.490	6.70	19.7	6.38	0.000	7.9
72J	101072	358.0	96.0	338.0	1270.0	11.8	4.40	1.35	79.50	0.000	0.500	6.80	21.4	6.40	0.000	8.0
72K	271072	346.0	92.0	302.0	1150.0	11.7	4.70	0.91	77.80	0.000	0.620	6.70	21.0	6.38	0.000	7.9
72L	131172	340.0	86.5	328.0	1090.0	11.0	4.20	0.86	70.50	0.000	0.460	6.00	20.5	6.38	0.000	8.0
72M	271172	345.0	88.0	321.0	1133.0	11.1	4.20	0.97	71.70	0.000	0.470	6.40	21.0	6.46	0.000	8.0
72N	180173	350.0	87.0	328.0	1190.0	11.1	4.30	1.10	70.00	0.000	0.550	6.40	22.2	6.33	0.000	7.8
72O	160373	354.0	79.8	333.0	1110.0	11.2	4.20	0.97	71.20	0.000	0.490	6.30	21.0	6.39	0.000	7.9
72P	40473	354.0	79.0	330.0	1160.0	11.4	4.18	0.92	70.70	0.000	0.730	6.45	21.0	6.45	0.000	7.6
72Q	230473	346.0	89.4	312.0	1160.0	11.2	3.68	1.00	68.60	0.000	0.440	6.20	21.0	6.50	0.000	7.7
72R	70573	349.0	90.3	302.0	1110.0	11.4	3.80	0.90	69.00	0.000	0.440	6.20	21.6	6.41	0.000	7.7
72S	250573	351.0	84.6	362.0	1160.0	11.2	3.85	1.05	70.00	0.000	0.450	6.30	21.0	6.49	0.000	7.7
72T	70673	356.0	84.7	376.0	1140.0	11.2	3.80	1.10	69.50	0.000	0.540	6.30	20.8	6.46	0.000	7.9
72U	250673	356.0	84.4	377.0	1100.0	11.2	3.70	1.00	69.70	0.000	0.480	6.20	21.0	6.45	0.000	7.7
72V	20873	356.0	91.0	381.0	1230.0	12.0	3.70	1.40	72.00	0.005	0.440	6.50	21.6	6.38	0.210	7.8

*Chemical composition of the periodical samples from drill hole 72.

TABLE III-8.*

RAW DATA IN PARTS PER MILLION

SAMP	DATE	CA	MG	HCO3	SO4	NA	K	CL	FE	CU	ZN	MN	H4SIO4	PH	EH	TEMP
73A	300672	43.2	28.0	135.0	145.0	2.2	0.59	1.40	1.00	0.000	3.500	1.20	15.7	6.20	0.313	7.8
73B	100772	48.9	32.2	145.0	139.0	2.3	0.59	0.99	1.00	0.000	4.070	1.39	15.6	7.10	0.318	7.8
73C	240772	39.2	26.4	119.0	112.0	2.1	0.53	1.10	1.10	0.000	3.080	1.04	14.8	6.70	0.347	7.6
73D	100872	39.7	25.7	122.0	110.0	2.1	0.52	0.99	0.76	0.000	3.220	1.11	15.1	7.00	0.000	7.8
73E	170872	38.4	25.7	121.0	105.0	2.0	0.49	0.87	1.78	0.000	3.080	1.00	15.2	6.85	0.000	7.8
73F	290872	48.7	31.0	139.0	149.0	2.3	0.55	1.20	0.98	0.000	4.240	1.44	15.8	6.75	0.000	7.8
73G	70972	53.7	34.6	149.0	170.0	2.4	0.59	1.10	0.98	0.000	4.890	1.70	16.0	6.65	0.000	7.8
73H	160972	59.2	40.2	139.0	197.0	2.5	0.73	1.20	1.15	0.000	5.410	1.90	16.5	6.62	0.000	7.8
73I	250972	63.2	40.4	144.0	216.0	2.6	0.75	1.20	1.43	0.000	5.820	2.05	16.6	6.65	0.000	7.9
73J	101072	67.1	43.7	146.0	259.0	2.7	0.68	1.50	0.60	0.000	6.330	2.30	16.7	6.72	0.000	7.8
73K	271072	70.0	45.5	144.0	262.0	2.8	0.70	1.70	1.43	0.000	6.750	2.50	17.2	6.72	0.000	7.7
73L	131172	64.2	41.7	131.0	233.0	2.7	0.68	1.80	1.28	0.000	6.040	2.08	16.7	6.40	0.000	7.8
73M	271172	62.9	40.2	131.0	209.0	2.7	0.69	1.71	1.38	0.000	6.210	2.20	17.2	6.55	0.000	7.8
73N	180173	47.2	30.7	113.0	155.0	2.2	0.56	1.40	0.93	0.000	4.320	1.50	15.6	6.52	0.000	7.9
73O	160373	32.5	23.5	97.8	97.0	1.8	0.48	1.10	0.79	0.000	3.250	1.03	14.4	6.70	0.000	7.6
73P	40473	27.6	21.3	90.0	79.0	1.7	0.42	1.10	0.64	0.000	2.840	0.88	13.5	6.70	0.000	7.4
73Q	230473	21.9	17.3	91.0	80.0	1.8	0.43	1.10	0.50	0.000	2.860	1.05	13.9	6.62	0.000	7.4
73R	70573	30.0	22.0	99.0	86.0	1.8	0.42	1.20	0.43	0.000	3.450	1.02	13.8	6.86	0.000	7.4
73S	240573	28.0	18.5	102.0	68.0	1.6	0.38	1.20	0.38	0.000	2.810	0.82	12.3	6.91	0.000	7.4
73T	70673	31.9	20.3	111.0	96.0	1.7	0.41	1.30	0.38	0.000	2.900	0.99	13.3	6.86	0.000	7.4
73U	250673	36.4	22.5	121.0	111.0	1.8	0.45	1.40	0.42	0.000	3.400	1.15	14.0	6.73	0.000	7.5
73V	20873	47.2	31.6	139.0	157.0	2.2	0.53	1.74	0.87	0.000	5.100	1.50	14.9	6.75	0.359	7.6

*Chemical corposition of the periodical samples from drill hole 73.

APPENDIX IV PLOTS OF THE VARIATION OF THE CONSTITUENTS WITH TIME

Figures IV-1, -2, -3, -4, -5 give plots of $\log_{10}$ molarity versus time for samples from sites 51, 52, 71, 72 and 73 respectively. The analytical error is designated on these figures by error bars of plus and minus two standard deviations. This standard deviation is a pooled estimate from duplicate determinations. Figure IV-6 is a plot of $\log_{10}$ precipitation in inches versus time for the two day average and twenty day average of the precipitation data.

Day	Date
0	1 May 1972
50	19 June 1972
100	8 August 1972
150	27 September 1972
200	16 November 1972
250	5 January 1973
300	24 February 1973
350	15 April 1973
400	4 June 1973
450	24 July 1973
500	12 September 1973

Figure IV-1. Plot of $\log_{10}$ molarity versus time for constituents in periodical samples taken from site 51.

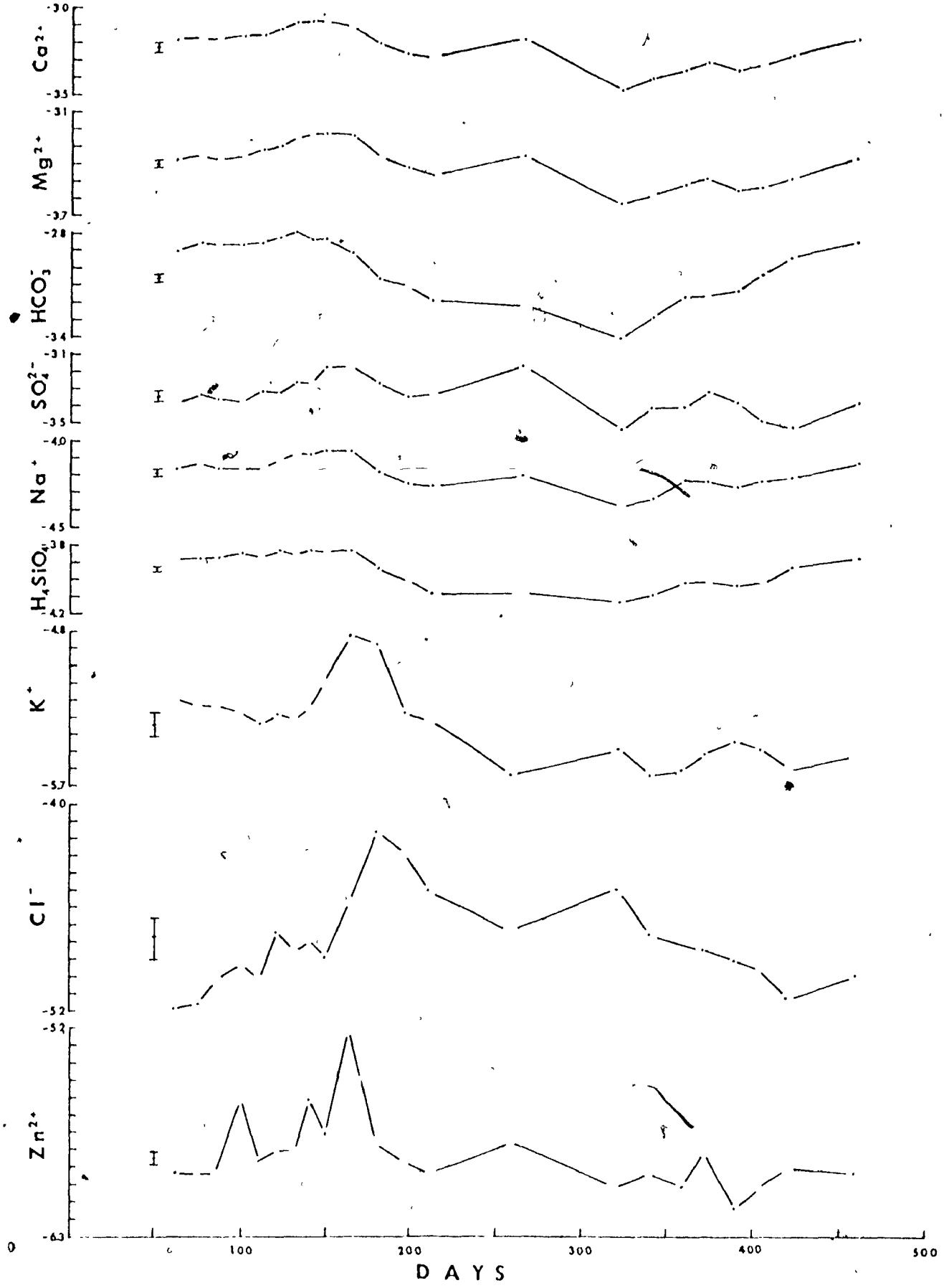

Ca2+
-30
-33
Mg2+
-31
-37
HCO3-
-28
-34
SO42-
-31
-35
Na+
-40
-45
H4SiO4
-38
-42
K+
-48
-57
Cl-
-40
-52
Zn2+
-52
-63
0
100
200
300
400
500
DAYS

Figure IV-2. Plot of $\log_{10}$ molarity versus time for constituents in periodical samples taken from site 52.

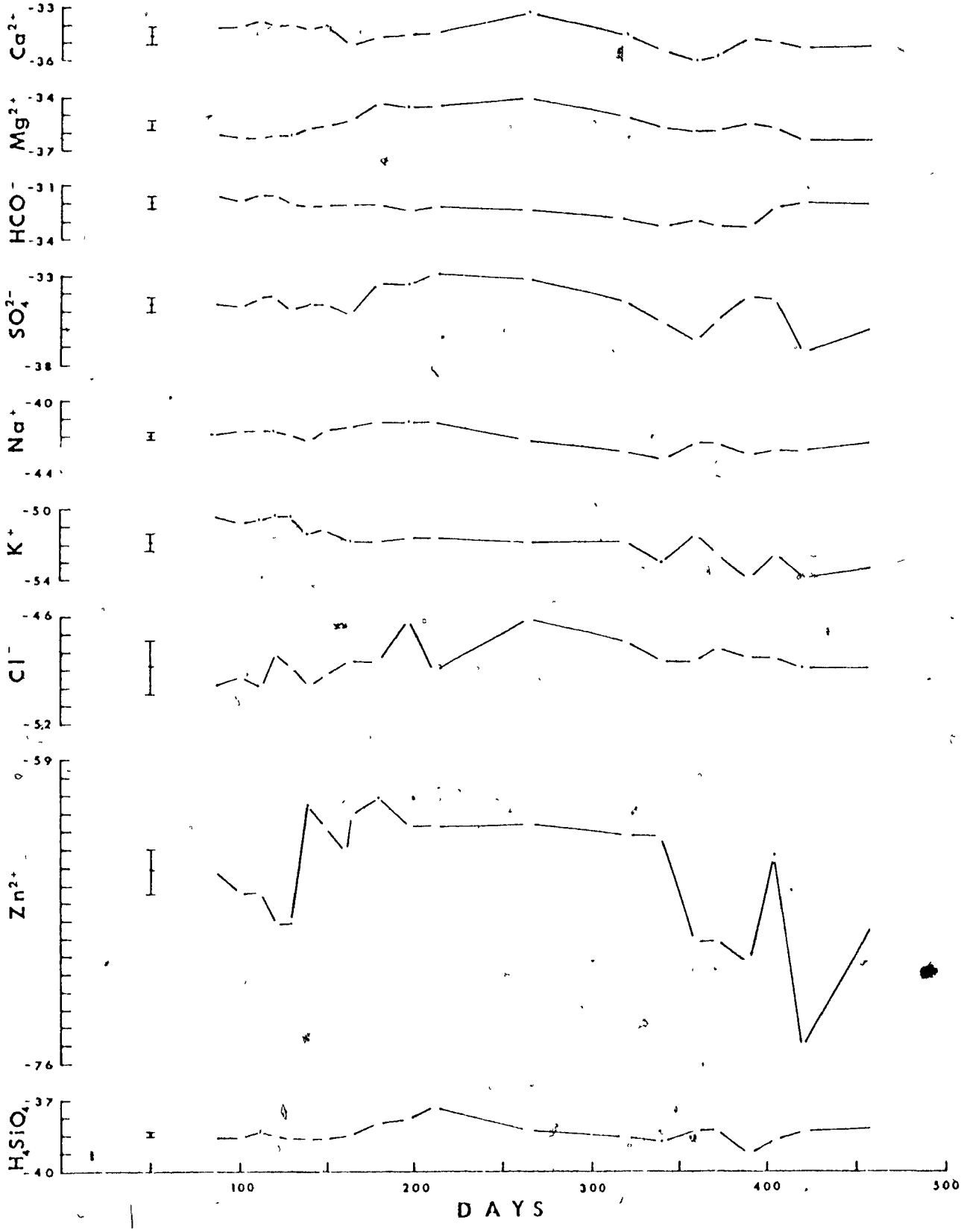
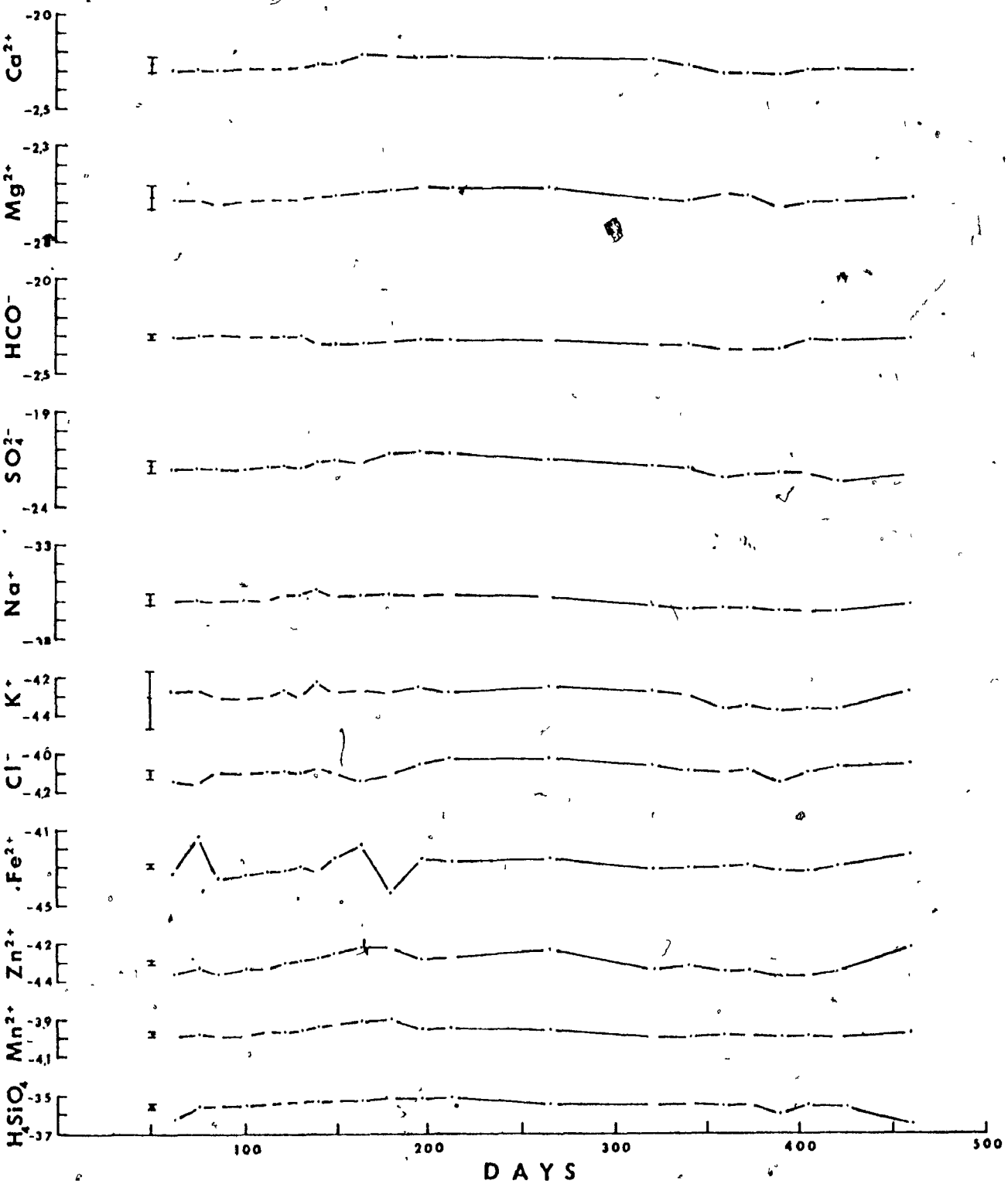

Ca^{2+}
-33
-36
Mg^{2+}
-34
-37
HCO^{-}_{3}
-31
-34
SO^{2-}_{4}
-33
-38
Na^{+}
-40
-44
K^{+}
-50
-54
Cl^{-}
-46
-52
Zn^{2+}
-59
-76
H_4SiO_4
-37
-40
100
200
300
400
500
DAYS

Figure IV-3. Plot of $\log_{10}$ molarity versus time for constituents in periodical samples taken from site 71.


Ca2+
-20
-2,5
Mg2+
-2,3
-2,8
HCO-
-20
-2,5
SO4 2-
-19
-24
Na+
-33
-38
K+
-42
-44
Cl-
-40
-42
Fe2+
-41
-45
Zn2+
-42
-44
Mn2+
-39
-41
H4SiO4
-35
-37
100
200
300
400
500
DAYS

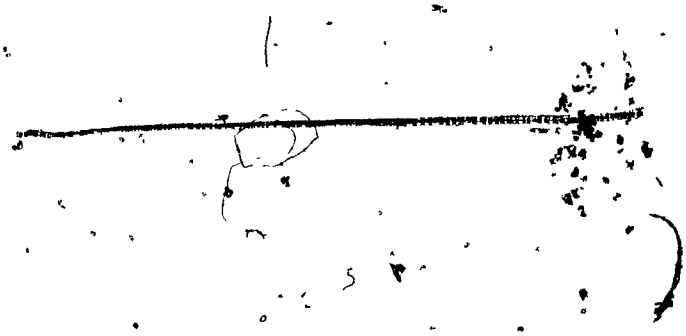


Figure IV-4. Plot of $\log_{10}$ molarity versus time for constituents in periodical samples taken from site 72.

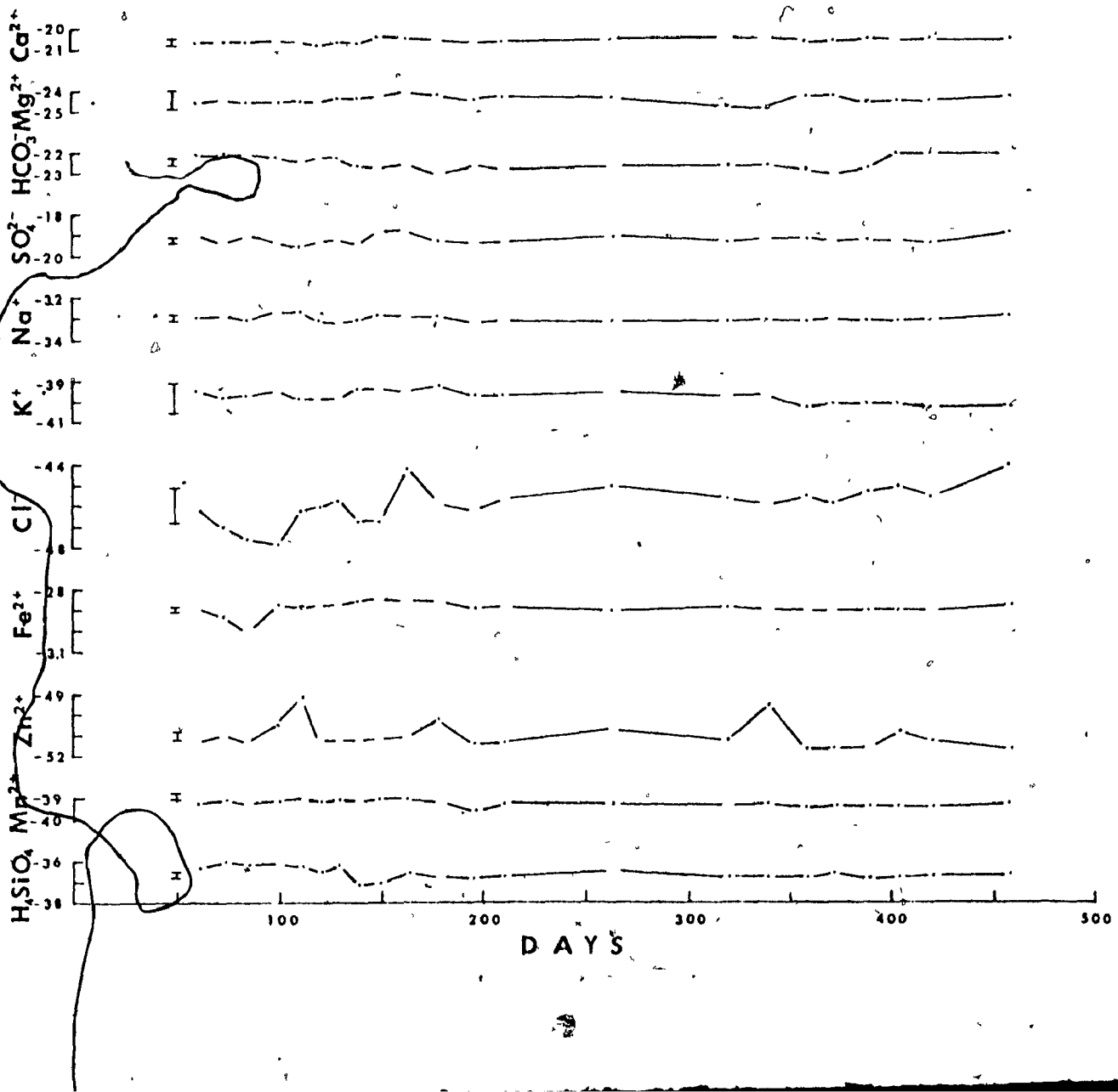

Ca2+
-20
-21
Mg2+
-24
-25
HCO3-
-22
-23
SO4 2-
-18
-20
Na+
-32
-34
K+
-39
-41
Cl-
-44
-46
Fe2+
-28
-31
Zn2+
-49
-52
Mn2+
-39
-40
H4SiO4
-36
-38
100
200
300
400
500
DAYS

Figure IV-5. Plot of $\log_{10}$ molarity versus time for constituents in periodical samples taken from site 73.

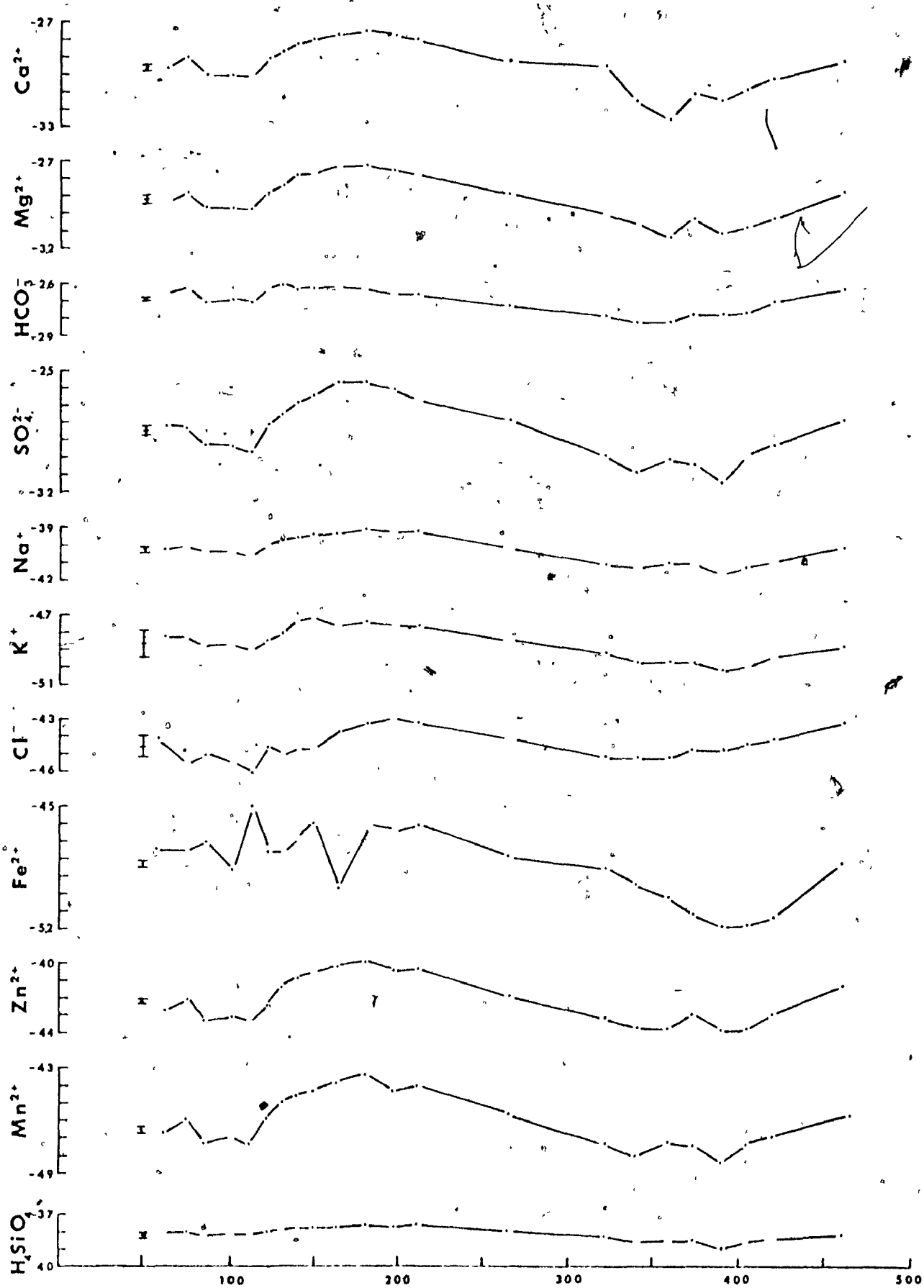
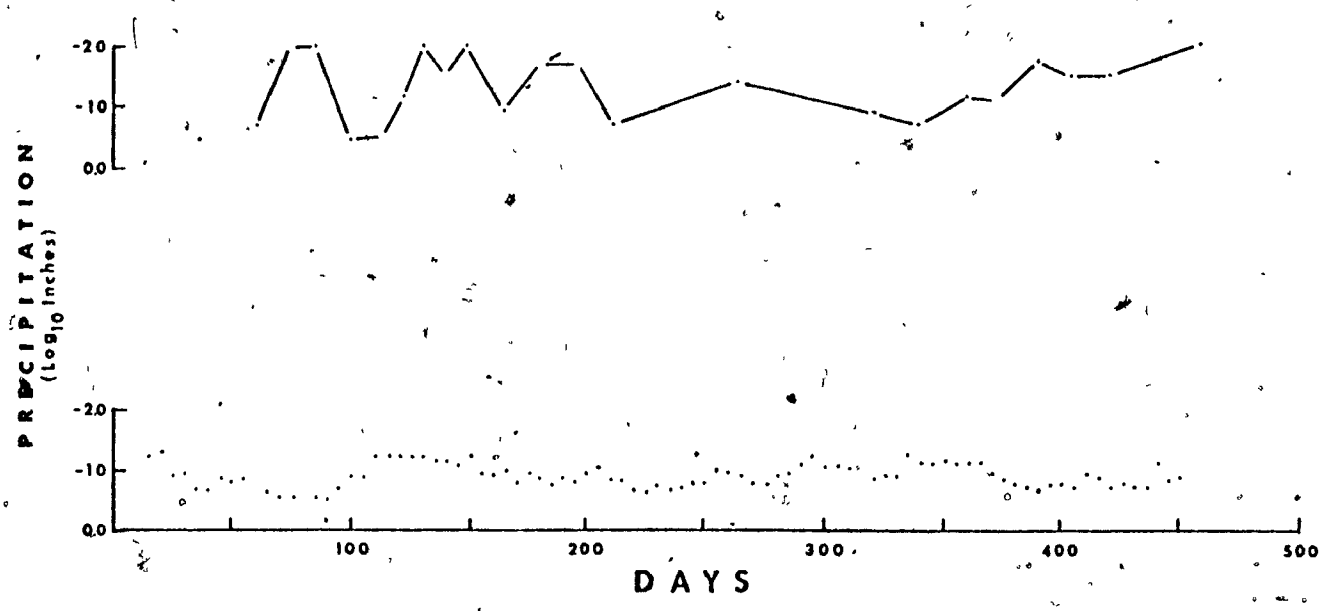

Ca2+
-27
-33
Mg2+
-27
-32
HCO3-
-26
-29
SO42-
-25
-32
Na+
-39
-42
K+
-47
-51
Cl-
-43
-46
Fe2+
-45
-52
Zn2+
-40
-44
Mn2+
-43
-49
H4SiO4
-37
-40
100
200
300
400
500

Figure IV-6. Plot of $\log_{10}$ precipitation in inches versus time for the two day average (upper plot) and the twenty day average (lower plot) for the precipitation data.


-2.0
-1.0
0.0
PRECIPITATION
(Log10 Inches)
-2.0
-1.0
0.0
100
200
300
400
500
DAYS

APPENDIX.V CORRELATION COEFFICIENTS OF THE PERIODICAL SAMPLING DATA

Product moment correlation coefficients were calculated for the periodical sampling data. The program that was used for these calculations is a subprogram on file at the McGill University Computing Center. The program is entitled BECORI and is distributed by International Mathematical and Statistical Libraries, Inc. The same program was used to calculate the means and standard deviations of the data.

Figure V-1. Correlation matrix for constituents from sample site 51.

CORRELATION MATRIX

	CA	MG	HCO3	SO4	NA	K	CL	ZN	SI	PH	TEMP
CA	1.000										
MG	0.988	1.000									
HCO3	0.851	0.784	1.000								
SO4	0.698	0.768	0.261	1.000							
NA	0.959	0.952	0.868	0.645	1.000						
K	0.459	0.563	0.289	0.540	0.538	1.000					
CL	-0.296	-0.206	-0.445	-0.001	-0.247	0.172	1.000				
ZN	0.467	0.537	0.244	0.545	0.535	0.695	-0.019	1.000			
SI	0.874	0.834	0.958	0.353	0.909	0.468	-0.331	0.437	1.000		
PH	0.591	0.520	0.761	0.149	0.595	0.295	-0.389	-0.045	0.709	1.000	
TEMP	0.453	0.348	0.822	-0.195	0.538	-0.035	-0.400	-0.137	0.743	0.748	1.000

Figure V-2. Correlation matrix for constituents from sample site 52.

CORRELATION MATRIX

	CA	MG	HCO3	SO4	NA	K	CL	ZN	SI	PH	TEMP
CA	1.000										
MG	0.235	1.000									
HCO3	0.460	-0.326	1.000								
SO4	0.642	0.767	0.046	1.000							
NA	0.405	0.339	0.489	0.532	1.000						
K	0.546	-0.164	0.549	0.225	0.537	1.000					
CL	0.133	0.636	-0.381	0.424	0.022	-0.207	1.000				
ZN	0.241	0.680	-0.054	0.569	0.456	0.113	0.162	1.000			
SI	-0.000	0.487	0.154	0.350	0.627	0.078	0.224	0.275	1.000		
PH	0.099	-0.768	0.624	-0.535	-0.009	0.192	-0.551	-0.503	-0.296	1.000	
TEMP	0.246	-0.567	0.780	-0.278	0.302	0.455	-0.427	-0.275	-0.008	0.699	1.000

Figure V-3. Correlation matrix for constituents from sample site 71.

CORRELATION MATRIX

	CA	MG	HCO3	SO4	NA	K	CL	FE	ZN	MN	SI	PH
CA	1.000											
MG	0.767	1.000										
HCO3	-0.039	-0.114	1.000									
SO4	0.845	0.696	0.042	1.000								
NA	0.620	0.559	0.232	0.779	1.000							
K	0.544	0.378	0.280	0.639	0.813	1.000						
CL	0.452	0.535	0.096	0.361	0.229	0.214	1.000					
FE	0.182	0.158	0.109	0.006	0.129	0.289	-0.165	1.000				
ZN	0.734	0.683	0.077	0.668	0.760	0.639	0.269	0.260	1.000			
MN	0.691	0.589	0.110	0.740	0.858	0.632	0.021	0.152	0.883	1.000		
SI	0.682	0.689	0.273	0.697	0.717	0.608	0.477	0.155	0.648	0.683	1.000	
PH	-0.321	-0.356	-0.369	-0.218	-0.303	-0.389	-0.463	0.059	-0.190	-0.228	-0.712	1.000

Figure V-4. Correlation matrix for constituents from sample site 72.

CORRELATION MATRIX

	CA	MG	HCO3	SO4	NA	K	CL	FE	ZN	MN	SI	PH
CA	1.000											
MG	0.081	1.000										
HCO3	-0.056	-0.298	1.000									
SO4	0.466	0.411	0.112	1.000								
NA	0.169	0.234	0.132	0.204	1.000							
K	-0.084	0.112	-0.313	0.208	0.321	1.000						
CL	0.517	0.378	0.007	0.404	-0.172	-0.374	1.000					
FE	0.174	0.392	-0.340	0.136	0.262	0.388	0.254	1.000				
ZN	0.047	-0.281	-0.148	-0.225	0.439	0.293	-0.171	0.188	1.000			
MN	-0.176	0.289	0.145	0.276	0.606	0.541	-0.191	0.440	0.333	1.000		
SI	-0.425	-0.109	0.491	-0.026	0.322	-0.047	-0.336	-0.402	0.205	0.331	1.000	
PH	0.113	-0.162	0.022	-0.138	-0.233	-0.438	0.127	-0.326	-0.105	-0.351	-0.240	1.000

Figure V-5. Correlation matrix for constituents from sample site 73.

CORRELATION MATRIX

	CA	MG	HCO3	SO4	NA	K	CL	FE	ZN	MN	SI	PH
CA	1.000											
MG	0.992	1.000										
HCO3	0.847	0.811	1.000									
SO4	0.978	0.980	0.781	1.000								
NA	0.973	0.975	0.827	0.955	1.000							
K	0.948	0.956	0.793	0.926	0.958	1.000						
CL	0.561	0.549	0.330	0.639	0.511	0.430	1.000					
FE	0.619	0.625	0.533	0.542	0.679	0.676	0.112	1.000				
ZN	0.955	0.964	0.733	0.970	0.929	0.889	0.682	0.508	1.000			
MN	0.959	0.966	0.730	0.982	0.943	0.908	0.638	0.515	0.987	1.000		
SI	0.931	0.934	0.793	0.908	0.972	0.950	0.426	0.734	0.864	0.890	1.000	
PH	-0.288	-0.298	-0.111	-0.370	-0.342	-0.387	-0.489	-0.258	-0.306	-0.321	-0.389	1.000

APPENDIX VI OUTPUT FOR THE SATURATION INDEX PROGRAM

The appendix is divided into six sections as follows:

Appendix VIa Output for areal data

Appendix VIb Output for periodical data from sample site 51

Appendix VIc Output for periodical data from sample site 52.

Appendix VId Output for periodical data from sample site 71

Appendix VIe Output for periodical data from sample site 72

Appendix VIf Output for periodical data from sample site 73

The output consists of the following headings:

TOTAL MOLARITY

IONIC MOLARITY

IONIC ACTIVITY

ACTIVITY PRODUCTS

SATURATION INDEX

EQUILIBRIUM PE

Miscellaneous output items include: pH, Eh, temperature, P_{CO_2}, ion balance error, total dissolved solids and ionic strength.

APPENDIX VIa SATURATION INDEX OUTPUT FOR THE AREAL DATA

TOTAL MOLARITY*

SAMP	DATE	CA	MG	ALK	S	NA	K	CL	FE
1	210872	-3.223	-3.150	-2.665	-3.602	-4.320	-5.115	-4.647	100.000
6	30672	-3.415	-3.895	-3.006	-4.028	-4.282	-5.337	-4.809	100.000
7	30672	-3.327	-3.881	-2.928	-4.028	-4.215	-5.313	-4.772	100.000
12	30672	-3.433	-3.670	-2.947	-4.028	-4.320	-5.337	-4.772	100.000
14	40672	-3.674	-4.240	-3.294	-4.028	-4.870	-4.605	-5.073	100.000
30	210872	-3.546	-3.842	-3.206	-3.852	-4.248	-5.337	-4.851	-5.349
41	200772	-3.188	-3.441	-2.910	-3.403	-4.131	-4.979	-5.006	100.000
51	290672	-3.187	-3.377	-2.935	-3.381	-4.157	-5.115	-5.188	100.000
52	290672	-3.410	-3.517	-3.156	-3.397	-4.019	-5.250	-4.887	100.000
53	30672	-3.185	-2.963	-2.364	-3.603	-3.328	-4.747	-4.596	100.000
54	30672	-3.186	-3.107	-2.518	-3.520	-4.083	-5.074	-4.851	100.000
55	30672	-3.035	-3.275	-2.509	-3.807	-4.131	-5.250	-4.809	100.000
58	40672	-3.257	-3.201	-2.624	-3.381	-3.718	-4.876	-4.851	100.000
64	180772	-2.970	-3.225	-2.540	-3.551	-3.947	-5.013	-4.948	-4.492
65	180772	-3.101	-3.696	-2.803	-3.568	-4.106	-5.194	-5.006	100.000
66	200772	-3.188	-3.024	-2.555	-3.520	-3.708	-4.468	-4.948	-5.242
68	230772	-3.410	-3.842	-3.037	-4.080	-4.185	-5.101	-4.737	100.000
70	210872	-3.188	-3.417	-2.790	-3.301	-3.914	-4.885	-4.948	-4.256
71	290672	-2.300	-2.586	-2.303	-2.203	-3.591	-4.178	-4.152	-4.333
72	290672	-2.066	-2.462	-2.209	-1.894	-3.298	-3.861	-4.601	-2.897

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED

TOTAL MOLARITY*

SAMP	DATE	CU	ZN	MN	H4SIO4	TDS	PH	PE	TEMP C
1	210872	-7.104	-7.116	100.000	-3.992	-0.679	7.200	300.000	11.000
6	30672	-6.762	-7.116	100.000	-3.963	-0.998	6.600	8.759	7.000
7	30672	-6.055	-6.284	100.000	-3.861	-0.924	6.600	7.929	9.000
12	30672	-6.900	100.000	100.000	-4.018	-0.961	6.790	7.989	7.500
14	40672	-6.502	-6.639	-5.574	-4.268	-1.244	6.410	7.572	17.000
30	210872	-6.657	-6.400	-6.740	-3.886	-1.088	7.100	300.000	16.000
41	200772	-6.627	-6.116	-6.740	-3.921	-0.790	7.300	300.000	16.000
51	290672	100.000	-6.338	100.000	-3.887	-0.778	7.580	7.888	15.600
52	290672	100.000	-6.213	100.000	-3.851	-0.917	6.800	9.103	7.500
53	30672	-6.502	100.000	-6.740	-3.743	-0.430	7.800	4.875	9.000
54	30672	-6.502	-7.117	100.000	-4.066	-0.568	7.460	6.072	9.000
55	30672	-6.803	-7.117	-6.439	-3.944	-0.572	7.780	7.715	9.000
58	40672	-6.803	100.000	-6.439	-3.805	-0.613	7.330	6.434	8.000
64	180772	-6.104	-5.774	-6.138	-3.805	-0.550	7.400	300.000	9.000
65	180772	-6.326	-5.702	-6.439	-3.887	-0.759	7.200	300.000	9.000
66	200772	-7.326	-7.117	-6.138	-3.603	-0.553	7.700	300.000	9.000
68	230772	100.000	-6.815	-6.138	-3.921	-1.011	6.600	300.000	9.000
70	210872	-5.958	-5.625	-5.418	-3.646	-0.673	7.000	300.000	9.000
71	290672	-6.326	-4.354	-3.985	-3.562	0.087	6.600	4.591	7.800
72	290672	-5.880	-5.144	-3.928	-3.640	0.334	6.400	3.191	7.900

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED
300 = NO MEASURMENT PERFORMED

IONIC MOLARITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
1	210872	-3.233	-3.173	-2.670	-3.657	-4.321	-5.116	-4.647	200.000
6	30672	-3.420	-3.905	-3.007	-4.054	-4.283	-5.337	-4.809	200.000
7	30672	-3.331	-3.892	-2.929	-4.059	-4.216	-5.314	-4.772	200.000
12	30672	-3.437	-3.681	-2.948	-4.057	-4.321	-5.337	-4.772	200.000
14	40672	-3.679	-4.249	-3.295	-4.046	-4.870	-4.606	-5.073	200.000
30	210872	-3.554	-3.854	-3.207	-3.877	-4.248	-5.337	-4.851	-5.367
41	200772	-3.206	-3.467	-2.914	-3.450	-4.132	-4.980	-5.006	200.000
51	290672	-3.215	-3.404	-2.909	-3.429	-4.158	-5.116	-5.188	200.000
52	290672	-3.428	-3.538	-3.168	-3.429	-4.020	-5.250	-4.887	200.000
53	30672	-3.196	-2.995	-2.373	-3.665	-3.330	-4.748	-4.596	200.000
54	30672	-3.499	-3.135	-2.524	-3.575	-4.084	-5.074	-4.851	200.000
55	30672	-3.043	-3.299	-2.515	-3.864	-4.132	-5.250	-4.809	200.000
58	40672	-3.274	-3.230	-2.629	-3.427	-3.719	-4.877	-4.851	200.000
64	180772	-2.981	-3.250	-2.545	-3.616	-3.948	-5.013	-4.948	-4.512
65	180772	-3.113	-3.716	-2.805	-3.612	-4.107	-5.195	-5.006	200.000
66	200772	-3.201	-3.051	-2.563	-3.581	-3.709	-4.469	-4.948	-5.274
68	230772	-3.414	-3.851	-3.038	-4.107	-4.186	-5.101	-4.737	200.000
70	210872	-3.209	-3.446	-2.793	-3.347	-3.916	-4.886	-4.948	-4.278
71	290672	-2.403	-2.702	-2.313	-2.333	-3.597	-4.183	-4.152	-4.425
72	290672	-2.212	-2.625	-2.220	-2.047	-3.308	-3.870	-4.601	-3.028

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
1	210872	-7.873	-7.132	200.000	-3.992	-6.846	-4.722	-7.436	200.000
6	30672	-6.957	-7.123	200.000	-3.963	-7.280	-5.756	-7.750	200.000
7	30672	-6.287	-6.290	200.000	-3.861	-7.145	-5.672	-7.697	200.000
12	30672	-7.201	200.000	200.000	-4.018	-7.249	-5.478	-7.796	200.000
14	40672	-6.609	-6.647	-5.631	-4.268	-7.943	-6.373	-8.326	-7.036
30	210872	-7.055	-6.413	-6.788	-3.886	-7.729	-5.901	-7.546	-8.117
41	200772	-7.341	-6.144	-6.835	-3.921	-7.119	-5.252	-7.037	-7.902
51	290672	200.000	-6.369	200.000	-3.887	-7.121	-5.185	-7.044	200.000
52	290672	200.000	-6.238	200.000	-3.851	-7.459	-5.554	-6.877	200.000
53	30672	-8.042	200.000	-6.873	-3.743	-6.508	-4.267	-6.473	-7.430
54	30672	-7.593	-7.135	200.000	-4.066	-6.648	-4.546	-7.124	200.000
55	30672	-8.205	-7.131	-6.540	-3.944	-6.481	-4.700	-7.459	-7.225
58	40672	-7.682	200.000	-6.558	-3.805	-6.807	-4.740	-6.603	-7.352
64	180772	-7.116	-5.791	-6.247	-3.805	-6.455	-4.687	-7.033	-6.968
65	180772	-6.978	-5.719	-6.525	-3.887	-6.823	-5.390	-7.162	-7.482
66	200772	-8.601	-7.137	-6.248	-3.603	-6.691	-4.503	-6.758	-6.985
68	230772	200.000	-6.821	-6.182	-3.921	-7.332	-5.734	-7.709	-7.347
70	210872	-6.469	-5.654	-5.533	-3.646	-6.915	-5.116	-6.714	-6.486
71	290672	-6.809	-4.530	-4.350	-3.562	-5.740	-4.006	-5.521	-4.951
72	290672	-6.298	-5.415	-4.389	-3.640	-5.507	-3.877	-5.004	-4.947

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
1	210872	200.000	-8.155	-9.056	200.000	-9.254	-9.474	-5.946	-7.299
6	30672	200.000	-8.768	-9.987	200.000	-9.075	-10.200	-6.935	-7.579
7	30672	200.000	-8.738	-9.819	200.000	-8.326	-9.289	-6.831	-7.437
12	30672	200.000	-8.771	-9.771	200.000	-9.111	200.000	-6.680	-7.560
14	40672	-10.125	-7.928	-10.923	200.000	-8.513	-9.510	-7.292	-8.446
30	210872	-10.637	-8.512	-9.540	-6.926	-8.315	-8.632	-6.525	-7.742
41	200772	-10.507	-7.762	-8.947	200.000	-8.424	-8.186	-6.032	-7.349
51	290672	200.000	-7.882	-8.694	200.000	200.000	-8.148	-6.752	-7.372
52	290672	200.000	-8.066	-9.676	200.000	200.000	-9.105	-6.879	-7.474
53	30672	-10.340	-7.836	-7.205	200.000	-8.920	200.000	-5.075	-6.023
54	30672	200.000	-8.058	-8.443	200.000	-8.801	-9.304	-5.566	-6.921
55	30672	-10.017	-8.521	-8.161	200.000	-9.092	-8.978	-5.237	-6.960
58	40672	-10.522	-7.714	-8.322	200.000	-9.056	200.000	-5.813	-6.658
64	180772	-10.108	-8.043	-8.390	-6.084	-8.388	-8.023	-5.647	-6.808
65	180772	-10.568	-8.194	-8.997	200.000	-8.432	-8.132	-6.107	-7.215
66	200772	-9.807	-7.462	-7.868	-6.544	-9.572	-9.067	-5.364	-6.587
68	230772	-10.807	-8.568	-9.895	200.000	200.000	-9.816	-6.940	-7.513
70	210872	-9.782	-7.628	-8.997	-6.238	-8.129	-8.273	-6.295	-7.016
71	290672	-9.141	-6.066	-8.685	-6.925	-9.009	-7.691	-6.231	-6.288
72	290672	-9.412	-5.526	-8.530	-5.760	-8.731	-8.807	-6.337	-5.934

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
1	210872	-6.464	200.000	-8.739	-9.449	200.000	-4.862	-4.802	200.000
6	30672	-8.155	200.000	-9.063	-8.871	200.000	-5.384	-5.901	200.000
7	30672	-8.039	200.000	-8.240	-8.209	200.000	-5.304	-5.882	200.000
12	30672	-7.679	200.000	200.000	-9.124	200.000	-5.410	-5.683	200.000
14	40672	-8.791	200.000	-8.513	-8.440	-6.932	-5.566	-6.097	-13.746
30	210872	-7.650	-7.189	-8.138	-8.746	-7.945	-5.299	-5.567	-14.151
41	200772	-6.808	200.000	-7.508	-8.671	-7.632	-4.591	-4.818	-13.745
51	290672	-6.469	200.000	-7.718	200.000	200.000	-4.584	-4.741	200.000
52	290672	-7.748	200.000	-7.580	200.000	200.000	-4.793	-4.931	200.000
53	30672	-5.449	200.000	200.000	-9.680	-7.957	-4.886	-4.698	-12.865
54	30672	-6.064	200.000	-8.695	-9.114	200.000	-4.771	-4.721	200.000
55	30672	-5.897	200.000	-8.966	-10.011	-7.793	-4.900	-5.171	-12.676
58	40672	-6.402	200.000	200.000	-9.045	-7.365	-4.688	-4.667	-13.264
64	180772	-6.266	-6.193	-7.391	-8.687	-7.264	-4.603	-4.887	-12,800
65	180772	-7.163	200.000	-7.264	-8.495	-7.488	-4.680	-5.299	-13.508
66	200772	-5.782	-6.916	-8.698	-10.134	-7.226	-4.784	-4.648	-12.517
68	230772	-8.100	200.000	-8.808	200.000	-7.588	-5.424	-5.879	-13.966
70	210872	-7.090	-5.656	-6.950	-7.737	-6.247	-4.528	-4.780	-12.714
71	290672	-6.435	-5.058	-5.084	-7.336	-4.321	-2.980	-3.291	-11.630
72	290672	-6.520	-3.483	-5.791	-6.647	-4.182	-2.611	-3.026	-11.839

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SAMP.	DATE	IONIC MOLARITY* FE(OH)2	CACO3	CUCO3
1	210872	200.000	-6.276	-7.191
6	30672	200.000	-7.423	-7.218
7	30672	200.000	-7.229	-6.451
12	30672	200.000	-7.188	-7.212
14	40672	200.000	-7.963	-7.206
30	210872	-9.450	-7.093	-6.901
41	200772	200.000	-6.292	-6.734
51	290672	200.000	-6.026	200.000
52	290672	200.000	-7.391	200.000
53	30672	200.000	-5.405	-6.517
54	30672	200.000	-5.882	-6.542
55	30672	200.000	-5.395	-6.823
58	40672	200.000	-6.201	-6.870
64	180772	-8.594	-5.751	-6.152
65	180772	200.000	-6.312	-6.444
66	200772	-8.754	-5.686	-7.353
68	230772	200.000	-7.414	200.000
70	210872	-9.144	-6.606	-6.133
71	290672	-10.316	-5.903	-6.570
72	290672	-9.362	-5.882	-6.230

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
1	210872	-3.347	-3.282	-2.699	-3.775	-4.350	-5.146	-4.677	200.000
6	30672	-3,497	-3.979	-3.026	-4.132	-4.302	-5.357	-4.829	200.000
7	30672	-3.413	-3.972	-2.950	-4.143	-4.237	-5.335	-4.793	200.000
12	30672	-3.518	-3.759	-2.969	-4.139	-4.341	-5.358	-4.793	200.000
14	40672	-3.739	-4.308	-3.310	-4.107	-4.886	-4.621	-5.088	200.000
30	210872	-3.626	-3.924	-3.226	-3.950	-4.266	-5.356	-4.869	-5.439
41	200772	-3.310	-3.568	-2.941	-3.558	-4.159	-5.008	-5.033	200.000
51	290672	-3.321	-3.506	-2.936	-3.538	-4.186	-5.144	-5.216	200.000
52	290672	-3.519	-3.626	-3.181	-3.521	-4.043	-5.274	-4.911	200.000
53	30672	-3.332	-3.125	-2.408	-3.806	-3.365	-4.784	-4.632	200.000
54	30672	-3.321	-3.282	-2.556	-3.702	-4.116	-5.107	-4.883	200.000
55	30672	-3.163	-3.415	-2.546	-3.989	-4.163	-5.282	-4.841	200.000
58	40672	-3.390	-3.341	-2.659	-3.547	-3.749	-4.908	-4.881	200.000
64	180772	-3.108	-3.372	-2.578	-3.748	-3.981	-5.047	-4.982	-4.639
65	180772	-3.215	-3.815	-2.832	-3.717	-4.133	-5.222	-5.033	200.000
66	200772	-3.326	-3.171	-2.595	-3.711	-3.742	-4.502	-4.981	-5.399
68	230772	-3.491	-3.926	-3.058	-4.185	-4.205	-5.121	-4.757	200.000
70	210872	-3.319	-3.553	-2.822	-3.461	-3.944	-4.915	-4.977	-4.389
71	290672	-2.640	-2.922	-2.377	-2.588	-3.661	-4.251	-4.219	-4.662
72	290672	-2.499	-2.887	-2.298	-2.360	-3.386	-3.954	-4.685	-3.315

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
1	210872	-7.986	-7.246	200.000	-3.992	-6.875	-4.751	-7.466	200.000
6	30672	-7.034	-7.199	200.000	-3.963	-7.299	-5.776	-7.770	200.000
7	30672	-6.369	-6.372	200.000	-3.861	-7.166	-5.693	-7.718	200.000
12	30672	-7.282	200.000	200.000	-4.018	-7.269	-5.498	-7.816	200.000
14	40672	-6.669	-6.707	-5.691	-4.268	-7.958	-6.388	-8.341	-7.051
30	210872	-7.127	-6.484	-6.860	-3.886	-7.747	-5.920	-7.564	-8.135
41	200772	-7.446	-6.248	-6.939	-3.921	-7.146	-5.278	-7.064	-7.929
51	290672	200.000	-6.475	200.000	-3.887	-7.148	-5.213	-7.071	200.000
52	290672	200.000	-6.328	200.000	-3.851	-7.483	-5.577	-6.900	200.000
53	30672	-8.177	200.000	-7.009	-3.743	-6.543	-4.303	-6.509	-7.466
54	30672	-7.715	-7.258	200.000	-4.066	-6.679	-4.578	-7.156	200.000
55	30672	-8.326	-7.251	-6.661	-3.944	-6.512	-4.731	-7.490	-7.256
58	40672	-7.797	200.000	-6.674	-3.805	-6.837	-4.770	-6.633	-7.382
64	180772	-7.243	-5.918	-6.374	-3.805	-6.488	-4.720	-7.066	-7.001
65	180772	-7.081	-5.821	-6.627	-3.887	-6.849	-5.417	-7.189	-7.509
66	200772	-8.726	-7.262	-6.373	-3.603	-6.724	-4.536	-6.790	-7.017
68	230772	200.000	-6.898	-6.259	-3.921	-7.351	-5.754	-7.729	-7.367
70	210872	-6.580	-5.764	-5.644	-3.646	-6.943	-5.144	-6.743	-6.514
71	290672	-7.046	-4.767	-4.588	-3.562	-5.803	-4.069	-5.585	-5.015
72	290672	-6.586	-5.702	-4.676	-3.640	-5.586	-3.955	-5.082	-5.025

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
1	210872	200.000	-8.185	-9.085	200.000	-9.283	-9.503	-5.975	-7.299
6	30672	200.000	-8.788	-10.036	200.000	-9.094	-10.220	-6.954	-7.579
7	30672	200.000	-8.759	-9.840	200.000	-8.347	-9.310	-6.852	-7.437
12	30672	200.000	-8.792	-9.792	200.000	-9.131	200.000	-6.700	-7.560
14	40672	-10.140	-7.943	-10.938	200.000	-8.528	-9.526	-7.307	-8.446
30	210872	-10.655	-8.530	-9.558	-6.945	-8.333	-8.650	-6.544	-7.742
41	200772	-10.534	-7.789	-8.974	200.000	-8.451	-8.213	-6.058	-7.349
51	290672	200.000	-7.909	-8.721	200.000	200.000	-8.176	-5.779	-7.372
52	290672	200.000	-8.090	-9.699	200.000	200.000	-9.128	-6.903	-7.474
53	30672	-10.375	-7.871	-7.240	200.000	-8.958	200.000	-5.110	-6.023
54	30672	200.000	-8.090	-8.474	200.000	-8.833	-9.335	-5.597	-6.921
55	30672	-10.048	-8.552	-8.192	200.000	-9.123	-9.009	-5.268	-6.960
58	40672	-10.552	-7.744	-8.352	200.000	-9.086	200.000	-5.843	-6.658
64	180772	-10.141	-8.076	-8.423	-6.117	-8.421	-8.056	-5.679	-6.808
65	180772	-10.595	-8.220	-9.023	200.000	-8.458	-8.159	-6.133	-7.215
66	200772	-9.840	-7.494	-7.901	-6.577	-9.604	-9.100	-5.397	-6.587
68	230772	-10.826	-8.588	-9.914	200.000	200.000	-9.835	-6.959	-7.513
70	210872	-9.810	-7.657	-9.026	-6.266	-8.157	-8.302	-6.323	-7.016
71	290672	-9.205	-6.130	-8.749	-6.989	-9.073	-7.755	-6.294	-6.288
72	290672	-9.490	-5.605	-8.608	-5.838	-8.809	-8.886	-6.414	-5.934

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
1	210872	-6.464	200.000	-8.739	-9.449	200.000	-4.862	-4.802	200.000
6	30672	-8.155	200.000	-9.063	-8.871	200.000	-5.384	-5.901	200.000
7	30672	-8.039	200.000	-8.240	-8.209	200.000	-5.304	-5.882	200.000
12	30672	-7.679	200.000	200.000	-9.124	200.000	-5.410	-5.683	200.000
14	40672	-8.791	200.000	-8.513	-8.440	-6.932	-5.566	-6.097	-13.746
30	210872	-7.650	-7.189	-8.138	-8.746	-7.945	-5.299	-5.567	-14.151
41	200772	-6.808	200.000	-7.508	-8.671	-7.632	-4.591	-4.818	-13.745
51	290672	-6.469	200.000	-7.718	200.000	200.000	-4.584	-4.741	200.000
52	290672	-7.748	200.000	-7.580	200.000	200.000	-4.793	-4.931	200.000
53	30672	-5.449	200.000	200.000	-9.680	-7.957	-4.886	-4.698	-12.865
54	30672	-6.064	200.000	-8.685	-9.114	200.000	-4.771	-4.721	200.000
55	30672	-5.897	200.000	-8.966	-10.011	-7.793	-4.900	-5.171	-12.676
58	40672	-6.402	200.000	200.000	-9.045	-7.365	-4.688	-4.667	-13.264
64	180772	-6.266	-6.193	-7.391	-8.687	-7.264	-4.603	-4.887	-12.800
65	180772	-7.163	200.000	-7.264	-8.495	-7.488	-4.680	-5.299	-13.508
66	200772	-5.782	-6.916	-8.698	-10.134	-7.226	-4.784	-4.648	-12.517
68	230772	-8.100	200.000	-8.808	200.000	-7.588	-5.424	-5.879	-13.966
70	210872	-7.090	-5.656	-6.950	-7.737	-6.247	-4.528	-4.780	-12.714
71	290672	-6.435	-5.058	-5.084	-7.336	-4.321	-2.980	-3.291	-11.630
72	290672	-6.520	-3.483	-5.791	-6.647	-4.182	-2.611	-3.026	-11.839

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
1	210872	200.000	-6.276	-7.191
6	30672	200.000	-7.423	-7.218
7	30672	200.000	-7.229	-6.451
12	30672	200.000	-7.188	-7.212
14	40672	200.000	-7.963	-7.206
30	210872	-9.450	-7.093	-6.901
41	200772	200.000	-6.292	-6.734
51	290672	200.000	-6.026	200.000
52	290672	200.000	-7.391	200.000
53	30672	200.000	-5.405	-6.517
54	30672	200.000	-5.882	-6.542
55	30672	200.000	-5.395	-6.823
58	40672	200.000	-6.201	-6.870
64	180772	-8.594	-5.751	-6.152
65	180772	200.000	-6.312	-6.444
66	200772	-8.754	-5.686	-7.353
68	230772	200.000	-7.414	200.000
70	210872	-9.144	-6.606	-6.133
71	290672	-10.316	-5.903	-6.570
72	290672	-9.362	-5.882	-6.230

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
1	210872	-9.322	200.000	-9.257	-18.580	-13.221	200.000	-7.122	-7.588
6	30672	-10.451	200.000	-10.934	-21.385	-14.153	200.000	-7.629	-7.821
7	30672	-10.265	200.000	-10.824	-21.089	-13.224	200.000	-7.556	-6.390
12	30672	-10.218	200.000	-10.460	-20.678	200.000	200.000	-7.657	-7.683
14	40672	-11.046	200.000	-11.615	-22.661	-14.014	-12.998	-7.846	-7.826
30	210872	-10.169	-11.983	-10.468	-20.637	-13.028	-13.403	-7.576	-6.598
41	200772	-9.369	200.000	-9.626	-18.995	-12.306	-12.998	-6.868	-6.349
51	290672	-9.100	200.000	-9.285	-18.385	-12.254	200.000	-6.859	200.000
52	290672	-10.421	200.000	-10.528	-20.950	-13.231	200.000	-7.040	200.000
53	30672	-8.442	200.000	-8.234	-16.676	200.000	-12.119	-7.138	-5.865
54	30672	-8.918	200.000	-8.850	-17.768	-12.855	200.000	-7.023	-6.108
55	30672	-8.431	200.000	-8.683	-17.114	-12.519	-11.929	-7.453	-6.359
58	40672	-9.233	200.000	-9.185	-18.417	200.000	-12.517	-6.937	-6.778
64	180772	-8.787	-10.319	-9.051	-17.839	-11.598	-12.054	-6.855	-5.366
65	180772	-9.348	200.000	-9.948	-19.297	-11.954	-12.761	-6.932	-5.894
66	200772	-8.723	-10.796	-8.567	-17.290	-12.659	-11.770	-7.036	-7.450
68	230772	-10.450	200.000	-10.886	-21.336	-13.857	-13.218	-7.676	200.000
70	210872	-9.642	-10.712	-9.876	-19.518	-12.087	-11.967	-6.780	-5.483
71	290672	-8.934	-10.956	-9.217	-18.151	-11.062	-10.882	-5.228	-7.186
72	290672	-8.914	-9.729	-9.301	-18.215	-12.117	-11.091	-4.860	-6.786

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
1	210872	-21.509	11.118	200.000	200.000	200.000	8.578	200.000	-5.929
6	30672	-21.809	9.221	200.000	200.000	200.000	8.016	200.000	-6.683
7	30672	-19.611	9.228	200.000	200.000	200.000	7.914	200.000	-6.456
12	30672	-21.665	9.821	200.000	200.000	200.000	200.000	200.000	-6.604
14	40672	-21.802	8.512	200.000	200.000	200.000	7.762	200.000	-6.747
30	210872	-20.269	10.276	15.861	15.861	9.067	8.404	8.379	-6.029
41	200772	-19.853	11.032	200.000	200.000	200.000	8.526	200.000	-5.550
51	290672	200.000	11.654	200.000	200.000	200.000	8.832	200.000	-5.337
52	290672	200.000	9.974	200.000	200.000	200.000	8.031	200.000	-6.177
53	30672	-19.152	12.475	200.000	200.000	200.000	200.000	200.000	-4.470
54	30672	-19.420	11.668	200.000	200.000	200.000	8.830	200.000	-5.779
55	30672	-19.952	12.145	200.000	200.000	200.000	9.185	200.000	-5.389
58	40672	-20.419	11.319	200.000	200.000	200.000	200.000	200.000	-5.187
64	180772	-18.288	11.428	17.561	17.561	9.324	8.608	8.611	-5.256
65	180772	-19.108	10.585	200.000	200.000	200.000	8.392	200.000	-5.795
66	200772	-21.573	12.229	17.701	17.701	9.716	9.072	9.047	-4.007
68	230772	200.000	9.274	200.000	200.000	200.000	7.985	200.000	-6.363
70	210872	-18.386	10.447	16.611	16.611	8.808	8.153	8.118	-5.208
71	290672	-20.526	10.278	15.138	15.138	8.246	7.519	7.655	-4.774
72	290672	-19.786	9.913	15.885	15.885	7.888	7.408	7.314	-4.833

*LOG TO THE BASE 10

200. = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
1	210872	11.053	-5.134	51.598	2.054	-13.118	-20.882	-20.817	-0.778
6	30672	9.703	-5.628	42.140	1.243	-13.554	-22.001	-22.484	-1.705
7	30672	9.787	-5.358	42.279	1.265	-13.079	-21.098	-21.657	-1.567
12	30672	10.062	-5.588	45.085	1.432	-13.624	-22.083	-22.325	-1.508
14	40672	9.081	-7.012	38.293	1.789	-15.548	-25.063	-25.632	-1.920
30	210872	10.574	-4.939	47.493	1.744	-12.712	-20.518	-20.816	-1.048
41	200772	11.290	-4.701	51.239	2.292	-12.544	-20.080	-20.338	-0.572
51	290672	11.839	-4.379	54.383	2.436	-12.152	-19.253	-19.438	-0.289
52	290672	10.081	-4.946	46.020	1.526	-12.648	-20.729	-20.836	-1.212
53	30672	12.268	-3.051	58.634	3.016	-10.536	-17.675	-17.468	0.437
54	30672	11.599	-4.788	54.272	2.353	-12.920	-20.929	-20.861	-0.550
55	30672	12.397	-4.271	56.782	2.498	-12.158	-19.152	-19.404	-0.197
58	40672	11.270	-4.028	52.788	2.422	-11.638	-19.166	-19.118	-0.282
64	180772	11.692	-4.190	53.335	2.353	-11.799	-18.745	-19.009	-0.297
65	180772	11.185	-4.707	49.038	1.978	-12.480	-19.907	-20.507	-0.831
66	200772	12.074	-3.247	57.544	3.198	-10.452	-16.747	-16.591	0.653
68	230772	9.709	-5.448	42.448	1.479	-13.290	-21.661	-22.096	-1.500
70	210872	10.681	-4.237	48.590	2.085	-11.530	-18.490	-18.724	-0.513
71	290672	10.560	-4.184	47.827	2.349	-11.307	-17.933	-18.215	-0.295
72	290672	10.301	-4.265	45.925	2.446	-11.544	-18.816	-19.204	-0.422

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
1	210872	-0.913	200.000	-1.372	-0.925	-2.514	200.000	-2.501	-1.189
6	30672	-2.051	200.000	-3.106	-2.355	-3.446	200.000	-3.002	-1.326
7	30672	-1.861	200.000	-2.968	-2.195	-2.521	200.000	-2.933	-0.610
12	30672	-1.818	200.000	-2.625	-1.999	200.000	200.000	-3.032	-1.257
14	40672	-2.615	200.000	-3.642	-2.914	-3.287	-2.611	-3.230	-1.328
30	210872	-1.742	-1.526	-2.509	-1.911	-2.305	-3.016	-2.960	-0.714
41	200772	-0.941	200.000	-1.668	-1.090	-1.583	-2.611	-2.251	-0.590
51	290672	-0.674	200.000	-1.332	-0.789	-1.535	200.000	-2.243	200.000
52	290672	-2.021	200.000	-2.694	-2.135	-2.524	200.000	-2.415	200.000
53	30672	-0.038	200.000	-0.378	0.012	200.000	-1.720	-2.515	-0.347
54	30672	-0.515	200.000	-0.993	-0.534	-2.152	200.000	-2.400	-0.469
55	30672	-0.028	200.000	-0.826	-0.207	-1.816	-1.530	-2.529	-0.594
58	40672	-0.831	200.000	-1.343	-0.865	200.000	-2.115	-2.312	-0.804
64	180772	-0.383	0.071	-1.195	-0.569	-0.894	-1.655	-2.232	-0.098
65	180772	-0.945	200.000	-2.092	-1.298	-1.251	-2.362	-2.309	-0.362
66	200772	-0.319	-0.407	-0.711	-0.295	-1.956	-1.371	-2.413	-1.140
68	230772	-2.046	200.000	-3.029	-2.318	-3.154	-2.820	-3.053	200.000
70	210872	-1.239	-0.323	-2.019	-1.409	-1.384	-1.568	-2.157	-0.156
71	290672	-0.533	-0.572	-1.377	-0.733	-0.355	-0.476	-0.603	-1.008
72	290672	-0.512	0.654	-1.461	-0.765	-1.413	-0.684	-0.235	-0.808

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
1	210872	-2.310	-3.303	200.000	200.000	200.000	200.000	200.000	-3.144
6	30672	-2.460	-4.399	200.000	200.000	200.000	-10.663	200.000	-3.815
7	30672	-1.361	-4.321	200.000	200.000	200.000	-9.781	200.000	-3.630
12	30672	-2.387	-4.080	200.000	200.000	200.000	200.000	200.000	-3.747
14	40672	-2.456	-4.397	200.000	200.000	200.000	-9.460	200.000	-4.080
30	210872	-1.689	-3.549	200.000	200.000	200.000	200.000	200.000	-3.343
41	200772	-1.482	-3.171	200.000	200.000	200.000	200.000	200.000	-2.864
51	290672	200.000	-2.874	200.000	200.000	200.000	-10.814	200.000	-2.643
52	290672	200.000	-4.003	200.000	200.000	200.000	-11.033	200.000	-3.319
53	30672	-1.131	-2.698	200.000	200.000	200.000	200.000	200.000	-1.643
54	30672	-1.265	-3.101	200.000	200.000	200.000	-8.839	200.000	-2.952
55	30672	-1.531	-2.863	200.000	200.000	200.000	-10.837	200.000	-2.563
58	40672	-1.764	-3.313	200.000	200.000	200.000	200.000	200.000	-2.340
64	180772	-0.699	-3.221	200.000	200.000	200.000	200.000	200.000	-2.429
65	180772	-1.109	-3.643	200.000	200.000	200.000	200.000	200.000	-2.968
66	200772	-2.341	-2.820	200.000	200.000	200.000	200.000	200.000	-1.181
68	230772	200.000	-4.298	200.000	200.000	200.000	200.000	200.000	-3.537
70	210872	-0.748	-3.711	200.000	200.000	200.000	200.000	200.000	-2.381
71	290672	-1.818	-3.840	-0.172	-1.790	-6.437	-6.018	-5.564	-1.922
72	290672	-1.448	-4.019	0.043	-1.575	-4.682	-4.508	-3.825	-1.984

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
1	210872	-3.584	-5.208	-1.811	-3.788	-5.242	-2.193	-1.981	-2.207
6	30672	-4.434	-5.686	-2.885	-4.672	-5.600	-2.718	-2.805	-3.071
7	30672	-4.304	-5.424	-2.807	-4.614	-5.164	-2.284	-2.397	-2.934
12	30672	-4.233	-5.648	-2.575	-4.474	-5.680	-2.764	-2.727	-2.889
14	40672	-4.315	-7.107	-2.958	-3.949	-7.781	-4.328	-4.401	-3.213
30	210872	-3.610	-5.032	-2.067	-4.011	-4.927	-2.048	-1.992	-2.429
41	200772	-3.252	-4.794	-1.693	-3.463	-4.759	-1.830	-1.753	-1.993
51	290672	-2.995	-4.470	-1.390	-3.326	-4.360	-1.413	-1.302	-1.737
52	290672	-4.223	-5.006	-2.481	-4.380	-4.704	-2.087	-1.982	-2.621
53	30672	-3.064	-3.117	-1.171	-2.863	-2.622	-0.573	-0.302	-1.113
54	30672	-3.398	-4.854	-1.607	-3.525	-5.005	-2.200	-1.998	-2.010
55	30672	-2.999	-4.337	-1.356	-3.381	-4.243	-1.312	-1.270	-1.690
58	40672	-3.606	-4.090	-1.788	-3.474	-3.703	-1.310	-1.125	-1.772
64	180772	-3.351	-4.256	-1.701	-3.525	-3.884	-1.108	-1.073	-1.780
65	180772	-3.605	-4.773	-2.131	-3.900	-4.565	-1.689	-1.822	-2.265
66	200772	-3.160	-3.313	-1.290	-2.681	-2.537	-0.109	0.136	-0.917
68	230772	-4.343	-5.514	-2.790	-4.400	-5.376	-2.566	-2.616	-2.873
70	210872	-3.857	-4.303	-2.175	-3.793	-3.615	-0.981	-0.930	-1.976
71	290672	-3.970	-4.245	-2.291	-3.551	-3.369	-0.691	-0.673	-1.785
72	290672	-4.096	-4.327	-2.477	-3.453	-3.608	-1.134	-1.167	-1.899

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

EQUILIBRIUM PE

SAMP	DATE	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	PPCO2	ERROR	I.STR.
1	210872	200.000	200.000	200.000	-2.563	200.000	-2.168	-0.333	0.00407
6	30672	200.000	200.000	200.000	-1.903	200.000	-1.918	-4.846	0.00172
7	30672	200.000	200.000	200.000	-1.851	200.000	-1.831	-4.165	0.00200
12	30672	200.000	200.000	200.000	200.000	200.000	-2.048	-4.606	0.00192
14	40672	200.000	200.000	200.000	-1.888	200.000	-1.952	-9.447	0.00099
30	210872	2.702	-2.078	-2.877	-2.508	-1.909	-2.564	0.580	0.00146
41	200772	200.000	200.000	200.000	-2.629	200.000	-2.479	1.967	0.00330
51	290672	200.000	200.000	200.000	-2.926	200.000	-2.757	2.559	0.00342
52	290672	200.000	200.000	200.000	-1.931	200.000	-2.270	-0.795	0.00248
53	30672	200.000	200.000	200.000	200.000	200.000	-2.489	-10.230	0.00615
54	30672	200.000	200.000	200.000	-2.767	200.000	-2.296	-10.828	0.00483
55	30672	200.000	200.000	200.000	-3.122	200.000	-2.607	-6.967	0.00469
58	40672	200.000	200.000	200.000	200.000	200.000	-2.275	-11.657	0.00429
64	180772	1.555	-3.289	-2.956	-2.545	-1.961	-2.259	1.097	0.00527
65	180772	200.000	200.000	200.000	-2.329	200.000	-2.312	-1.085	0.00326
66	200772	1.415	-3.429	-3.348	-3.009	-2.396	-2.576	0.473	0.00509
68	230772	200.000	200.000	200.000	-1.922	200.000	-1.939	1.738	0.00171
70	210872	2.505	-2.340	-2.440	-2.090	-1.468	-2.102	-6.548	0.00385
71	290672	4.076	-0.780	-1.846	-1.426	-0.973	-1.265	-6.253	0.02407
72	290672	3.321	-1.534	-1.491	-1.317	-0.634	-0.985	-9.701	0.04036

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

APPENDIX VIb SATURATION INDEX PROGRAM OUTPUT FOR THE PERIODICAL DATA FROM SAMPLE SITE 51

TOTAL MOLARITY*

SAMP	DATE	CA	MG	ALK	S	NA	K	CL	FE
51A	290672	-3.197	-3.377	-2.905	-3.381	-4.157	-5.177	-5.198	100.000
51B	130772	-3.178	-3.365	-2.856	-3.339	-4.131	-5.231	-5.152	100.000
51C	240772	-3.190	-3.377	-2.866	-3.359	-4.157	-5.231	-5.018	100.000
51D	60872	-3.170	-3.357	-2.866	-3.392	-4.157	-5.270	-4.937	100.000
51E	200872	-3.164	-3.325	-2.856	-3.320	-4.157	-5.337	-5.018	100.000
51F	290872	-3.129	-3.307	-2.831	-3.320	-4.114	-5.291	-4.744	100.000
51G	70972	-3.098	-3.259	-2.799	-3.258	-4.083	-5.314	-4.851	100.000
51H	160972	-3.089	-3.243	-2.851	-3.258	-4.074	-5.250	-4.786	100.000
51I	250972	-3.077	-3.234	-2.846	-3.176	-4.052	-5.101	-4.887	100.000
51J	101072	-3.115	-3.249	-2.936	-3.170	-4.056	-4.829	-4.572	100.000
51K	271072	-3.207	-3.357	-3.061	-3.267	-4.180	-4.876	-4.157	100.000
51L	131172	-3.271	-3.432	-3.113	-3.349	-4.251	-5.270	-4.294	100.000
51M	271172	-3.293	-3.467	-3.134	-3.329	-4.265	-5.313	-4.500	100.000
51N	180173	-3.193	-3.357	-3.217	-3.163	-4.206	-5.638	-4.730	100.000
51O	160373	-3.476	-3.645	-3.405	-3.535	-4.379	-5.478	-4.497	100.000
51P	40473	-3.413	-3.587	-3.287	-3.403	-4.340	-5.638	-4.750	100.000
51Q	230473	-3.362	-3.517	-3.170	-3.403	-4.231	-5.601	-3.987	100.000
51R	70573	-3.324	-3.488	-3.158	-3.320	-4.241	-5.513	-4.834	100.000
51S	240573	-3.362	-3.557	-3.172	-3.381	-4.265	-5.446	-4.896	100.000
51T	70673	-3.343	-3.547	-3.045	-3.491	-4.241	-5.495	-4.959	100.000
51U	250673	-3.279	-3.486	-2.947	-3.535	-4.212	-5.597	-5.118	100.000
51V	20873	-3.186	-3.373	-2.851	-3.381	-4.131	-5.513	-4.993	100.000

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED

TOTAL MOLARITY*

SAMP	DATE	CU	ZN	MN	H4SIO4	TDS	PH	PE	TEMP C
51A	290672	100.000	-6.037	100.000	-3.887	-0.778	7.860	7.898	15.600
51B	130772	100.000	-6.037	100.000	-3.877	-0.741	7.700	7.861	17.200
51C	240772	100.000	-6.037	100.000	-3.867	-0.752	7.500	6.617	16.200
51D	60872	100.000	-5.611	100.000	-3.848	-0.754	7.500	300.000	14.600
51E	200872	100.000	-5.970	100.000	-3.867	-0.731	7.650	300.000	14.000
51F	290872	100.000	-5.912	100.000	-3.845	-0.710	7.650	300.000	16.300
51G	70972	100.000	-5.912	100.000	-3.857	-0.674	7.600	300.000	14.400
51H	160972	100.000	-5.611	100.000	-3.839	-0.693	7.300	300.000	13.000
51I	250972	100.000	-5.815	100.000	-3.848	-0.666	7.650	300.000	13.100
51J	131072	100.000	-5.203	100.000	-3.836	-0.695	7.250	300.000	6.800
51K	271072	100.000	-5.861	100.000	-3.944	-0.805	7.450	300.000	8.200
51L	131172	100.000	-5.970	100.000	-4.013	-0.874	7.200	300.000	6.600
51M	271172	100.000	-6.037	100.000	-4.090	-0.908	7.100	300.000	3.600
51N	180173	100.000	-5.861	100.000	-4.084	-0.824	7.060	300.000	1.800
51O	160373	100.000	-6.116	100.000	-4.131	-1.094	6.900	300.000	3.500
51P	40473	100.000	-6.037	100.000	-4.089	-0.994	7.060	300.000	5.050
51Q	230473	100.000	-6.116	100.000	-4.015	-0.925	7.120	300.000	10.400
51R	70573	100.000	-5.912	100.000	-4.004	-0.895	7.240	300.000	11.100
51S	240573	100.000	-6.236	100.000	-4.042	-0.920	7.450	300.000	10.400
51T	70673	100.000	-6.108	100.000	-4.023	-0.912	7.380	300.000	13.000
51U	250673	100.000	-6.003	100.000	-3.938	-0.856	7.300	300.000	14.800
51V	20873	100.000	-6.030	100.000	-3.873	-0.749	7.230	300.000	17.700

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED
300 = NO MEASURMENT PERFORMED

IONIC MOLARITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
51A	290672	-3.216	-3.404	-2.911	-3.429	-4.158	-5.178	-5.188	200.000
51B	130772	-3.199	-3.395	-2.861	-3.390	-4.132	-5.231	-5.152	200.000
51C	240772	-3.209	-3.406	-2.871	-3.409	-4.158	-5.231	-5.018	200.000
51D	60872	-3.188	-3.383	-2.871	-3.442	-4.158	-5.271	-4.937	200.000
51E	200872	-3.185	-3.354	-2.861	-3.371	-4.158	-5.338	-5.018	200.000
51F	290872	-3.150	-3.337	-2.837	-3.375	-4.115	-5.292	-4.744	200.000
51G	70972	-3.121	-3.291	-2.804	-3.315	-4.084	-5.314	-4.851	200.000
51H	160972	-3.111	-3.273	-2.855	-3.316	-4.075	-5.251	-4.786	200.000
51I	250972	-3.103	-3.268	-2.852	-3.234	-4.053	-5.102	-4.887	200.000
51J	101072	-3.141	-3.280	-2.920	-3.221	-4.057	-4.830	-4.572	200.000
51K	271072	-3.230	-3.383	-3.065	-3.311	-4.181	-4.877	-4.157	200.000
51L	131172	-3.290	-3.454	-3.116	-3.388	-4.252	-5.271	-4.294	200.000
51M	271172	-3.314	-3.488	-3.197	-3.365	-4.266	-5.314	-4.500	200.000
51N	180173	-3.220	-3.383	-3.220	-3.204	-4.207	-5.639	-4.730	200.000
51O	160373	-3.490	-3.660	-3.407	-3.561	-4.380	-5.479	-4.497	200.000
51P	40473	-3.431	-3.606	-3.289	-3.432	-4.341	-5.639	-4.750	200.000
51Q	230473	-3.381	-3.539	-3.172	-3.437	-4.232	-5.602	-3.987	200.000
51R	70573	-3.346	-3.514	-3.161	-3.357	-4.242	-5.514	-4.834	200.000
51S	240573	-3.382	-3.580	-3.135	-3.414	-4.265	-5.447	-4.896	200.000
51T	70673	-3.359	-3.568	-3.048	-3.527	-4.242	-5.496	-4.959	200.000
51U	250673	-3.293	-3.506	-2.950	-3.577	-4.213	-5.597	-5.118	200.000
51V	20873	-3.205	-3.401	-2.854	-3.431	-4.132	-5.514	-4.993	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
51A	290672	200.000	-6.074	200.000	-3.887	-7.123	-5.187	-7.044	200.000
51B	130772	200.000	-6.074	200.000	-3.877	-7.081	-5.131	-6.983	200.000
51C	240772	200.000	-6.069	200.000	-3.867	-7.086	-5.150	-7.025	200.000
51D	60872	200.000	-5.640	200.000	-3.848	-7.043	-5.127	-7.057	200.000
51E	200872	200.000	-6.004	200.000	-3.867	-7.025	-5.092	-6.988	200.000
51F	290872	200.000	-5.948	200.000	-3.845	-6.999	-5.053	-6.954	200.000
51G	70972	200.000	-5.949	200.000	-3.857	-6.917	-4.978	-6.866	200.000
51H	160972	200.000	-5.644	200.000	-3.839	-6.939	-5.011	-6.856	200.000
51I	250972	200.000	-5.857	200.000	-3.848	-6.932	-5.005	-6.755	200.000
51J	101072	200.000	-5.240	200.000	-3.836	-6.951	-5.082	-6.734	200.000
51K	271072	200.000	-5.894	200.000	-3.944	-7.192	-5.320	-6.937	200.000
51L	131172	200.000	-5.997	200.000	-4.013	-7.275	-5.435	-7.075	200.000
51M	271172	200.000	-6.004	200.000	-4.030	-7.337	-5.548	-7.059	200.000
51N	180173	200.000	-5.898	200.000	-4.084	-7.254	-5.476	-6.849	200.000
51O	160373	200.000	-6.135	200.000	-4.131	-7.705	-5.914	-7.352	200.000
51P	40473	200.000	-6.062	200.000	-4.089	-7.557	-5.749	-7.194	200.000
51Q	230473	200.000	-6.142	200.000	-4.015	-7.466	-5.570	-7.104	200.000
51R	70573	200.000	-5.943	200.000	-4.004	-7.433	-5.537	-7.038	200.000
51S	240573	200.000	-6.264	200.000	-4.042	-7.430	-5.574	-7.113	200.000
51T	70673	200.000	-6.131	200.000	-4.023	-7.354	-5.475	-7.206	200.000
51U	250673	200.000	-6.024	200.000	-3.938	-7.218	-5.319	-7.235	200.000
51V	20873	200.000	-6.058	200.000	-3.873	-7.085	-5.130	-7.024	200.000

*LOG TO THE BASE 10
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
51A	290672	200.000	-7.944	-8.416	200.000	200.000	-7.573	-5.473	-7.374
51B	130772	200.000	-7.948	-8.484	200.000	200.000	-7.676	-5.566	-7.300
51C	240772	200.000	-7.973	-8.730	200.000	200.000	-7.907	-5.786	-7.334
51D	60872	200.000	-8.059	-8.748	200.000	200.000	-7.538	-5.804	-7.335
51E	200872	200.000	-8.063	-8.597	200.000	200.000	-7.777	-5.652	-7.327
51F	290872	200.000	-8.006	-8.504	200.000	200.000	-7.636	-5.601	-7.260
51G	70972	200.000	-7.989	-8.515	200.000	200.000	-7.761	-5.640	-7.199
51H	160972	200.000	-7.937	-8.873	200.000	200.000	-7.810	-6.007	-7.241
51I	250972	200.000	-7.709	-8.498	200.000	200.000	-7.671	-5.653	-7.217
51J	101072	200.000	-7.472	-9.049	200.000	200.000	-7.705	-6.201	-7.288
51K	271072	200.000	-7.586	-9.092	200.000	200.000	-8.093	-6.127	-7.550
51L	131172	200.000	-8.062	-9.482	200.000	200.000	-8.508	-6.450	-7.669
51M	271172	200.000	-8.106	-9.717	200.000	200.000	-8.803	-6.673	-7.762
51N	180173	200.000	-9.297	-9.755	200.000	200.000	-8.766	-6.763	-7.733
51O	160373	200.000	-8.450	-10.234	200.000	200.000	-9.066	-7.084	-8.077
51P	40473	200.000	-8.475	-9.899	200.000	200.000	-8.770	-6.784	-7.925
51Q	230473	200.000	-8.404	-9.545	200.000	200.000	-8.571	-6.536	-7.701
51R	70573	200.000	-8.233	-9.417	200.000	200.000	-8.227	-6.396	-7.702
51S	240573	200.000	-8.225	-9.211	200.000	200.000	-8.363	-6.169	-7.698
51T	70673	200.000	-8.366	-9.139	200.000	200.000	-8.198	-6.120	-7.597
51U	250673	200.000	-8.507	-9.073	200.000	200.000	-8.105	-6.081	-7.462
51V	20873	200.000	-8.267	-8.941	200.000	200.000	-8.112	-6.024	-7.292

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
S1A	290672	-6.191	200.000	-7.423	200.000	200.000	-4.585	-4.741	200.000
S1B	130772	-6.269	200.000	-7.385	200.000	200.000	-4.529	-4.682	200.000
S1C	240772	-6.504	200.000	-7.398	200.000	200.000	-4.559	-4.719	200.000
S1D	60872	-6.508	200.000	-7.008	200.000	200.000	-4.577	-4.747	200.000
S1E	200872	-6.333	200.000	-7.309	200.000	200.000	-4.510	-4.659	200.000
S1F	290872	-6.257	200.000	-7.255	200.000	200.000	-4.477	-4.627	200.000
S1G	70972	-6.265	200.000	-7.212	200.000	200.000	-4.404	-4.550	200.000
S1H	160972	-6.621	200.000	-6.911	200.000	200.000	-4.399	-4.547	200.000
S1I	250972	-6.265	200.000	-7.048	200.000	200.000	-4.316	-4.465	200.000
S1J	101072	-6.845	200.000	-6.430	200.000	200.000	-4.354	-4.525	200.000
S1K	271072	-6.856	200.000	-7.147	200.000	200.000	-4.506	-4.681	200.000
S1L	131172	-7.246	200.000	-7.317	200.000	200.000	-4.633	-4.832	200.000
S1M	271172	-7.508	200.000	-7.166	200.000	200.000	-4.639	-4.872	200.000
S1N	180173	-7.509	200.000	-7.066	200.000	200.000	-4.413	-4.648	200.000
S1O	160373	-8.071	200.000	-7.598	200.000	200.000	-4.978	-5.208	200.000
S1P	40473	-7.723	200.000	-7.406	200.000	200.000	-4.800	-5.022	200.000
S1Q	230473	-7.396	200.000	-7.487	200.000	200.000	-4.748	-4.912	200.000
S1R	70573	-7.233	200.000	-7.212	200.000	200.000	-4.637	-4.806	200.000
S1S	240573	-7.070	200.000	-7.584	200.000	200.000	-4.725	-4.929	200.000
S1T	70673	-6.998	200.000	-7.356	200.000	200.000	-4.805	-5.002	200.000
S1U	250671	-6.894	200.000	-7.509	200.000	200.000	-4.792	-4.981	200.000
S1V	20873	-6.729	200.000	-7.400	200.000	200.000	-4.572	-4.722	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
51A	230672	200.000	-5.748	200.000
51B	130772	200.000	-5.817	200.000
51C	240772	200.000	-6.053	200.000
51D	60872	200.000	-6.061	200.000
51E	200872	200.000	-5.912	200.000
51F	290872	200.000	-5.815	200.000
51G	70972	200.000	-5.843	200.000
51H	160972	200.000	-6.208	200.000
51I	250972	200.000	-5.849	200.000
51J	101072	200.000	-6.461	200.000
51K	271072	200.000	-6.457	200.000
51L	131172	200.000	-6.837	200.000
51M	271172	200.000	-7.089	200.000
51N	180173	200.000	-7.103	200.000
51O	160373	200.000	-7.656	200.000
51P	40473	200.000	-7.302	200.000
51Q	230473	200.000	-6.989	200.000
51R	70573	200.000	-6.816	200.000
51S	240573	200.000	-6.623	200.000
51T	70673	200.000	-6.536	200.000
51U	250673	200.000	-6.426	200.000
51V	20873	200.000	-6.275	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
51A	290672	-3.322	-3.506	-2.938	-3.538	-4.186	-5.206	-5.716	200.000
51B	130772	-3.308	-3.500	-2.890	-3.502	-4.160	-5.260	-5.181	200.000
51C	240772	-3.317	-3.509	-2.898	-3.519	-4.186	-5.260	-5.047	200.000
51D	60872	-3.296	-3.487	-2.898	-3.553	-4.186	-5.299	-4.965	200.000
51E	200872	-3.295	-3.461	-2.890	-3.485	-4.187	-5.367	-5.047	200.000
51F	290872	-3.263	-3.446	-2.866	-3.492	-4.144	-5.322	-4.773	200.000
51G	70972	-3.238	-3.404	-2.834	-3.437	-4.114	-5.346	-4.882	200.000
51H	160972	-3.228	-3.386	-2.886	-3.437	-4.105	-5.282	-4.817	200.000
51I	250972	-3.223	-3.384	-2.883	-3.359	-4.084	-5.134	-4.919	200.000
51J	101072	-3.257	-3.392	-2.950	-3.341	-4.088	-4.861	-4.603	200.000
51K	271072	-3.345	-3.485	-3.092	-3.420	-4.208	-4.905	-4.185	200.000
51L	131172	-3.388	-3.549	-3.141	-3.489	-4.277	-5.297	-4.320	200.000
51M	271172	-3.410	-3.581	-3.222	-3.463	-4.290	-5.339	-4.526	200.000
51N	180173	-3.327	-3.486	-3.249	-3.314	-4.235	-5.667	-4.758	200.000
51O	160373	-3.569	-3.737	-3.427	-3.642	-4.400	-5.499	-4.517	200.000
51P	40473	-3.518	-3.690	-3.311	-3.521	-4.363	-5.661	-4.773	200.000
51Q	230473	-3.473	-3.628	-3.196	-3.532	-4.256	-5.626	-4.612	200.000
51R	70573	-3.442	-3.607	-3.185	-3.455	-4.266	-5.539	-4.859	200.000
51S	240573	-3.474	-3.669	-3.159	-3.508	-4.289	-5.471	-4.920	200.000
51T	70673	-3.450	-3.657	-3.071	-3.621	-4.265	-5.520	-4.983	200.000
51U	250673	-3.389	-3.600	-2.974	-3.676	-4.238	-5.622	-5.144	200.000
51V	20873	-3.313	-3.505	-2.882	-3.542	-4.160	-5.547	-5.022	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
S1A	290672	200.000	-6.180	200.000	-3.887	-7.150	-5.215	-7.071	200.000
S1B	130772	200.000	-6.183	200.000	-3.877	-7.109	-5.159	-7.011	200.000
S1C	240772	200.000	-6.176	200.000	-3.867	-7.113	-5.178	-7.053	200.000
S1D	60872	200.000	-5.748	200.000	-3.848	-7.071	-5.155	-7.085	200.000
S1E	200872	200.000	-6.115	200.000	-3.867	-7.054	-5.120	-7.017	200.000
S1F	290872	200.000	-6.061	200.000	-3.845	-7.028	-5.082	-6.984	200.000
S1G	70972	200.000	-6.066	200.000	-3.857	-6.947	-5.009	-6.897	200.000
S1H	160972	200.000	-5.761	200.000	-3.839	-6.969	-5.041	-6.886	200.000
S1I	250972	200.000	-5.977	200.000	-3.848	-6.963	-5.037	-6.786	200.000
S1J	101072	200.000	-5.356	200.000	-3.836	-6.981	-5.112	-6.764	200.000
S1K	271072	200.000	-6.000	200.000	-3.944	-7.219	-5.347	-6.965	200.000
S1L	131172	200.000	-6.095	200.000	-4.013	-7.300	-5.461	-7.101	200.000
S1M	271172	200.000	-6.160	200.000	-4.090	-7.362	-5.573	-7.084	200.000
S1N	180173	200.000	-6.005	200.000	-4.084	-7.281	-5.504	-6.876	200.000
S1O	160373	200.000	-6.214	200.000	-4.131	-7.726	-5.934	-7.372	200.000
S1P	40473	200.000	-6.148	200.000	-4.089	-7.579	-5.771	-7.216	200.000
S1Q	230473	200.000	-6.234	200.000	-4.015	-7.490	-5.594	-7.128	200.000
S1R	70573	200.000	-6.039	200.000	-4.004	-7.458	-5.562	-7.062	200.000
S1S	240573	200.000	-6.356	200.000	-4.042	-7.454	-5.597	-7.137	200.000
S1T	70673	200.000	-6.223	200.000	-4.023	-7.377	-5.498	-7.230	200.000
S1U	250673	200.000	-6.120	200.000	-3.938	-7.243	-5.344	-7.260	200.000
S1V	20873	200.000	-6.166	200.000	-3.873	-7.113	-5.157	-7.052	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
51A	290672	200.000	-7.971	-8.443	200.000	200.000	-7.601	-5.501	-7.374
51B	130772	200.000	-7.976	-8.513	200.000	200.000	-7.705	-5.594	-7.300
51C	240772	200.000	-8.001	-8.758	200.000	200.000	-7.934	-5.814	-7.334
51D	60872	200.000	-8.087	-8.776	200.000	200.000	-7.565	-5.832	-7.335
51E	200872	200.000	-8.092	-8.625	200.000	200.000	-7.805	-5.680	-7.327
51F	290872	200.000	-8.035	-8.533	200.000	200.000	-7.666	-5.630	-7.260
51G	70972	200.000	-8.019	-8.545	200.000	200.000	-7.792	-5.670	-7.199
51H	160972	200.000	-7.967	-8.503	200.000	200.000	-7.840	-6.038	-7.241
51I	290972	200.000	-7.740	-8.520	200.000	200.000	-7.702	-5.684	-7.217
51J	101072	200.000	-7.502	-8.073	200.000	200.000	-7.735	-6.231	-7.288
51K	271072	200.000	-7.613	-9.119	200.000	200.000	-8.120	-6.154	-7.550
51L	131172	200.000	-8.087	-9.507	200.000	200.000	-8.533	-6.476	-7.669
51M	271172	200.000	-8.131	-9.742	200.000	200.000	-8.828	-6.697	-7.762
51N	180173	200.000	-8.325	-9.782	200.000	200.000	-8.794	-6.790	-7.733
51O	160373	200.000	-8.473	-10.255	200.000	200.000	-9.086	-7.104	-8.077
51P	40473	200.000	-8.497	-9.922	200.000	200.000	-8.792	-6.806	-7.925
51Q	230473	200.000	-8.427	-9.569	200.000	200.000	-8.595	-6.559	-7.701
51R	70573	200.000	-8.258	-9.441	200.000	200.000	-8.252	-6.420	-7.702
51S	240573	200.000	-8.248	-9.235	200.000	200.000	-8.387	-6.192	-7.698
51T	70673	200.000	-8.389	-9.162	200.000	200.000	-8.222	-6.143	-7.587
51U	250673	200.000	-8.532	-9.098	200.000	200.000	-8.130	-6.106	-7.462
51V	20873	200.000	-8.294	-8.969	200.000	200.000	-8.139	-6.052	-7.292

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
51A	290672	-6.191	200.000	-7.423	200.000	200.000	-4.585	-4.741	200.000
51B	130772	-6.269	200.000	-7.385	200.000	200.000	-4.529	-4.682	200.000
51C	240772	-6.504	200.000	-7.398	200.000	200.000	-4.559	-4.719	200.000
51D	60872	-6.508	200.000	-7.008	200.000	200.000	-4.577	-4.747	200.000
51E	200872	-6.333	200.000	-7.309	200.000	200.000	-4.510	-4.659	200.000
51F	290872	-6.257	200.000	-7.255	200.000	200.000	-4.477	-4.627	200.000
51G	70972	-6.265	200.000	-7.212	200.000	200.000	-4.404	-4.550	200.000
51H	160972	-6.621	200.000	-6.911	200.000	200.000	-4.399	-4.547	200.000
51I	250972	-6.265	200.000	-7.048	200.000	200.000	-4.316	-4.465	200.000
51J	161072	-6.845	200.000	-6.430	200.000	200.000	-4.354	-4.525	200.000
51K	271072	-6.856	200.000	-7.147	200.000	200.000	-4.506	-4.681	200.000
51L	131172	-7.246	200.000	-7.317	200.000	200.000	-4.633	-4.832	200.000
51M	271172	-7.508	200.000	-7.366	200.000	200.000	-4.639	-4.872	200.000
51N	180173	-7.507	200.000	-7.066	200.000	200.000	-4.413	-4.648	200.000
51O	160373	-8.071	200.000	-7.508	200.000	200.000	-4.978	-5.208	200.000
51P	40473	-7.723	200.000	-7.406	200.000	200.000	-4.800	-5.022	200.000
51Q	230473	-7.396	200.000	-7.487	200.000	200.000	-4.748	-4.912	200.000
51R	70573	-7.233	200.000	-7.212	200.000	200.000	-4.637	-4.806	200.000
51S	240573	-7.070	200.000	-7.584	200.000	200.000	-4.725	-4.929	200.000
51T	70673	-6.998	200.000	-7.556	200.000	200.000	-4.805	-5.002	200.000
51U	250673	-6.894	200.000	-7.503	200.000	200.000	-4.792	-4.981	200.000
51V	20873	-6.729	200.000	-7.406	200.000	200.000	-4.572	-4.722	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
51A	290672	200.000	-5.748	200.000
51B	130772	200.000	-5.817	200.000
51C	240772	200.000	-6.053	200.000
51D	60872	200.000	-6.061	200.000
51E	200872	200.000	-5.912	200.000
51F	290872	200.000	-5.815	200.000
51G	70972	200.000	-5.843	200.000
51H	160972	200.000	-6.208	200.000
51I	250972	200.000	-5.849	200.000
51J	101072	200.000	-6.461	200.000
51K	271072	200.000	-6.457	200.000
51L	131172	200.000	-6.837	200.000
51M	271172	200.000	-7.089	200.000
51N	180173	200.000	-7.103	200.000
51O	160373	200.000	-7.656	200.000
51P	40473	200.000	-7.302	200.000
51Q	230473	200.000	-6.989	200.000
51R	70573	200.000	-6.816	200.000
51S	240573	200.000	-6.623	200.000
51T	70673	200.000	-6.536	200.000
51U	250673	200.000	-6.426	200.000
51V	20673	200.000	-6.275	200.000

*LOG TO THE BASE 10

.200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
51A	290672	-8.822	200.000	-9.007	-17.829	-11.681	200.000	-6.860	200.000
51B	130772	-8.902	200.000	-9.094	-17.996	-11.777	200.000	-6.810	200.000
51C	240772	-9.131	200.000	-9.323	-18.454	-11.990	200.000	-6.836	200.000
51D	60872	-9.128	200.000	-9.319	-18.446	-11.580	200.000	-6.849	200.000
51E	200872	-8.975	200.000	-9.141	-18.116	-11.795	200.000	-6.780	200.000
51F	290872	-8.893	200.000	-9.076	-17.970	-11.691	200.000	-6.755	200.000
51G	70972	-8.909	200.000	-9.074	-17.983	-11.737	200.000	-6.675	200.000
51H	160972	-9.266	200.000	-9.424	-18.689	-11.799	200.000	-6.665	200.000
51I	250972	-9.907	200.000	-9.067	-17.975	-11.661	200.000	-6.582	200.000
51J	101072	-9.488	200.000	-9.623	-19.111	-11.587	200.000	-6.599	200.000
51K	271072	-9.489	200.000	-9.639	-19.129	-12.154	200.000	-6.755	200.000
51L	131172	-9.863	200.000	-10.024	-19.887	-12.570	200.000	-6.877	200.000
51M	271172	-10.107	200.000	-10.278	-20.385	-12.858	200.000	-6.873	200.000
51N	180173	-10.117	200.000	-10.276	-20.333	-12.795	200.000	-6.641	200.000
51O	160373	-10.673	200.000	-10.841	-21.514	-13.318	200.000	-7.211	200.000
51P	40473	-10.324	200.000	-10.496	-20.820	-12.954	200.000	-7.038	200.000
51Q	230473	-10.032	200.000	-10.197	-20.220	-12.793	200.000	-7.005	200.000
51R	70573	-9.862	200.000	-10.027	-19.889	-12.459	200.000	-6.897	200.000
51S	240573	-9.666	200.000	-9.861	-19.527	-12.548	200.000	-6.982	200.000
51T	70673	-9.593	200.000	-9.800	-19.394	-12.366	200.000	-7.071	200.000
51U	250673	-9.494	200.000	-9.705	-19.199	-12.225	200.000	-7.065	200.000
51V	20873	-9.354	200.000	-9.567	-18.921	-12.217	200.000	-6.855	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
51A	290672	200.000	12.214	200.000	200.000	200.000	9.075	200.000	-5.119
51B	130772	200.000	11.900	200.000	200.000	200.000	8.911	200.000	-5.313
51C	240772	200.000	11.491	200.000	200.000	200.000	8.712	200.000	-5.494
51D	60872	200.000	11.513	200.000	200.000	200.000	8.663	200.000	-5.496
51E	200872	200.000	11.839	200.000	200.000	200.000	8.850	200.000	-5.451
51F	290872	200.000	11.854	200.000	200.000	200.000	8.844	200.000	-5.362
51G	70972	200.000	11.796	200.000	200.000	200.000	8.788	200.000	-5.461
51H	160972	200.000	11.214	200.000	200.000	200.000	8.450	200.000	-5.660
51I	230972	200.000	11.916	200.000	200.000	200.000	8.817	200.000	-5.180
51J	101072	200.000	11.108	200.000	200.000	200.000	8.337	200.000	-5.283
51K	271072	200.000	11.415	200.000	200.000	200.000	8.627	200.000	-5.342
51L	131172	200.000	10.951	200.000	200.000	200.000	8.398	200.000	-6.123
51M	271172	200.000	10.619	200.000	200.000	200.000	8.303	200.000	-6.419
51N	180173	200.000	10.634	200.000	200.000	200.000	8.225	200.000	-6.775
51O	160373	200.000	10.063	200.000	200.000	200.000	8.132	200.000	-6.861
51P	60473	200.000	10.430	200.000	200.000	200.000	8.269	200.000	-6.779
51Q	230473	200.000	10.612	200.000	200.000	200.000	8.341	200.000	-6.537
51R	70573	200.000	10.873	200.000	200.000	200.000	8.427	200.000	-6.307
51S	240573	200.000	11.231	200.000	200.000	200.000	8.681	200.000	-6.105
51T	70673	200.000	11.103	200.000	200.000	200.000	8.610	200.000	-6.185
51U	250673	200.000	11.000	200.000	200.000	200.000	8.524	200.000	-6.198
51V	20773	200.000	10.955	200.000	200.000	200.000	8.443	200.000	-6.059

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
51A	290672	12.398	-4.099	57.181	2.654	-11.872	-18.694	-18.879	-0.018
51B	130772	12.092	-4.213	55.625	2.440	-11.967	-18.921	-19.113	-0.213
51C	240772	11.683	-4.420	53.587	2.240	-12.154	-19.252	-19.445	-0.423
51D	60872	11.704	-4.383	53.718	2.201	-12.079	-19.081	-19.272	-0.419
51E	200872	12.005	-4.271	55.330	2.283	-12.005	-18.931	-19.096	-0.311
51F	290872	12.037	-4.184	55.425	2.328	-11.874	-18.724	-18.907	-0.254
51G	70972	11.962	-4.229	55.122	2.254	-11.944	-18.898	-19.064	-0.327
51H	160972	11.372	-4.483	52.231	2.018	-12.162	-19.341	-19.499	-0.593
51I	250972	12.077	-4.131	55.733	2.516	-11.827	-18.709	-18.869	-0.129
51J	101072	11.243	-4.510	51.703	2.389	-12.182	-19.446	-19.581	-0.393
51K	271072	11.565	-4.645	53.132	2.545	-12.532	-19.984	-20.133	-0.352
51L	131172	11.012	-5.164	50.241	1.903	-13.130	-21.094	-21.255	-0.961
51M	271172	10.793	-5.370	49.005	1.761	-13.550	-21.928	-22.100	-1.197
51N	180173	10.793	-5.343	49.096	1.393	-13.511	-21.879	-22.038	-1.407
51O	160373	10.231	-5.761	46.184	1.401	-14.023	-22.814	-22.982	-1.601
51P	40473	10.602	-5.481	48.061	1.399	-13.658	-22.108	-22.280	-1.460
51Q	230473	10.767	-5.367	49.044	1.494	-13.198	-21.357	-21.512	-1.269
51R	70573	11.038	-5.034	50.363	1.701	-13.042	-20.993	-21.158	-1.066
51S	240573	11.426	-4.923	52.113	1.979	-13.007	-20.909	-21.104	-0.855
51T	70673	11.310	-4.931	51.493	1.860	-12.976	-20.872	-21.079	-0.935
51U	250673	11.211	-4.814	51.064	1.678	-12.689	-20.292	-20.503	-0.969
51V	70873	11.147	-4.677	50.301	1.688	-12.423	-19.840	-20.032	-0.897

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
51A	290672	-0.397	200.000	-1.054	-0.511	-0.962	200.000	-2.033	200.000
51B	130772	-0.470	200.000	-1.118	-0.580	-1.051	200.000	-2.194	200.000
51C	240772	-0.703	200.000	-1.362	-0.818	-1.267	200.000	-2.220	200.000
51D	60872	-0.706	200.000	-1.381	-0.829	-0.865	200.000	-2.232	200.000
51E	200872	-0.556	200.000	-1.212	-0.669	-1.080	200.000	-2.162	200.000
51F	290872	-0.465	200.000	-1.113	-0.575	-0.969	200.000	-2.139	200.000
51G	70972	-0.488	200.000	-1.139	-0.599	-1.022	200.000	-2.058	200.000
51H	180972	-0.850	200.000	-1.509	-0.964	-1.088	200.000	-2.046	200.000
51I	250972	-0.491	200.000	-1.151	-0.606	-0.950	200.000	-1.963	200.000
51J	101072	-1.092	200.000	-1.799	-1.220	-0.880	200.000	-1.972	200.000
51K	271072	-1.087	200.000	-1.794	-1.220	-1.447	200.000	-2.130	200.000
51L	131172	-1.464	200.000	-2.202	-1.609	-1.859	200.000	-2.250	200.000
51M	271172	-1.712	200.000	-2.500	-1.874	-2.143	200.000	-2.240	200.000
51N	180174	-1.783	200.000	-2.524	-1.887	-2.072	200.000	-2.004	200.000
51O	160373	-2.279	200.000	-3.065	-2.440	-2.603	200.000	-2.578	200.000
51P	40473	-1.927	200.000	-2.697	-2.085	-2.243	200.000	-2.408	200.000
51Q	230473	-1.625	200.000	-2.311	-1.750	-2.090	200.000	-2.384	200.000
51R	70573	-1.453	200.000	-2.140	-1.579	-1.752	200.000	-2.276	200.000
51S	240573	-1.253	200.000	-1.985	-1.403	-1.845	200.000	-2.360	200.000
51T	70673	-1.178	200.000	-1.885	-1.316	-1.655	200.000	-2.453	200.000
51U	250673	-1.072	200.000	-1.764	-1.204	-1.510	200.000	-2.448	200.000
51V	20873	-0.930	200.000	-1.574	-1.038	-1.491	200.000	-2.239	200.000

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
51A	290672	200.000	-2.594	200.000	200.000	200.000	-11.057	200.000	-2.425
51B	130772	200.000	-2.696	200.000	200.000	200.000	-10.903	200.000	-2.650
51C	240772	200.000	-2.935	200.000	200.000	200.000	-9.438	200.000	-2.811
51D	60872	200.000	-2.973	200.000	200.000	200.000	200.000	200.000	-2.782
51E	200872	200.000	-2.836	200.000	200.000	200.000	200.000	200.000	-2.726
51F	290872	200.000	-2.749	200.000	200.000	200.000	200.000	200.000	-2.682
51G	70972	200.000	-2.844	200.000	200.000	200.000	200.000	200.000	-2.743
51H	160972	200.000	-3.184	200.000	200.000	200.000	200.000	200.000	-2.915
51I	250972	200.000	-2.829	200.000	200.000	200.000	200.000	200.000	-2.737
51J	151072	200.000	-3.463	200.000	200.000	200.000	200.000	200.000	-2.410
51K	271072	200.000	-3.257	200.000	200.000	200.000	200.000	200.000	-2.499
51L	131172	200.000	-3.599	200.000	200.000	200.000	200.000	200.000	-3.246
51M	271172	200.000	-3.829	200.000	200.000	200.000	200.000	200.000	-3.477
51N	180173	200.000	-3.892	200.000	200.000	200.000	200.000	200.000	-3.793
51O	160373	200.000	-4.111	200.000	200.000	[illegible]000	200.000	200.000	-3.916
51P	40473	200.000	-3.868	200.000	200.000	200.000	200.000	200.000	-3.869
51Q	230473	200.000	-3.578	200.000	200.000	200.000	200.000	200.000	-3.739
51R	70573	200.000	-3.422	200.000	200.000	200.000	200.000	200.000	-3.524
51S	240573	200.000	-3.269	200.000	200.000	200.000	200.000	200.000	-3.307
51T	70673	200.000	-3.240	200.000	200.000	200.000	200.000	200.000	-3.440
51U	230673	200.000	-3.229	200.000	200.000	200.000	200.000	200.000	-3.489
51V	20873	200.000	-3.151	200.000	200.000	200.000	200.000	200.000	-3.406

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AN-K	AR-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
51A	290672	-2.715	-4.190	-1.110	-3.108	-4.080	-1.134	-1.022	-1.491
51B	130772	-2.801	-4.310	-1.218	-3.294	-4.203	-1.258	-1.142	-1.660
51C	240772	-3.047	-4.513	-1.452	-3.511	-4.373	-1.417	-1.306	-1.856
51D	60872	-3.104	-4.470	-1.487	-3.578	-4.269	-1.320	-1.217	-1.861
51E	200872	-2.979	-4.356	-1.344	-3.507	-4.184	-1.240	-1.128	-1.766
51F	290872	-2.866	-4.278	-1.265	-3.422	-4.095	-1.154	-1.038	-1.702
51G	70972	-2.984	-4.316	-1.353	-3.528	-4.131	-1.227	-1.112	-1.779
51H	160972	-3.338	-4.565	-1.685	-3.789	-4.322	-1.438	-1.327	-2.027
51I	250972	-2.982	-4.212	-1.331	-3.289	-3.990	-1.123	-1.012	-1.605
51J	101072	-3.673	-4.567	-1.936	-3.529	-4.224	-1.440	-1.353	-1.879
51K	271072	-3.450	-4.709	-1.747	-3.348	-4.602	-1.720	-1.633	-1.834
51L	131172	-3.798	-5.160	-2.089	-4.019	-5.168	-2.262	-2.190	-2.397
51M	271172	-4.043	-5.414	-2.313	-4.217	-5.527	-2.651	-2.604	-2.628
51N	180173	-4.125	-5.379	-2.368	-4.619	-5.451	-2.609	-2.568	-2.829
51O	160373	-4.328	-5.805	-2.599	-4.579	-5.998	-3.033	-3.045	-2.995
51P	40473	-4.072	-5.531	-2.358	-4.552	-5.665	-2.755	-2.698	-2.859
51Q	230473	-3.753	-5.238	-2.095	-4.359	-5.310	-2.425	-2.327	-2.656
51R	70573	-3.587	-5.109	-1.931	-4.140	-5.168	-2.249	-2.152	-2.468
51S	240573	-3.423	-4.995	-1.778	-3.874	-5.119	-2.201	-2.124	-2.280
51T	70673	-3.369	-5.012	-1.758	-3.947	-5.137	-2.203	-2.117	-2.339
51U	250673	-3.342	-4.902	-1.746	-4.098	-4.883	-1.927	-1.832	-2.360
51V	20873	-3.253	-4.775	-1.676	-4.038	-4.668	-1.721	-1.603	-2.279

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

EQUILIBRIUM PE

SAMP	DATE	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	PPCO2	ERROR	I.STR.
51A	290672	200.000	200.000	200.000	-3.170	200.000	-3.039	2.570	0.00342
51B	130772	200.000	200.000	200.000	-3.042	200.000	-2.820	-0.996	0.00363
51C	240772	200.000	200.000	200.000	-2.820	200.000	-2.635	-0.837	0.00353
51D	60872	200.000	200.000	200.000	-2.734	200.000	-2.645	2.988	0.00358
51E	200872	200.000	200.000	200.000	-2.907	200.000	-2.790	0.757	0.00378
51F	290872	200.000	200.000	200.000	-2.934	200.000	-2.752	2.270	0.00397
51G	70972	200.000	200.000	200.000	-2.855	200.000	-2.683	1.574	0.00435
51H	160972	200.000	200.000	200.000	-2.484	200.000	-2.442	6.679	0.00435
51I	250972	200.000	200.000	200.000	-2.853	200.000	-2.789	3.233	0.00459
51J	1.1072	200.000	200.000	200.000	-2.219	200.000	-2.493	3.682	0.00438
51K	271072	200.000	200.000	200.000	-2.544	200.000	-2.827	4.593	0.00350
51L	131172	200.000	200.000	200.000	-2.275	200.000	-2.636	4.575	0.00299
51M	271172	200.000	200.000	200.000	-2.103	200.000	-2.632	4.790	0.00285
51N	190173	200.000	200.000	200.000	-1.977	200.000	-2.627	5.803	0.00363
51O	160373	200.000	200.000	200.000	-1.929	200.000	-2.638	7.574	0.00187
51P	40473	200.000	200.000	200.000	-2.106	200.000	-2.674	0.637	0.00227
51Q	230473	200.000	200.000	200.000	-2.312	200.000	-2.588	-1.047	0.00256
51R	70573	200.000	200.000	200.000	-2.415	200.000	-2.694	-0.202	0.00278
51S	240573	200.000	200.000	200.000	-2.654	200.000	-2.881	-3.418	0.00253
51T	70673	200.000	200.000	200.000	-2.644	200.000	-2.708	-0.666	0.00250
51U	290673	200.000	200.000	200.000	-2.600	200.000	-2.520	1.519	0.00278
51V	20873	200.000	200.000	200.000	-2.586	200.000	-2.340	-0.557	0.00353

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

APPENDIX VIc SATURATION INDEX PROGRAM OUTPUT FOR THE PERIODICAL DATA FROM SAMPLE SITE 52

TOTAL MOLARITY*

SAMP	DATE	CA	MG	ALK	S	NA	K	CL	FE
52A	290672	-3.410	-3.517	-3.156	-3.397	-4.019	-5.260	-4.787	100.000
52B	130772	-3.399	-3.523	-3.183	-3.403	-4.215	-5.212	-5.188	100.000
52C	240772	-3.442	-3.615	-3.152	-3.464	-4.185	-5.036	-4.993	100.000
52D	60872	-3.404	-3.630	-3.183	-3.477	-4.157	-5.074	-4.937	100.000
52E	200872	-3.383	-3.638	-3.152	-3.439	-4.157	-5.061	-4.993	100.000
52F	290872	-3.410	-3.622	-3.152	-3.426	-4.171	-5.048	-4.802	100.000
52G	70972	-3.402	-3.622	-3.206	-3.491	-4.185	-5.048	-4.887	100.000
52H	160972	-3.424	-3.580	-3.217	-3.464	-4.215	-5.145	-4.993	100.000
52I	250972	-3.413	-3.573	-3.217	-3.464	-4.157	-5.115	-4.937	100.000
52J	101072	-3.506	-3.541	-3.206	-3.520	-4.141	-5.177	-4.851	100.000
52K	271072	-3.473	-3.446	-3.206	-3.349	-4.106	-5.177	-4.868	100.000
52L	131172	-3.451	-3.472	-3.241	-3.349	-4.104	-5.161	-4.615	100.000
52M	271172	-3.448	-3.456	-3.217	-3.329	-4.114	-5.161	-4.916	100.000
52N	180173	-3.334	-3.408	-3.241	-3.311	-4.206	-5.177	-4.615	100.000
52O	160373	-3.460	-3.505	-3.272	-3.439	-4.268	-5.177	-4.750	100.000
52P	40473	-3.542	-3.573	-3.323	-3.551	-4.312	-5.291	-4.851	100.000
52Q	230473	-3.594	-3.598	-3.287	-3.660	-4.244	-5.130	-4.851	100.000
52R	70573	-3.574	-3.580	-3.317	-3.551	-4.248	-5.250	-4.794	100.000
52S	240573	-3.466	-3.545	-3.323	-3.403	-4.282	-5.388	-4.834	100.000
52T	70673	-3.482	-3.565	-3.206	-3.426	-4.265	-5.236	-4.834	100.000
52U	250673	-3.527	-3.638	-3.183	-3.727	-4.275	-5.377	-4.896	100.000
52V	20873	-3.503	-3.637	-3.183	-3.585	-4.215	-5.313	-4.878	100.000

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED

TOTAL MOLARITY*

SAMP	DATE	CU	ZN	MN	H4SIO4	TDS	PH	PE	TEMP C
52A	290672	100.000	-6.213	100.000	-3.851	-0.917	6.400	9..03	7.500
52B	130772	-7.803	-5.912	100.000	-4.005	-0.946	6.600	9.666	7.300
52C	240772	-7.326	-6.514	100.000	-3.911	-0.955	6.950	7.192	12.000
52D	60872	100.000	-6.639	100.000	-3.911	-0.966	7.200	300.000	9.800
52E	200872	100.000	-6.639	100.000	-3.887	-0.937	7.150	300.000	9.000
52F	290872	100.000	-6.815	100.000	-3.900	-0.938	7.100	300.000	10.500
52G	70972	100.000	-6.815	100.000	-3.911	-0.977	6.900	300.000	10.600
52H	160972	100.000	-6.162	100.000	-3.921	-0.976	6.900	300.000	8.700
52I	250972	100.000	-6.271	100.000	-3.911	-0.972	6.950	300.000	9.400
52J	101072	100.000	-6.213	100.000	-3.900	-0.993	6.920	300.000	8.100
52K	271072	100.000	-6.116	100.000	-3.836	-0.919	6.720	300.000	7.800
52L	131172	100.000	-6.271	100.000	-3.862	-0.924	6.650	300.000	7.400
52M	271172	100.000	-6.271	100.000	-3.743	-0.902	6.620	300.000	6.500
52N	190173	100.000	-6.271	100.000	-3.867	-0.899	6.600	300.000	6.200
52O	160373	100.000	-6.324	100.000	-3.911	-0.985	6.700	300.000	6.200
52P	40473	100.000	-6.324	100.000	-3.940	-1.059	6.740	300.000	5.650
52Q	230473	100.000	-6.912	100.000	-3.873	-1.074	6.750	300.000	5.900
52R	70573	100.000	-6.912	100.000	-3.873	-1.051	6.760	300.000	7.200
52S	240573	100.000	-7.037	100.000	-4.005	-1.003	6.810	300.000	5.000
52T	70673	100.000	-6.435	100.000	-3.925	-0.968	6.680	300.000	6.000
52U	250673	100.000	-7.514	100.000	-3.877	-1.043	7.300	300.000	9.500
52V	20874	100.000	100.000	100.000	-3.861	-1.004	7.020	300.000	12.200

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED
300 = NO MEASURMENT PERFORMED

IONIC MOLARITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FF++
52A	290672	-3.428	-3.538	-3.158	-3.429	-4.020	-5.250	-4.887	200.000
52B	130772	-3.417	-3.543	-3.185	-3.435	-4.216	-5.213	-5.188	200.000
52C	240772	-3.458	-3.636	-3.154	-3.494	-4.186	-5.037	-4.993	200.000
52D	60872	-3.420	-3.649	-3.185	-3.508	-4.158	-5.074	-4.937	200.000
52E	200872	-3.400	-3.658	-3.154	-3.469	-4.158	-5.061	-4.993	200.000
52F	290872	-3.428	-3.644	-3.154	-3.457	-4.172	-5.049	-4.802	200.000
52G	70972	-3.417	-3.641	-3.207	-3.522	-4.186	-5.049	-4.887	200.000
52H	140972	-3.440	-3.599	-3.219	-3.494	-4.216	-5.146	-4.993	200.000
52I	250972	-3.423	-3.592	-3.219	-3.495	-4.158	-5.116	-4.937	200.000
52J	101072	-3.521	-3.558	-3.208	-3.549	-4.142	-5.178	-4.851	200.000
52K	271072	-3.493	-3.469	-3.208	-3.390	-4.107	-5.178	-4.868	200.000
52L	131172	-3.471	-3.495	-3.244	-3.380	-4.105	-5.162	-4.615	200.000
52M	271172	-3.463	-3.479	-3.219	-3.360	-4.114	-5.162	-4.916	200.000
52N	180173	-3.455	-3.431	-3.244	-3.347	-4.207	-5.178	-4.615	200.000
52O	100373	-3.477	-3.524	-3.274	-3.468	-4.269	-5.178	-4.750	200.000
52P	40473	-3.356	-3.588	-3.325	-3.577	-4.313	-5.292	-4.851	200.000
52Q	230473	-3.605	-3.611	-3.289	-3.685	-4.245	-5.130	-4.851	200.000
52R	70573	-3.688	-3.595	-3.319	-3.577	-4.248	-5.250	-4.794	200.000
52S	240573	-3.485	-3.564	-3.325	-3.431	-4.283	-5.389	-4.834	200.000
52T	70673	-3.503	-3.585	-3.207	-3.454	-4.265	-5.237	-4.834	200.000
52U	250673	-3.537	-3.651	-3.186	-3.754	-4.276	-5.378	-4.896	200.000
52V	20873	-3.516	-3.654	-3.185	-3.613	-4.216	-5.314	-4.878	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
52A	220672	200.000	-6.237	200.000	-3.851	-7.459	-5.554	-6.877	200.000
52B	130772	-7.952	-5.936	200.000	-4.005	-7.472	-5.586	-7.078	200.000
52C	240772	-7.639	-6.537	200.000	-3.911	-7.541	-5.644	-7.111	200.000
52D	60872	200.000	-6.662	200.000	-3.911	-7.505	-5.688	-7.093	200.000
52E	200872	200.000	-6.663	200.000	-3.887	-7.445	-5.668	-7.055	200.000
52F	200872	200.000	-6.840	200.000	-3.900	-7.492	-5.653	-7.058	200.000
52G	70972	200.000	-6.836	200.000	-3.911	-7.534	-5.702	-7.136	200.000
52H	160972	200.000	-6.184	200.000	-3.921	-7.544	-5.672	-7.136	200.000
52I	[redacted]972	200.000	-6.293	200.000	-3.911	-7.543	-5.666	-7.081	200.000
52J	101072	200.000	-6.233	200.000	-3.900	-7.603	-5.617	-7.113	200.000
52K	271072	200.000	-6.143	200.000	-3.836	-7.579	-5.536	-6.917	200.000
52L	131172	200.000	-6.298	200.000	-3.802	-7.587	-5.596	-6.914	200.000
52M	271172	200.000	-6.299	200.000	-3.743	-7.549	-5.559	-6.904	200.000
52N	180173	200.000	-6.300	200.000	-3.867	-7.460	-5.538	-6.987	200.000
52O	160373	200.000	-6.346	200.000	-3.911	-7.603	-5.652	-7.160	200.000
52P	40473	200.000	-6.342	200.000	-3.940	-7.718	-5.760	-7.305	200.000
52Q	230473	200.000	-6.926	200.000	-3.873	-7.731	-5.744	-7.341	200.000
52R	70573	200.000	-6.930	200.000	-3.873	-7.764	-5.761	-7.241	200.000
52S	240573	200.000	-7.061	200.000	-4.005	-7.645	-5.742	-7.134	200.000
52T	70673	200.000	-6.458	200.000	-3.925	-7.556	-5.645	-7.141	200.000
52U	250673	200.000	-7.529	200.000	-3.877	-7.609	-5.682	-7.447	200.000
52V	20873	200.000	200.000	200.000	-3.861	-7.627	-5.688	-7.254	200.000

*LOG TO THE BASE 10.
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
52A	290672	200.000	-8.066	-10.076	200.000	200.000	-9.504	-7.279	-7.474
52B	130772	200.000	-8.036	-10.102	200.000	-10.067	-9.011	-7.109	-7.698
52C	240772	200.000	-7.876	-9.628	200.000	-9.211	-9.069	-6.668	-7.634
52D	60872	200.000	-7.945	-9.409	200.000	200.000	-9.031	-6.477	-7.638
52E	200872	200.000	-7.902	-9.439	200.000	200.000	-9.116	-6.506	-7.607
52F	290872	200.000	-7.864	-9.483	200.000	200.000	-9.282	-6.537	-7.621
52G	70972	200.000	-7.927	-9.749	200.000	200.000	-9.473	-6.789	-7.687
52H	160972	200.000	-8.013	-9.815	200.000	200.000	-8.898	-6.825	-7.729
52I	250972	200.000	-7.978	-9.698	200.000	200.000	-8.929	-6.766	-7.672
52J	101072	200.000	-8.102	-9.716	200.000	200.000	-8.950	-6.801	-7.643
52K	271072	200.000	-7.944	-9.882	200.000	200.000	-9.078	-7.005	-7.612
52L	131172	200.000	-7.930	-9.997	200.000	200.000	-9.320	-7.116	-7.645
52M	271172	200.000	-7.919	-10.026	200.000	200.000	-9.389	-7.134	-7.631
52N	180173	200.000	-7.930	-10.169	200.000	200.000	-9.426	-7.183	-7.750
52O	160373	200.000	-8.041	-10.156	200.000	200.000	-9.365	-7.113	-7.837
52P	40473	200.000	-8.261	-10.215	200.000	200.000	-9.339	-7.131	-7.928
52Q	230473	200.000	-8.201	-10.095	200.000	200.000	-9.901	-7.082	-7.822
52R	70573	200.000	-8.205	-10.103	200.000	200.000	-9.841	-7.084	-7.857
52S	240573	200.000	-8.224	-10.128	200.000	200.000	-10.021	-7.071	-7.902
52T	70673	200.000	-8.086	-10.108	200.000	200.000	-9.505	-7.069	-7.767
52U	250673	200.000	-8.488	-9.426	200.000	200.000	-9.803	-6.381	-7.751
52V	20873	200.000	-8.264	-9.614	200.000	200.000	200.000	-6.627	-7.693

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
S2A	290672	-8.148	200.000	-7.579	200.000	200.000	-4.793	-4.931	200.000
S2B	130772	-7.983	200.000	-7.283	-9.272	200.000	-4.787	-4.943	200.000
S2C	240772	-7.612	200.000	-7.921	-8.992	200.000	-4.864	-5.037	200.000
S2D	60872	-7.443	200.000	-8.066	200.000	200.000	-4.847	-5.087	200.000
S2E	200872	-7.486	200.000	-8.035	200.000	200.000	-4.795	-5.070	200.000
S2F	290872	-7.497	200.000	-8.195	200.000	200.000	-4.805	-5.027	200.000
S2G	70972	-7.744	200.000	-8.252	200.000	200.000	-4.855	-5.085	200.000
S2H	180972	-7.745	200.000	-7.579	200.000	200.000	-4.858	-5.036	200.000
S2I	250972	-7.677	200.000	-7.688	200.000	200.000	-4.846	-5.024	200.000
S2J	11072	-7.680	200.000	-7.679	200.000	200.000	-4.990	-5.051	200.000
S2K	271072	-7.805	200.000	-7.437	200.000	200.000	-4.810	-4.912	200.000
S2L	131172	-7.942	200.000	-7.592	200.000	200.000	-4.788	-4.841	200.000
S2M	271172	-7.949	200.000	-7.579	200.000	200.000	-4.772	-4.818	200.000
S2N	180173	-7.955	200.000	-7.576	200.000	200.000	-4.655	-4.768	200.000
S2O	180373	-7.967	200.000	-7.724	200.000	200.000	-4.878	-4.963	200.000
S2P	40473	-8.042	200.000	-7.815	200.000	200.000	-5.053	-5.128	200.000
S2Q	230473	-8.010	200.000	-8.500	200.000	200.000	-5.202	-5.249	200.000
S2R	70573	-7.997	200.000	-8.397	200.000	200.000	-5.078	-5.117	200.000
S2S	240573	-7.966	200.000	-8.403	200.000	200.000	-4.851	-4.977	200.000
S2T	70673	-7.983	200.000	-7.820	200.000	200.000	-4.885	-5.010	200.000
S2U	250673	-7.339	200.000	-9.162	200.000	200.000	-5.193	-5.321	200.000
S2V	20873	-7.582	200.000	200.000	200.000	200.000	-5.029	-5.161	200.000

*LOG TO THE BASE 10.
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
52A	290672	200.000	-7.791	200.000
52B	130772	200.000	-7.610	-8.404
52C	240772	200.000	-7.183	-7.645
52D	60872	200.000	-6.965	200.000
52E	200872	200.000	-6.980	200.000
52F	290872	200.000	-7.031	200.000
52G	70972	200.000	-7.270	200.000
52H	160972	200.000	-7.338	200.000
52I	250972	200.000	-7.265	200.000
52J	141072	200.000	-7.394	200.000
52K	271072	200.000	-7.582	200.000
52L	131172	200.000	-7.672	200.000
52M	271172	200.000	-7.692	200.000
52N	130173	200.000	-7.633	200.000
52O	160373	200.000	-7.674	200.000
52P	40473	200.000	-7.764	200.000
52Q	230473	200.000	-7.758	200.000
52R	70573	200.000	-7.742	200.000
52S	240573	200.000	-7.642	200.000
52T	70673	200.000	-7.652	200.000
52U	250673	200.000	-6.976	200.000
52V	20873	200.000	-7.192	200.000

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IONIC ACTIVITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
32A	290672	-3.519	-3.626	-3.131	-3.621	-4.043	-5.274	-4.911	200.000
32B	130772	-3.507	-3.631	-3.208	-3.527	-4.239	-5.236	-5.211	200.000
32C	240772	-3.545	-3.720	-3.176	-3.582	-4.208	-5.059	-5.016	200.000
32D	60872	-3.506	-3.733	-3.207	-3.596	-4.180	-5.037	-4.959	200.000
32E	200872	-3.488	-3.744	-3.176	-3.559	-4.181	-5.084	-5.016	200.000
32F	290872	-3.516	-3.729	-3.176	-3.546	-4.194	-5.072	-4.824	200.000
32G	70972	-3.503	-3.725	-3.229	-3.615	-4.208	-5.071	-4.909	200.000
32H	160972	-3.526	-3.683	-3.241	-3.583	-4.238	-5.168	-5.016	200.000
32I	250972	-3.516	-3.677	-3.241	-3.584	-4.180	-5.138	-4.960	200.000
32J	101072	-3.604	-3.640	-3.229	-3.634	-4.163	-5.200	-4.873	200.000
32K	271072	-3.584	-3.558	-3.231	-3.474	-4.131	-5.202	-4.892	200.000
32L	131172	-3.562	-3.583	-3.267	-3.473	-4.128	-5.185	-4.639	200.000
32M	271172	-3.561	-3.568	-3.243	-3.455	-4.138	-5.186	-4.940	200.000
32N	190173	-3.451	-3.524	-3.269	-3.446	-4.232	-5.203	-4.640	200.000
32O	160373	-3.563	-3.608	-3.296	-3.557	-4.291	-5.200	-4.773	200.000
32P	40473	-3.635	-3.666	-3.345	-3.659	-4.333	-5.312	-4.871	200.000
32Q	230473	-3.681	-3.685	-3.308	-3.762	-4.264	-5.150	-4.870	200.000
32R	70573	-3.666	-3.672	-3.339	-3.657	-4.268	-5.271	-4.814	200.000
32S	240573	-3.570	-3.647	-3.347	-3.519	-4.305	-5.411	-4.856	200.000
32T	70673	-3.586	-3.668	-3.229	-3.541	-4.287	-5.259	-4.856	200.000
32U	250673	-3.614	-3.726	-3.205	-3.833	-4.295	-5.398	-4.917	200.000
32V	20873	-3.537	-3.733	-3.206	-3.695	-4.287	-5.335	-4.839	200.000

*LOG TO THE BASE 10

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IONIC ACTIVITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
52A	290672	200.000	-6.328	200.000	-3.851	-7.483	-5.577	-6.900	200.000
52B	130772	-8.042	-6.026	200.000	-4.005	-7.495	-5.609	-7.101	200.000
52C	240772	-7.725	-6.623	200.000	-3.911	-7.563	-5.666	-7.133	200.000
52D	60872	200.000	-6.747	200.000	-3.911	-7.527	-5.710	-7.115	200.000
52L	200872	200.000	-6.751	200.000	-3.887	-7.467	-5.690	-7.078	200.000
52F	290872	200.000	-6.928	200.000	-3.900	-7.515	-5.676	-7.081	200.000
52G	70972	200.000	-6.922	200.000	-3.911	-7.556	-5.724	-7.158	200.000
52H	160972	200.000	-6.270	200.000	-3.921	-7.546	-5.694	-7.158	200.000
52I	250972	200.000	-6.380	200.000	-3.911	-7.565	-5.680	-7.103	200.000
52J	101072	200.000	-6.316	200.000	-3.900	-7.624	-5.639	-7.135	200.000
52K	271072	200.000	-6.235	200.000	-3.836	-7.602	-5.559	-6.941	200.000
52L	131172	200.000	-6.389	200.000	-3.802	-7.610	-5.619	-6.937	200.000
52M	271172	200.000	-6.391	200.000	-3.743	-7.573	-5.582	-6.927	200.000
52N	180173	200.000	-6.396	200.000	-3.867	-7.485	-5.563	-7.012	200.000
52O	160373	200.000	-6.433	200.000	-3.911	-7.625	-5.674	-7.182	200.000
52P	40473	200.000	-6.421	200.000	-3.940	-7.739	-5.781	-7.325	200.000
52Q	230473	200.000	-7.002	200.000	-3.873	-7.751	-5.763	-7.360	200.000
52R	70573	200.000	-7.009	200.000	-3.873	-7.784	-5.781	-7.261	200.000
52S	240573	200.000	-7.147	200.000	-4.005	-7.667	-5.764	-7.156	200.000
52T	70673	200.000	-6.544	200.000	-3.925	-7.578	-5.667	-7.162	200.000
52U	250673	200.000	-7.606	200.000	-3.877	-7.629	-5.701	-7.467	200.000
52V	20873	200.000	200.000	200.000	-3.861	-7.648	-5.709	-7.274	200.000

*LOG TO THE BASE 10
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
52A	290672	200.000	-8.090	-10.039	200.000	200.000	-9.527	-7.002	-7.474
52B	130772	200.000	-8.059	-10.125	200.000	-10.090	-9.034	-7.132	-7.608
52C	240772	200.000	-7.898	-9.650	200.000	-9.233	-9.091	-6.690	-7.634
52D	60872	200.000	-7.967	-9.431	200.000	200.000	-9.053	-6.499	-7.638
52E	200872	200.000	-7.925	-9.461	200.000	200.000	-9.138	-6.528	-7.607
52F	290872	200.000	-7.887	-9.506	200.000	200.000	-9.305	-6.559	-7.621
52G	70972	200.000	-7.949	-9.771	200.000	200.000	-9.495	-6.811	-7.687
52H	160972	200.000	-8.035	-9.837	200.000	200.000	-8.920	-6.847	-7.729
52I	250972	200.000	-8.000	-9.720	200.000	200.000	-8.952	-6.788	-7.672
52J	101072	200.000	-8.123	-9.737	200.000	200.000	-8.971	-6.822	-7.643
52K	271072	200.000	-7.967	-9.413	200.000	200.000	-9.102	-7.029	-7.612
52L	141172	200.000	-7.954	-10.021	200.000	200.000	-9.343	-7.139	-7.645
52M	271172	200.000	-7.943	-10.049	200.000	200.000	-9.413	-7.158	-7.631
52N	180173	200.000	-7.955	-10.134	200.000	200.000	-9.450	-7.207	-7.750
52O	160373	200.000	-8.163	-10.178	200.000	200.000	-9.387	-7.135	-7.637
52P	40473	200.000	-8.281	-10.235	200.000	200.000	-9.359	-7.152	-7.729
52Q	230473	200.000	-8.220	-10.115	200.000	200.000	-9.920	-7.101	-7.822
52R	70573	200.000	-8.225	-10.123	200.000	200.000	-9.861	-7.104	-7.857
52S	240573	200.000	-8.245	-10.150	200.000	200.000	-10.043	-7.093	-7.902
52T	70673	200.000	-8.108	-10.130	200.000	200.000	-9.527	-7.091	-7.767
52U	250673	200.000	-8.308	-9.446	200.000	200.000	-9.823	-6.400	-7.731
52V	20873	200.000	-8.285	-9.635	200.000	200.000	200.000	-6.648	-7.693

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY* °

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
52A	290672	-8.148	200.000	-7.579	200.000	200.000	-4.733	-4.931	200.000
52B	130772	-7.983	200.000	-7.283	-9.272	200.000	-4.787	-4.943	200.000
52C	240772	-7.612	200.000	-7.921	-8.092	200.000	-4.864	-5.037	200.000
52D	60872	-7.443	200.000	-8.066	200.000	200.000	-4.847	-5.087	200.000
52E	200872	-7.486	200.000	-8.035	200.000	200.000	-4.735	-5.070	200.000
52F	290872	-7.497	200.000	-8.135	200.000	200.000	-4.805	-5.027	200.000
52G	70972	-7.744	200.000	-8.252	200.000	200.000	-4.855	-5.085	200.000
52H	160972	-7.745	200.000	-7.579	200.000	200.000	-4.858	-5.036	200.000
52I	250972	-7.677	200.000	-7.688	200.000	200.000	-4.846	-5.024	200.000
52J	101072	-7.680	200.000	-7.679	200.000	200.000	-4.790	-5.051	200.000
52K	271072	-7.805	200.000	-7.437	200.000	200.000	-4.810	-4.812	200.000
52L	131172	-7.942	200.000	-7.532	200.000	200.000	-4.789	-4.841	200.000
52M	271172	-7.949	200.000	-7.579	200.000	200.000	-4.772	-4.818	200.000
52N	180173	-7.935	200.000	-7.576	200.000	200.000	-4.655	-4.768	200.000
52O	100373	-7.967	200.000	-7.724	200.000	200.000	-4.878	-4.963	200.000
52P	40473	-8.042	200.000	-7.815	200.000	200.000	-5.053	-5.128	200.000
52Q	230473	-8.010	200.000	-8.500	200.000	200.000	-5.202	-5.249	200.000
52R	70573	-7.997	200.000	-8.337	200.000	200.000	-5.078	-5.117	200.000
52S	240573	-7.966	200.000	-8.403	200.000	200.000	-4.851	-4.977	200.000
52T	70673	-7.983	200.000	-7.820	200.000	200.000	-4.885	-5.010	200.000
52U	250673	-7.339	200.000	-9.162	200.000	200.000	-5.193	-5.321	200.000
52V	20773	-7.582	200.000	200.000	200.000	200.000	-5.029	-5.161	200.000

*LOG TO THE BASE 10
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

CAMP	DATE	FE(OH)2	CACO3	CUCO3
S2A	290672	200.000	-7.791	200.000
S2B	130772	200.000	-7.610	-8.404
S2C	240772	200.000	-7.183	-7.645
S2D	60872	200.000	-6.965	200.000
S2E	200872	200.000	-6.980	200.000
S2F	270872	200.000	-7.031	200.000
S2G	70972	200.000	-7.270	200.000
S2H	160972	200.000	-7.330	200.000
S2I	250972	200.000	-7.265	200.000
S2J	101072	200.000	-7.394	200.000
S2K	271072	200.000	-7.582	200.000
S2L	131172	200.000	-7.672	200.000
S2M	271172	200.000	-7.692	200.000
S2N	180173	200.000	-7.633	200.000
S2O	160373	200.000	-7.674	200.000
S2P	40473	200.000	-7.764	200.000
S2Q	230473	200.000	-7.758	200.000
S2R	70573	200.000	-7.742	200.000
S2S	240573	200.000	-7.642	200.000
S2T	70673	200.000	-7.652	200.000
S2U	250673	200.000	-6.976	200.000
S2V	20873	200.000	-7.192	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
52A	290672	-10.821	200.000	-10.928	-21.749	-13.630	200.000	-7.040	200.000
52B	130772	-10.639	200.000	-10.763	-21.402	-13.158	200.000	-7.034	-10.016
52C	240772	-10.235	200.000	-10.410	-20.644	-13.313	200.000	-7.127	-8.241
52D	60872	-10.005	200.000	-10.232	-20.237	-13.246	200.000	-7.102	200.000
52E	200872	-10.016	200.000	-10.272	-20.288	-13.279	200.000	-7.047	200.000
52F	290872	-10.075	200.000	-10.288	-20.363	-13.487	200.000	-7.062	200.000
52G	70972	-10.313	200.000	-10.535	-20.849	-13.733	200.000	-7.113	200.000
52H	160972	-10.373	200.000	-10.529	-20.902	-13.117	200.000	-7.109	200.000
52I	250972	-10.309	200.000	-10.464	-20.768	-13.168	200.000	-7.100	200.000
52J	101072	-10.427	200.000	-10.462	-20.889	-13.139	200.000	-7.233	200.000
52K	271072	-10.613	200.000	-10.596	-21.199	-13.263	200.000	-7.058	200.000
52L	131172	-10.701	200.000	-10.722	-21.423	-13.528	200.000	-7.035	200.000
52M	271172	-10.718	200.000	-10.726	-21.445	-13.549	200.000	-7.015	200.000
52N	180173	-10.659	200.000	-10.732	-21.390	-13.603	200.000	-6.897	200.000
52O	160373	-10.699	200.000	-10.743	-21.442	-13.568	200.000	-7.121	200.000
52P	40473	-10.787	200.000	-10.817	-21.604	-13.573	200.000	-7.294	200.000
52Q	230473	-10.782	200.000	-10.796	-21.568	-14.104	200.000	-7.444	200.000
52R	70573	-10.771	200.000	-10.777	-21.547	-14.113	200.000	-7.324	200.000
52S	240573	-10.663	200.000	-10.740	-21.402	-14.239	200.000	-7.089	200.000
52T	70673	-10.677	200.000	-10.752	-21.436	-13.635	200.000	-7.127	200.000
52U	250673	-10.015	200.000	-10.127	-20.141	-14.006	200.000	-7.447	200.000
52V	200773	-10.244	200.000	-10.380	-20.624	200.000	200.000	-7.272	200.000

*LOG TO THE BASE 10

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ACTIVITY PRODUCT*

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
S2A	290672	200.000	9.174	200.000	200.000	200.000	7.631	200.000	-6.577
S2B	130772	-25.190	9.560	200.000	200.000	200.000	7.794	200.000	-6.646
S2C	240772	-22.656	10.180	200.000	200.000	200.000	8.226	200.000	-5.930
S2D	60872	200.000	10.667	200.000	200.000	200.000	8.493	200.000	-5.718
S2E	200872	200.000	10.556	200.000	200.000	200.000	8.439	200.000	-5.707
S2F	290872	200.000	10.471	200.000	200.000	200.000	8.409	200.000	-5.772
S2G	70972	200.000	10.075	200.000	200.000	200.000	8.216	200.000	-5.992
S2H	160972	200.000	10.117	200.000	200.000	200.000	8.132	200.000	-6.111
S2I	250972	200.000	10.223	200.000	200.000	200.000	8.196	200.000	-6.009
S2J	101072	200.000	10.200	200.000	200.000	200.000	8.164	200.000	-6.080
S2K	271072	200.000	9.882	200.000	200.000	200.000	7.934	200.000	-6.154
S2L	131172	200.000	9.717	200.000	200.000	200.000	7.883	200.000	-6.139
S2M	271172	200.000	9.672	200.000	200.000	200.000	7.851	200.000	-6.051
S2N	180173	200.000	9.676	200.000	200.000	200.000	7.830	200.000	-6.337
S2O	160373	200.000	9.792	200.000	200.000	200.000	7.949	200.000	-6.322
S2P	40473	200.000	9.814	200.000	200.000	200.000	8.000	200.000	-6.452
S2Q	230473	200.000	9.815	200.000	200.000	200.000	8.096	200.000	-6.147
S2R	70573	200.000	9.848	200.000	200.000	200.000	8.093	200.000	-6.257
S2S	240573	200.000	9.973	200.000	200.000	200.000	8.143	200.000	-6.611
S2T	70673	200.000	9.692	200.000	200.000	200.000	7.941	200.000	-6.429
S2U	250673	200.000	10.874	200.000	200.000	200.000	8.730	200.000	-5.851
S2V	20873	200.000	10.307	200.000	200.000	200.000	200.000	200.000	-6.036

*LOG TO THE BASE 10
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ACTIVITY PRODUCT*

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
52A	290672	9.281	-5.346	42.020	1.126	-13.048	-21.529	-21.636	-1.652
52B	130772	9.693	-5.649	43.843	1.364	-13.659	-22.345	-22.469	-1.595
52C	240772	10.355	-5.079	46.991	1.891	-12.900	-20.929	-21.104	-1.013
52D	60872	10.894	-4.801	49.424	2.103	-18.622	-20.391	-20.617	-0.764
52E	200872	10.812	-4.804	48.895	2.066	-12.577	-20.280	-20.536	-0.785
52F	290872	10.684	-4.895	48.453	2.028	-12.695	-20.516	-20.730	-0.846
52G	70972	10.297	-5.129	46.466	1.829	-12.950	-20.987	-21.209	-1.076
52H	160972	10.274	-5.181	46.666	1.732	-13.023	-21.097	-21.253	-1.137
52I	230972	10.384	-5.051	47.207	1.812	-12.873	-20.900	-21.061	-1.050
52J	101072	10.236	-5.044	47.102	1.720	-12.844	-20.965	-21.000	-1.098
52K	271072	9.856	-5.083	45.576	1.518	-12.755	-20.833	-20.807	-1.222
52L	131172	9.738	-5.082	44.785	1.465	-12.685	-20.676	-20.697	-1.254
52M	271172	9.679	-5.004	44.615	1.434	-12.489	-20.263	-20.271	-1.213
52N	180173	9.749	-5.366	44.512	1.337	-13.100	-21.197	-21.265	-1.383
52O	160373	9.837	-5.412	45.051	1.500	-13.233	-21.449	-21.492	-1.345
52P	40473	9.845	-5.473	45.133	1.428	-13.352	-21.673	-21.703	-1.417
52Q	230473	9.819	-5.261	45.203	1.600	-13.008	-21.168	-21.171	-1.234
52R	70573	9.854	-5.255	45.366	1.489	-13.002	-21.133	-21.139	-1.293
52S	240573	10.050	-5.505	45.860	1.399	-13.514	-21.989	-22.066	-1.473
52T	70673	9.774	-5.457	44.535	1.421	-13.307	-21.625	-21.707	-1.434
52U	250673	10.986	-4.749	50.493	1.902	-12.502	-20.027	-20.139	-0.792
52V	20973	10.443	-4.938	47.676	1.685	-12.659	-20.441	-20.577	-1.045

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

		SATURATION INDEX							
SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
52A	290672	-2.421	200.000	-3.033	-2.535	-2.923	200.000	-2.415	200.000
52B	130772	-2.239	200.000	-2.931	-2.362	-2.451	200.000	-2.408	-2.423
52C	240772	-1.822	200.000	-2.510	-1.949	-2.602	200.000	-2.507	-1.535
52D	60872	-1.599	200.000	-2.363	-1.763	-2.543	200.000	-2.480	200.000
52F	200872	-1.612	200.000	-2.415	-1.794	-2.576	200.000	-2.424	200.000
52F	290872	-1.667	200.000	-2.410	-1.820	-2.779	200.000	-2.441	200.000
52G	70972	-1.905	200.000	-2.655	-2.063	-3.025	200.000	-2.492	200.000
52H	160972	-1.970	200.000	-2.677	-2.103	-2.410	200.000	-2.485	200.000
52I	250972	-1.839	200.000	-2.602	-2.031	-2.461	200.000	-2.477	200.000
52J	101072	-2.025	200.000	-2.618	-2.100	-2.432	200.000	-2.614	200.000
52K	271072	-2.212	200.000	-2.747	-2.257	-2.556	200.000	-2.433	200.000
52L	131172	-2.301	200.000	-2.887	-2.372	-2.825	200.000	-2.409	200.000
52M	271172	-2.320	200.000	-2.916	-2.389	-2.842	200.000	-2.388	200.000
52N	180173	-2.260	200.000	-2.916	-2.363	-2.896	200.000	-2.269	200.000
52O	100373	-2.301	200.000	-2.927	-2.389	-2.861	200.000	-2.493	200.000
52P	40473	-2.390	200.000	-3.009	-2.473	-2.866	200.000	-2.665	200.000
52Q	230473	-2.385	200.000	-2.974	-2.454	-3.397	200.000	-2.815	200.000
52R	70573	-2.371	200.000	-2.946	-2.436	-3.410	200.000	-2.698	200.000
52S	240573	-2.267	200.000	-2.941	-2.376	-3.529	200.000	-2.419	200.000
52T	70673	-2.277	200.000	-2.946	-2.387	-2.928	200.000	-2.499	200.000
52U	250673	-1.616	200.000	-2.263	-1.717	-3.303	200.000	-2.825	200.000
52V	20873	-1.831	200.000	-2.477	-1.918	200.000	200.000	-2.673	200.000

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
S2A	290672	200.000	-4.403	200.000	200.000	200.000	-10.633	200.000	-3.719
S2B	130772	-4.150	-4.213	200.000	200.000	200.000	-11.355	200.000	-3.784
S2C	240772	-2.883	-3.737	200.000	200.000	200.000	-9.427	200.000	-3.165
S2D	60872	200.000	-3.573	200.000	200.000	200.000	200.000	200.000	-2.908
S2E	200872	200.000	-3.657	200.000	200.000	200.000	200.000	200.000	-2.881
S2F	290872	200.000	-3.645	200.000	200.000	200.000	200.000	200.000	-2.976
S2G	70972	200.000	-3.839	200.000	200.000	200.000	200.000	200.000	-3.199
S2H	160972	200.000	-3.887	200.000	200.000	200.000	200.000	200.000	-3.279
S2I	250972	200.000	-3.809	200.000	200.000	200.000	200.000	200.000	-3.191
S2J	151072	200.000	-3.868	200.000	200.000	200.000	200.000	200.000	-3.234
S2K	271072	200.000	-4.038	200.000	200.000	200.000	200.000	200.000	-3.302
S2L	131172	200.000	-4.136	200.000	200.000	200.000	200.000	200.000	-3.279
S2M	271172	200.000	-4.192	200.000	200.000	200.000	200.000	200.000	-3.172
S2N	180173	200.000	-4.201	200.000	200.000	200.000	200.000	200.000	-3.452
S2O	160373	200.000	-4.143	200.000	200.000	200.000	200.000	200.000	-3.436
S2P	40473	200.000	-4.153	200.000	200.000	200.000	200.000	200.000	-3.555
S2Q	230473	200.000	-4.143	200.000	200.000	200.000	200.000	200.000	-3.254
S2R	70573	200.000	-4.078	200.000	200.000	200.000	200.000	200.000	-3.393
S2S	240573	200.000	-4.098	200.000	200.000	200.000	200.000	200.000	-3.699
S2T	70673	200.000	-4.201	200.000	200.000	200.000	200.000	200.000	-3.539
S2U	250673	200.000	-3.480	200.000	200.000	200.000	200.000	200.000	-3.035
S2V	20871	200.000	-3.666	200.000	200.000	200.000	200.000	200.000	-3.275

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AN-K	AH-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
52A	290672	-4.623	-5.406	-2.881	-4.780	-5.104	-2.487	-2.382	-3.021
52B	130772	-4.426	-5.708	-2.705	-4.546	-5.711	-2.894	-2.798	-2.970
52C	240772	-3.889	-5.157	-2.240	-3.934	-5.043	-2.224	-2.127	-2.415
52D	60872	-3.716	-4.870	-2.067	-3.761	-4.723	-1.937	-1.879	-2.200
52E	200872	-3.792	-4.870	-2.145	-3.813	-4.662	-1.875	-1.836	-2.224
52F	220872	-3.790	-4.967	-2.141	-3.823	-4.809	-2.006	-1.937	-2.271
52G	70972	-3.979	-5.202	-2.337	-4.021	-5.066	-2.242	-2.177	-2.480
52H	160972	-4.074	-5.246	-2.378	-4.152	-5.103	-2.281	-2.194	-2.545
52I	250972	-3.988	-5.119	-2.301	-4.060	-4.966	-2.189	-2.100	-2.462
52J	101072	-4.119	-5.106	-2.353	-4.175	-4.911	-2.210	-2.066	-2.513
52K	271072	-4.323	-5.144	-2.516	-4.382	-4.817	-2.142	-1.968	-2.627
52L	131172	-4.339	-5.141	-2.608	-4.443	-4.739	-2.060	-1.913	-2.659
52M	271172	-4.469	-5.060	-2.655	-4.490	-4.525	-1.845	-1.697	-2.626
52N	180173	-4.447	-5.421	-2.675	-4.533	-5.130	-2.304	-2.191	-2.783
52O	160373	-4.403	-5.407	-2.67[illegible]	-4.430	-5.263	-2.435	-2.307	-2.748
52P	40473	-4.424	-5.525	-2.611	-4.512	-5.371	-2.543	-2.411	-2.817
52Q	230473	-4.426	-5.315	-2.616	-4.335	-5.031	-2.292	-2.146	-2.649
52R	70573	-4.350	-5.314	-2.556	-4.422	-5.052	-2.286	-2.133	-2.695
52S	240573	-4.351	-5.555	-2.580	-4.553	-5.520	-2.635	-2.491	-2.871
52T	70673	-4.443	-5.511	-2.679	-4.513	-5.333	-2.522	-2.414	-2.831
52U	250673	-3.683	-4.817	-1.961	-3.967	-4.597	-1.753	-1.639	-2.227
52V	20873	-3.837	-5.016	-2.146	-4.136	-4.805	-1.982	-1.864	-2.443

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

EQUILIBRIUM PE

SAMP	DATE	FE(OH)3	FE2O3	MFS2	ZNS	CUFES2	PPCO2	ERROR	I.STR.
52A	290672	200.000	200.000	200.000	-1.531	200.000	-1.870	-0.795	0.00248
52B	130772	200.000	200.000	200.000	-1.689	200.000	-2.099	0.542	0.00244
52C	240772	200.000	200.000	200.000	-2.235	200.000	-2.389	-4.552	0.00219
52D	60872	200.000	200.000	200.000	-2.449	200.000	-2.683	0.096	0.00220
52F	200872	200.000	200.000	200.000	-2.376	200.000	-2.607	-2.799	0.00231
52F	290872	200.000	200.000	200.000	-2.383	200.000	-2.548	-5.109	0.00230
52G	70972	200.000	200.000	200.000	-2.193	200.000	-2.401	2.521	0.00218
52H	160972	200.000	200.000	200.000	-2.061	200.000	-2.424	1.792	0.00221
52I	250972	200.000	200.000	200.000	-2.142	200.000	-2.470	3.144	0.00224
52J	141072	200.000	200.000	200.000	-2.078	200.000	-2.435	1.600	0.00208
52K	271072	200.000	200.000	200.000	-1.841	200.000	-2.230	-1.937	0.00252
52L	131172	200.000	200.000	200.000	-1.783	200.000	-2.206	-0.820	0.00249
52M	271172	200.000	200.000	200.000	-1.725	200.000	-2.158	-1.674	0.00257
52N	180173	200.000	200.000	200.000	-1.697	200.000	-2.165	6.362	0.00286
52O	160373	200.000	200.000	200.000	-1.815	200.000	-2.293	3.891	0.00225
52P	40473	200.000	200.000	200.000	-1.953	200.000	-2.385	5.211	0.00187
52Q	230473	200.000	200.000	200.000	-1.954	200.000	-2.356	5.572	0.00170
52R	70573	200.000	200.000	200.000	-1.985	200.000	-2.390	2.969	0.00183
52S	240573	200.000	200.000	200.000	-1.973	200.000	-2.460	1.201	0.00222
52T	70673	200.000	200.000	200.000	-1.802	200.000	-2.207	-4.806	0.00221
52U	250673	200.000	200.000	200.000	-2.679	200.000	-2.783	3.267	0.00174
52V	20873	200.000	200.000	200.000	200.000	200.000	-2.488	-1.464	0.00191

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

APPENDIX VId SATURATION INDEX PROGRAM OUTPUT FOR THE PERIODICAL DATA FROM SAMPLE SITE 71

TOTAL MOLARITY*

SAMP	DATE	CA	MG	ALK	S	NA	K	CL	FE
71A	290672	-2.300	-2.586	-2.303	-2.203	-3.591	-4.271	-4.152	-4.333
71B	130772	-2.298	-2.585	-2.295	-2.196	-3.584	-4.271	-4.170	-4.140
71C	240772	-2.305	-2.610	-2.293	-2.196	-3.591	-4.314	-4.103	-4.367
71D	60872	-2.298	-2.585	-2.297	-2.196	-3.591	-4.314	-4.111	-4.159
71E	200872	-2.298	-2.588	-2.300	-2.191	-3.587	-4.314	-4.103	-4.333
71F	290872	-2.288	-2.580	-2.297	-2.176	-3.551	-4.271	-4.103	-4.324
71G	70972	-2.279	-2.574	-2.295	-2.180	-3.566	-4.314	-4.111	-4.300
71H	160972	-2.273	-2.566	-2.342	-2.156	-3.528	-4.231	-4.080	-4.333
71I	250972	-2.263	-2.558	-2.330	-2.154	-3.561	-4.292	-4.119	-4.263
71J	101072	-2.218	-2.547	-2.333	-2.159	-3.551	-4.271	-4.152	-4.191
71K	271072	-2.231	-2.527	-2.325	-2.114	-3.549	-4.292	-4.119	-4.447
71L	131172	-2.222	-2.513	-2.315	-2.104	-3.551	-4.256	-4.073	-4.270
71M	271172	-2.225	-2.519	-2.312	-2.115	-3.553	-4.292	-4.045	-4.281
71N	180173	-2.234	-2.524	-2.318	-2.143	-3.561	-4.268	-4.045	-4.270
71O	160373	-2.247	-2.575	-2.343	-2.175	-3.610	-4.292	-4.073	-4.316
71P	40473	-2.271	-2.588	-2.347	-2.186	-3.622	-4.307	-4.103	-4.316
71Q	230473	-2.309	-2.649	-2.359	-2.227	-3.614	-4.381	-4.119	-4.316
71R	70574	-2.309	-2.551	-2.336	-2.222	-3.614	-4.362	-4.103	-4.305
71S	240574	-2.322	-2.620	-2.363	-2.206	-3.630	-4.389	-4.170	-4.333
71T	70674	-2.292	-2.585	-2.315	-2.201	-3.630	-4.389	-4.119	-4.333
71U	250673	-2.298	-2.586	-2.312	-2.250	-3.630	-4.389	-4.088	-4.311
71V	20873	-2.290	-2.556	-2.303	-2.211	-3.599	-4.292	-4.073	-4.256

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED

TOTAL MOLARITY*

SAMP	DATE	CU	ZN	MN	H4SIO4	TDS	PH	PC	TEMP C
71A	290672	-6.326	-4.351	-3.985	-3.562	0.087	6.500	4.591	7.800
71B	130772	-6.202	-4.327	-3.977	-3.555	0.093	6.800	4.521	7.700
71C	240772	-6.503	-4.362	-3.992	-3.562	0.090	6.700	4.236	7.600
71D	60872	-6.326	-4.343	-3.985	-3.562	0.092	6.700	300.000	7.800
71E	200872	-6.326	-4.330	-3.973	-3.510	0.095	6.400	300.000	7.800
71F	290872	-6.202	-4.311	-3.970	-3.548	0.104	6.700	300.000	7.800
71G	70972	-6.202	-4.293	-3.962	-3.545	0.105	6.600	300.000	7.800
71H	160972	-6.202	-4.278	-3.948	-3.543	0.108	6.700	300.000	7.800
71I	250972	100.000	-4.257	-3.928	-3.538	0.112	6.700	300.000	7.900
71J	1[illegible]072	100.000	-4.224	-3.908	-3.531	0.120	6.720	300.000	7.700
71Y	271072	100.000	-4.228	-3.902	-3.531	0.143	6.700	300.000	7.700
71L	131172	100.000	-4.286	-3.953	-3.526	0.153	6.620	300.000	7.900
71M	271172	100.000	-4.279	-3.953	-3.518	0.147	6.640	300.000	7.800
71N	180173	100.000	-4.247	-3.962	-3.521	0.127	6.530	300.000	7.800
71O	160373	100.000	-4.352	-4.002	-3.557	0.100	6.480	300.000	7.800
71P	40473	100.000	-4.333	-4.013	-3.557	0.090	6.780	300.000	7.400
71Q	230473	100.000	-4.360	-4.000	-3.558	0.061	6.650	300.000	7.400
71R	70573	100.000	-4.356	-4.008	-3.562	0.065	6.730	300.000	7.400
71S	240573	100.000	-4.361	-4.016	-3.621	0.063	7.300	300.000	7.500
71T	70673	100.000	-4.381	-4.016	-3.571	0.085	6.740	300.000	7.500
71U	250673	100.000	-4.360	-4.016	-3.576	0.063	6.730	300.000	7.500
71V	20873	-6.503	-4.245	-3.977	-3.560	0.086	6.750	4.433	7.600

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED
300 = NO MEASURMENT PERFORMED

IONIC MOLARITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
71A	290672	-2.403	-2.702	-2.311	-2.333	-3.597	-4.276	-4.152	-4.424
71B	130772	-2.402	-2.703	-2.305	-2.326	-3.590	-4.276	-4.170	-4.234
71C	240772	-2.409	-2.729	-2.303	-2.123	-3.597	-4.320	-4.103	-4.462
71D	60872	-2.402	-2.704	-2.309	-2.326	-3.597	-4.320	-4.111	-4.443
71L	200872	-2.403	-2.706	-2.310	-2.321	-3.593	-4.320	-4.103	-4.426
71F	290872	-2.394	-2.700	-2.308	-2.307	-3.557	-4.276	-4.103	-4.420
71G	70972	-2.384	-2.694	-2.305	-2.312	-3.572	-4.320	-4.111	-4.395
71H	160972	-2.383	-2.688	-2.353	-2.289	-3.534	-4.237	-4.088	-4.431
71I	230972	-2.372	-2.680	-2.330	-2.289	-3.567	-4.298	-4.119	-4.362
71J	101072	-2.392	-2.664	-2.344	-2.302	-3.557	-4.276	-4.152	-4.286
71K	271072	-2.345	-2.654	-2.337	-2.252	-3.555	-4.233	-4.119	-4.550
71L	131172	-2.337	-2.642	-2.326	-2.243	-3.538	-4.263	-4.073	-4.374
71M	271172	-2.339	-2.640	-2.323	-2.254	-3.559	-4.298	-4.045	-4.383
71N	180173	-2.342	-2.645	-2.329	-2.289	-3.568	-4.276	-4.045	-4.367
71O	160373	-2.352	-2.672	-2.355	-2.312	-3.616	-4.298	-4.073	-4.410
71P	40473	-2.375	-2.705	-2.357	-2.319	-3.628	-4.313	-4.103	-4.410
71Q	230473	-2.406	-2.658	-2.371	-2.362	-3.619	-4.386	-4.119	-4.404
71R	70573	-2.407	-2.661	-2.368	-2.336	-3.620	-4.368	-4.103	-4.394
71S	240573	-2.427	-2.736	-2.374	-2.332	-3.636	-4.394	-4.170	-4.431
71T	70673	-2.394	-2.700	-2.325	-2.333	-3.636	-4.394	-4.119	-4.425
71U	250673	-2.380	-2.692	-2.322	-2.386	-3.635	-4.394	-4.088	-4.393
71V	20873	-2.389	-2.669	-2.314	-2.347	-3.604	-4.297	-4.073	-4.346

*LOG TO THE BASE 10

POC = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
71A	290672	-6.754	-4.527	-4.350	-3.562	-5.740	-4.006	-5.521	-4.951
71B	130772	-6.813	-4.506	-4.346	-3.555	-5.730	-3.999	-5.508	-4.940
71C	240772	-7.051	-4.540	-4.365	-3.562	-5.733	-4.022	-5.510	-4.955
71D	60872	-6.872	-4.522	-4.354	-3.562	-5.734	-4.001	-5.515	-4.950
71E	200872	-6.708	-4.511	-4.341	-3.510	-5.728	-4.008	-5.505	-4.933
71F	290872	-6.747	-4.496	-4.345	-3.548	-5.729	-4.001	-5.459	-4.943
71G	70972	-6.687	-4.481	-4.335	-3.543	-5.717	-3.992	-5.479	-4.931
71H	160972	-6.719	-4.468	-4.325	-3.543	-5.704	-4.035	-5.420	-4.971
71I	250972	200.000	-4.447	-4.304	-3.536	-5.753	-4.025	-5.454	-4.947
71J	101072	200.000	-4.408	-4.275	-3.531	-5.699	-4.006	-5.461	-4.916
71K	271072	200.000	-4.429	-4.290	-3.531	-5.716	-3.991	-5.412	-4.927
71L	131172	200.000	-4.489	-4.345	-3.520	-5.701	-4.073	-5.409	-4.973
71M	271172	200.000	-4.480	-4.341	-3.518	-5.699	-3.970	-5.413	-4.965
71N	180173	200.000	-4.435	-4.337	-3.521	-5.704	-3.972	-5.469	-4.963
71O	160373	200.000	-4.534	-4.368	-3.557	-5.736	-4.042	-5.525	-5.015
71P	40473	200.000	-4.514	-4.373	-3.557	-5.753	-4.033	-5.533	-5.026
71Q	230473	200.000	-4.527	-4.383	-3.598	-5.793	-4.017	-5.569	-5.005
71R	70573	200.000	-4.526	-4.360	-3.562	-5.791	-4.017	-5.563	-5.013
71S	240573	200.000	-4.560	-4.391	-3.621	-5.817	-4.096	-5.553	-5.038
71T	70673	200.000	-4.558	-4.391	-3.571	-5.739	-4.016	-5.559	-4.994
71U	250673	200.000	-4.570	-4.360	-3.576	-5.720	-4.003	-5.609	-4.967
71V	20873	-7.072	-4.417	-4.335	-3.560	-5.725	-3.975	-5.543	-4.938

*LOG TO THE BASE 10.

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MNOH+	KSO4	NACO3	FEOH+	CUOH+	ZNOH+	CO3	NAHCO3
71A	290672	-9.241	-6.159	-8.785	-7.025	-9.055	-7.788	-6.331	-6.288
71B	130772	-8.242	-6.154	-8.472	-6.539	-8.819	-7.472	-6.024	-6.273
71C	240772	-9.063	-6.193	-8.577	-6.870	-9.159	-7.608	-6.124	-6.278
71D	60872	-9.045	-6.196	-8.586	-6.944	-8.973	-7.583	-6.126	-6.283
71E	200872	-9.332	-6.191	-8.878	-7.128	-9.109	-7.872	-6.428	-6.281
71F	230872	-9.038	-6.137	-8.542	-6.823	-8.849	-7.559	-6.126	-6.244
71G	70972	-9.128	-6.186	-8.653	-6.898	-8.890	-7.645	-6.223	-6.256
71H	160972	-9.020	-6.282	-8.564	-6.836	-8.823	-7.533	-6.171	-6.267
71I	250972	-8.935	-6.143	-8.593	-6.763	200.000	-7.568	-6.166	-6.229
71J	101072	-8.957	-6.140	-8.563	-6.677	200.000	-7.459	-6.143	-6.294
71K	271072	-9.994	-6.115	-8.575	-6.963	200.000	-7.503	-6.156	-6.276
71L	131172	-9.126	-6.078	-8.647	-6.865	200.000	-7.640	-6.224	-6.278
71M	271172	-9.132	-6.117	-8.625	-6.853	200.000	-7.610	-6.201	-6.267
71N	180173	-9.205	-6.125	-8.747	-6.944	200.000	-7.673	-6.317	-6.280
71O	160373	-9.282	-6.165	-8.869	-7.034	200.000	-7.818	-6.393	-6.352
71P	40473	-9.038	-6.187	-8.586	-6.749	200.000	-7.513	-6.100	-6.363
71Q	230473	-9.106	-6.298	-8.719	-6.870	200.000	-7.653	-6.244	-6.366
71R	70573	-9.036	-6.274	-8.636	-6.780	200.000	-7.572	-6.161	-6.363
71S	240573	-8.482	-6.273	-8.086	-6.241	200.000	-7.031	-5.596	-6.384
71T	70673	-9.044	-6.273	-8.599	-6.798	200.000	-7.591	-6.107	-6.338
71U	250673	-9.032	-6.329	-8.606	-6.777	200.000	-7.561	-6.114	-6.333
71V	20873	-8.985	-6.197	-8.547	-6.705	-9.132	-7.437	-6.085	-6.297

*LOG TO THE BASE 10

/00 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
71A	290672	-6.535	-5.058	-5.081	-7.281	-4.321	-2.980	-3.231	-11.730
71B	130772	-6.230	-4.862	-5.056	-7.335	-4.311	-2.974	-3.287	-11.420
71C	240772	-6.355	-5.084	-5.083	-7.567	-4.323	-2.976	-3.308	-11.536
71D	60872	-6.331	-5.070	-5.070	-7.393	-4.318	-2.973	-3.285	-11.529
71E	240872	-6.638	-5.043	-5.054	-7.224	-4.300	-2.969	-3.284	-11.819
71F	290872	-6.331	-5.034	-5.030	-7.253	-4.295	-2.951	-3.268	-11.523
71G	70972	-6.422	-5.015	-5.022	-7.201	-4.292	-2.948	-3.268	-11.611
71H	160972	-6.366	-5.031	-4.989	-7.212	-4.268	-2.926	-3.242	-11.551
71I	220972	-6.335	-4.964	-4.970	200.000	-4.243	-2.918	-3.236	-11.526
71J	101072	-6.320	-4.908	-4.991	200.000	-4.234	-2.889	-3.242	-11.479
71K	271072	-6.326	-5.128	-4.929	200.000	-4.296	-2.967	-3.187	-11.510
71L	131172	-6.394	-4.948	-4.984	200.000	-4.256	-2.855	-3.169	-11.534
71M	271172	-6.364	-4.965	-4.992	200.000	-4.260	-2.964	-3.191	-11.608
71N	180173	-6.475	-4.977	-4.966	200.000	-4.284	-2.835	-3.209	-11.715
71O	160373	-6.532	-5.032	-5.078	200.000	-4.327	-2.918	-3.269	-11.816
71P	40473	-6.313	-5.034	-5.059	200.000	-4.339	-2.944	-3.287	-11.530
71Q	230473	-6.402	-5.061	-5.106	200.000	-4.344	-3.009	-3.275	-11.639
71R	70573	-6.323	-5.046	-5.100	200.000	-4.349	-3.004	-3.272	-11.567
71S	240571	-5.830	-5.054	-5.105	200.000	-4.341	-2.995	-3.318	-11.020
71T	70673	-6.310	-5.058	-5.113	200.000	-4.351	-2.972	-3.292	-11.536
71U	250673	-6.307	-5.076	-5.132	200.000	-4.378	-3.006	-3.332	-11.520
71V	20873	-6.258	-4.995	-4.988	-7.616	-4.322	-2.982	-3.276	-11.470

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC*MOLARITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
71A	290672	-10.516	-6.003	-6.616
71B	130772	-9.734	-5.697	-6.369
71C	240774	-10.169	-5.802	-6.704
71D	60872	-10.139	-5.797	-6.529
71E	200872	-10.719	-6.101	-6.667
71F	290872	-10.115	-5.793	-6.406
71G	70972	-10.230	-5.881	-6.445
71H	160972	-10.128	-5.829	-6.426
71I	250972	-10.051	-5.915	200.000
71J	101072	-9.955	-5.747	200.000
71K	271072	-10.262	-5.786	200.000
71L	131172	-10.240	-5.848	200.000
71M	271172	-10.208	-5.826	200.000
71N	181273	-10.408	-5.940	200.000
71O	160373	-10.546	-6.021	200.000
71P	40473	-9.978	-5.749	200.000
71Q	230473	-10.227	-5.918	200.000
71R	70573	-10.057	-5.836	200.000
71S	240573	-8.943	-5.288	200.000
71T	70673	-10.062	-5.771	200.000
71U	250673	-10.043	-5.762	200.000
71V	20873	-9.954	-5.745	-6.689

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC* ACTIVITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
71A	290672	-2.640	-2.922	-2.377	-2.588	-3.661	-4.343	-4.219	-4.661
71B	130772	-2.640	-2.924	-2.369	-2.582	-3.654	-4.344	-4.237	-4.472
71C	240772	-2.646	-2.949	-2.367	-2.577	-3.661	-4.387	-4.170	-4.628
71D	60872	-2.640	-2.924	-2.372	-2.581	-3.661	-4.387	-4.178	-4.681
71E	200872	-2.641	-2.927	-2.374	-2.576	-3.657	-4.387	-4.170	-4.664
71F	230872	-2.634	-2.923	-2.372	-2.565	-3.622	-4.345	-4.171	-4.661
71G	70972	-2.625	-2.917	-2.370	-2.571	-3.636	-4.383	-4.179	-4.636
71H	160972	-2.625	-2.912	-2.418	-2.549	-3.599	-4.306	-4.157	-4.673
71I	290972	-2.615	-2.905	-2.413	-2.551	-3.632	-4.367	-4.188	-4.605
71J	101072	-2.569	-2.893	-2.410	-2.568	-3.624	-4.347	-4.222	-4.532
71K	271072	-2.594	-2.885	-2.404	-2.521	-3.623	-4.369	-4.190	-4.739
71L	131172	-2.588	-2.874	-2.394	-2.514	-3.626	-4.335	-4.143	-4.526
71M	271172	-2.589	-2.877	-2.391	-2.523	-3.627	-4.370	-4.118	-4.634
71N	180173	-2.599	-2.873	-2.396	-2.555	-3.634	-4.345	-4.115	-4.614
71O	160373	-2.594	-2.916	-2.420	-2.572	-3.681	-4.366	-4.142	-4.652
71P	140473	-2.614	-2.926	-2.421	-2.576	-3.692	-4.381	-4.171	-4.650
71Q	230473	-2.641	-2.876	-2.434	-2.614	-3.682	-4.452	-4.185	-4.638
71R	70573	-2.643	-2.879	-2.431	-2.608	-3.683	-4.434	-4.170	-4.629
71S	240573	-2.660	-2.952	-2.436	-2.582	-3.698	-4.460	-4.236	-4.664
71T	70673	-2.631	-2.921	-2.389	-2.588	-3.699	-4.461	-4.186	-4.662
71U	230673	-2.615	-2.910	-2.385	-2.638	-3.698	-4.460	-4.154	-4.630
71V	20873	-2.627	-2.890	-2.378	-2.603	-3.668	-4.365	-4.141	-4.584

ALOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

CAMP	DATE	CU++	ZN++	MN++	NASIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
71A	290672	-6.991	-4.764	-4.588	-3.562	-5.803	-4.069	-5.585	-5.015
71B	110772	-7.052	-4.744	-4.584	-3.555	-5.794	-4.063	-5.572	-5.004
71C	240772	-7.208	-4.777	-4.601	-3.562	-5.797	-4.086	-5.574	-5.018
71D	60872	-7.110	-4.760	-4.592	-3.562	-5.798	-4.065	-5.579	-5.014
71E	200872	-6.946	-4.749	-4.577	-3.510	-5.802	-4.072	-5.569	-5.003
71F	290872	-6.987	-4.736	-4.58[illegible]	-3.548	-5.793	-4.065	-5.523	-5.008
71G	70972	-6.928	-4.722	-4.576	-3.545	-5.782	-4.057	-5.544	-4.996
71H	160972	-6.961	-4.711	-4.566	-3.543	-5.829	-4.100	-5.485	-5.036
71I	250972	200.000	-4.690	-4.547	-3.536	-5.818	-4.090	-5.520	-5.012
71J	101772	200.000	-4.654	-4.521	-3.531	-5.765	-4.073	-5.528	-4.982
71K	271072	200.000	-4.673	-4.545	-3.531	-5.783	-4.058	-5.479	-4.994
71L	131172	200.000	-4.741	-4.596	-3.520	-5.769	-4.038	-5.476	-5.040
71M	271172	200.000	-4.730	-4.591	-3.518	-5.766	-4.038	-5.486	-5.032
71N	180173	200.000	-4.682	-4.584	-3.521	-5.771	-4.039	-5.525	-5.029
71O	160373	200.000	-4.776	-4.610	-3.557	-5.801	-4.107	-5.590	-5.080
71P	40473	200.000	-4.753	-4.619	-3.557	-5.817	-4.117	-5.604	-5.089
71Q	230473	200.000	-4.762	-4.594	-3.558	-5.856	-4.080	-5.632	-5.068
71R	70573	200.000	-4.762	-4.59[illegible]	-3.562	-5.855	-4.080	-5.626	-5.076
71S	240573	200.000	-4.734	-4.614	-3.621	-5.879	-4.159	-5.615	-5.101
71T	70873	200.000	-4.795	-4.61[illegible]	-3.571	-5.803	-4.030	-5.623	-5.057
71U	250673	200.000	-4.755	-4.59[illegible]	-3.576	-5.783	-4.066	-5.672	-5.030
71V	20873	-7.311	-4.656	-4.574	-3.560	-5.789	-4.039	-5.607	-5.002

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
71A	290672	-9.305	-6.223	-8.841	-7.089	-9.119	-7.852	-6.394	-6.288
71B	130772	-9.006	-6.218	-8.536	-6.603	-8.883	-7.536	-6.088	-6.273
71C	240772	-9.127	-6.257	-8.641	-6.934	-9.223	-7.672	-6.187	-6.278
71D	60872	-9.109	-6.260	-8.644	-6.908	-9.037	-7.647	-6.189	-6.283
71E	200872	-9.396	-6.255	-8.942	-7.191	-9.173	-7.936	-6.492	-6.281
71F	290872	-9.103	-6.201	-8.606	-6.888	-8.914	-7.623	-6.190	-6.244
71G	70972	-9.193	-6.251	-8.718	-6.963	-8.955	-7.709	-6.287	-6.256
71H	160972	-9.085	-6.147	-8.629	-6.901	-8.898	-7.598	-6.235	-6.267
71I	230972	-9.061	-6.209	-8.659	-6.928	200.000	-7.574	-6.231	-6.298
71J	11072	-9.023	-6.207	-8.629	-6.743	200.000	-7.526	-6.209	-6.284
71K	271072	-9.061	-6.182	-8.642	-7.030	200.000	-7.570	-6.222	-6.276
71L	131172	-9.104	-6.141	-8.715	-6.933	200.000	-7.708	-6.291	-6.270
71M	271172	-9.169	-6.185	-8.692	-6.920	200.000	-7.677	-6.268	-6.267
71N	180173	-9.271	-6.191	-8.813	-7.011	200.000	-7.739	-6.383	-6.280
71O	100373	-9.347	-6.230	-8.934	-7.099	200.000	-7.883	-6.458	-6.352
71P	40473	-9.072	-6.252	-8.650	-6.814	200.000	-7.577	-6.164	-6.363
71Q	230473	-9.169	-6.361	-8.782	-6.933	200.000	-7.716	-6.306	-6.366
71R	70573	-9.100	-6.337	-8.693	-6.843	200.000	-7.636	-6.223	-6.363
71S	240573	-8.544	-6.336	-8.148	-6.303	200.000	-7.093	-5.658	-6.384
71T	70673	-9.138	-6.343	-8.663	-6.862	200.000	-7.655	-6.170	-6.338
71U	250673	-9.095	-6.392	-8.669	-6.839	200.000	-7.624	-6.177	-6.333
71V	20873	-9.049	-6.260	-8.611	-6.769	-9.196	-7.501	-6.148	-6.297

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
71A	290672	-6.535	-5.058	-5.081	-7.281	-4.321	-2.980	-3.291	-11.730
71B	130772	-6.230	-4.862	-5.056	-7.335	-4.311	-2.974	-3.287	-11.420
71C	240772	-6.355	-5.084	-5.083	-7.567	-4.323	-2.976	-3.308	-11.536
71D	60872	-6.331	-5.070	-5.070	-7.393	-4.318	-2.973	-3.285	-11.529
71E	200872	-6.638	-5.049	-5.054	-7.224	-4.300	-2.969	-3.284	-11.819
71F	270872	-6.331	-5.034	-5.030	-7.253	-4.295	-2.951	-3.268	-11.523
71G	70972	-6.422	-5.019	-5.022	-7.201	-4.292	-2.948	-3.269	-11.611
71H	160972	-6.366	-5.031	-4.989	-7.212	-4.262	-2.926	-3.242	-11.551
71I	250972	-6.355	-4.964	-4.970	200.000	-4.243	-2.918	-3.236	-11.526
71J	101072	-6.320	-4.968	-4.951	200.000	-4.234	-2.889	-3.242	-11.478
71K	271072	-6.326	-5.128	-4.929	200.000	-4.206	-2.867	-3.167	-11.510
71L	131172	-6.384	-4.948	-4.934	200.000	-4.256	-2.855	-3.169	-11.636
71M	271172	-6.364	-4.965	-4.982	200.000	-4.260	-2.864	-3.181	-11.608
71N	180173	-6.475	-4.977	-4.966	200.000	-4.284	-2.895	-3.209	-11.715
71O	160373	-6.592	-5.032	-5.078	200.000	-4.327	-2.918	-3.269	-11.816
71P	40473	-6.310	-5.034	-5.059	200.000	-4.339	-2.944	-3.287	-11.530
71Q	230473	-6.402	-5.061	-5.106	200.000	-4.344	-3.008	-3.275	-11.639
71R	70573	-6.323	-5.046	-5.100	200.000	-4.349	-3.004	-3.272	-11.567
71S	240573	-5.833	-5.054	-5.105	200.000	-4.341	-2.995	-3.318	-11.020
71T	70673	-6.310	-5.058	-5.113	200.000	-4.351	-2.972	-3.292	-11.536
71U	250673	-6.307	-5.076	-5.122	200.000	-4.378	-3.006	-3.332	-11.520
71V	20873	-6.258	-4.995	-4.988	-7.616	-4.322	-2.982	-3.276	-11.479

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PROGRAM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
71A	290672	-10.516	-6.003	-6.616
71B	130772	-9.734	-5.697	-6.369
71C	240772	-10.169	-5.802	-6.704
71D	60872	-10.135	-5.797	-6.529
71E	200872	-10.719	-6.101	-6.667
71F	290872	-10.115	-5.793	-6.406
71G	70972	-10.290	-5.881	-6.445
71H	100972	-10.128	-5.829	-6.426
71I	250972	-10.051	-5.815	200.000
71J	101072	-9.953	-5.747	200.000
71K	271072	-10.262	-5.786	200.000
71L	131172	-10.240	-5.848	200.000
71M	271172	-10.208	-5.826	200.000
71N	180173	-10.408	-5.940	200.000
71O	160373	-10.546	-6.021	200.000
71P	40473	-9.978	-5.749	200.000
71Q	230473	-10.227	-5.918	200.000
71R	70573	-10.037	-5.836	200.000
71S	240573	-8.943	-5.289	200.000
71T	70673	-10.062	-5.771	200.000
71U	250673	-10.049	-5.762	200.000
71V	20873	-9.954	-5.745	-6.689

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
71A	290672	-9.034	-11.056	-9.316	-18.350	-11.159	-10.982	-5.228	-7.377
71B	130772	-8.727	-10.560	-9.011	-17.739	-10.832	-10.672	-5.221	-6.591
71C	240772	-8.833	-10.885	-9.115	-17.968	-10.963	-10.788	-5.223	-7.362
71D	60872	-8.829	-10.870	-9.113	-17.941	-10.949	-10.781	-5.221	-7.009
71E	200872	-9.132	-11.156	-9.412	-18.551	-11.241	-11.070	-5.217	-7.583
71F	290872	-8.824	-10.853	-9.113	-17.937	-10.925	-10.775	-5.199	-6.763
71G	70972	-8.812	-10.923	-9.204	-18.116	-11.009	-10.863	-5.196	-6.943
71H	160972	-8.860	-10.908	-9.147	-18.007	-10.946	-10.803	-5.174	-6.757
71I	250972	-8.846	-10.836	-9.136	-17.983	-10.921	-10.778	-5.166	200.000
71J	101072	-8.778	-10.741	-9.101	-17.879	-10.863	-10.736	-5.137	200.000
71K	271072	-8.817	-11.021	-9.207	-17.924	-10.901	-10.762	-5.115	200.000
71L	131172	-8.880	-10.917	-9.163	-18.045	-11.032	-10.887	-5.103	200.000
71M	271172	-8.857	-10.901	-9.145	-18.002	-10.998	-10.859	-5.112	200.000
71N	140173	-8.971	-10.997	-9.256	-18.228	-11.065	-10.966	-5.143	200.000
71O	160373	-9.052	-11.110	-9.374	-18.425	-11.234	-11.068	-5.166	200.000
71P	40473	-8.778	-10.813	-9.090	-17.868	-10.917	-10.782	-5.190	200.000
71Q	240473	-8.948	-10.945	-9.182	-18.130	-11.069	-10.891	-5.255	200.000
71R	70573	-8.806	-10.852	-9.103	-17.968	-10.985	-10.819	-5.251	200.000
71S	240573	-8.318	-10.321	-8.610	-16.928	-10.451	-10.272	-5.242	200.000
71T	70673	-8.801	-10.832	-9.091	-17.892	-10.966	-10.788	-5.219	200.000
71U	230673	-8.792	-10.806	-9.047	-17.878	-10.931	-10.771	-5.253	200.000
71V	20873	-8.775	-10.732	-9.039	-17.814	-10.804	-10.722	-5.229	-7.269

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
71A	290672	-20.763	10.078	14.939	14.839	8.131	7.419	7.552	-4.967
71B	130772	-19.730	10.676	15.928	15.928	8.460	7.716	7.843	-4.654
71C	240772	-20.836	10.451	15.402	15.402	8.361	7.619	7.771	-4.810
71D	60872	-20.308	10.476	15.419	15.419	8.360	7.618	7.760	-4.810
71E	200872	-21.021	9.873	14.536	14.536	8.015	7.316	7.448	-5.006
71F	290872	-19.940	10.477	15.439	15.439	8.356	7.613	7.749	-4.740
71G	70972	-20.158	10.283	15.164	15.164	8.241	7.512	7.644	-4.877
71H	160972	-19.953	10.488	15.427	15.427	8.355	7.607	7.746	-4.692
71I	250972	200.000	10.495	15.435	15.495	8.350	7.605	200.000	-4.738
71J	101072	200.000	10.549	15.628	15.628	8.371	7.623	200.000	-4.683
71K	271072	200.000	10.515	15.301	15.301	8.360	7.600	200.000	-4.732
71L	131172	200.000	10.366	15.234	15.234	8.255	7.527	200.000	-4.754
71M	271172	200.000	10.403	15.287	15.287	8.280	7.547	200.000	-4.766
71N	180173	200.000	10.187	14.976	14.976	8.157	7.435	200.000	-4.857
71O	160373	200.000	10.044	14.788	14.788	8.105	7.399	200.000	-5.000
71P	40473	200.000	10.634	15.690	15.690	8.449	7.696	200.000	-4.715
71Q	230473	200.000	10.424	15.311	15.311	8.305	7.572	200.000	-4.919
71R	70573	200.000	10.581	15.561	15.561	8.395	7.651	200.000	-4.827
71S	240573	200.000	11.648	17.236	17.236	9.045	8.222	200.000	-4.402
71T	70673	200.000	10.559	15.558	15.558	8.406	7.663	200.000	-4.864
71U	250673	200.000	10.550	15.560	15.560	8.399	7.654	200.000	-4.882
71V	20873	-20.728	10.610	15.666	15.666	8.414	7.657	7.819	-4.735

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
71A	290672	10.360	-4.984	46.827	2.157	-11.407	-18.133	-18.415	-0.460
71B	130772	10.960	-3.965	49.827	2.456	-11.075	-17.482	-17.766	-0.123
71C	240772	10.754	-4.084	48.634	2.313	-11.207	-17.739	-18.042	-0.273
71D	60872	10.760	-4.084	48.820	2.313	-11.208	-17.732	-18.016	-0.267
71E	200872	10.159	-4.276	45.854	2.313	-11.295	-17.918	-18.204	-0.536
71F	290872	10.766	-4.017	48.838	2.355	-11.113	-17.615	-17.904	-0.225
71G	70972	10.575	-4.126	47.872	2.212	-11.215	-17.782	-18.073	-0.356
71H	160972	10.775	-3.985	48.835	2.334	-11.071	-17.569	-17.857	-0.193
71I	250972	10.785	-4.004	48.938	2.333	-11.075	-17.500	-17.790	-0.219
71J	101072	10.871	-3.966	49.207	2.373	-11.028	-17.378	-17.702	-0.176
71K	271072	10.806	-3.985	49.045	2.331	-11.047	-17.444	-17.734	-0.210
71L	131172	10.652	-4.045	48.311	2.285	-11.084	-17.505	-17.790	-0.261
71M	271172	10.691	-4.023	48.497	2.270	-11.059	-17.454	-17.742	-0.259
71N	180173	10.471	-4.146	47.412	2.185	-11.188	-17.636	-17.981	-0.367
71O	160373	10.366	-4.315	46.663	2.114	-11.429	-18.089	-18.411	-0.489
71P	40473	10.946	-4.026	49.612	2.399	-11.140	-17.509	-17.821	-0.171
71Q	230473	10.659	-4.149	48.061	2.198	-11.266	-17.809	-18.043	-0.345
71R	70573	10.817	-4.076	49.342	2.296	-11.109	-17.675	-17.912	-0.251
71S	240573	11.940	-3.639	54.617	2.940	-10.881	-17.026	-17.318	0.271
71T	70673	10.849	-4.102	49.225	2.279	-11.244	-17.721	-18.010	-0.278
71U	250673	10.845	-4.120	49.173	2.270	-11.272	-17.763	-18.058	-0.292
71V	20873	10.873	-4.039	49.488	2.385	-11.159	-17.607	-17.871	-0.188

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
71A	290672	-0.633	-0.672	-1.477	-0.833	-0.452	-0.576	-0.602	-1.104
71H	130772	-0.326	-0.179	-1.174	-0.528	-0.125	-0.266	-0.596	-0.710
71C	240772	-0.432	-0.508	-1.239	-0.643	-0.256	-0.386	-0.597	-1.096
71D	60872	-0.427	-0.486	-1.273	-0.628	-0.242	-0.374	-0.596	-0.920
71L	200872	-0.731	-0.772	-1.380	-0.933	-0.534	-0.664	-0.592	-1.207
71F	290872	-0.423	-0.467	-1.274	-0.626	-0.248	-0.369	-0.574	-0.797
71G	70972	-0.511	-0.539	-1.365	-0.716	-0.302	-0.457	-0.571	-0.886
71H	160972	-0.459	-0.525	-1.308	-0.661	-0.239	-0.346	-0.549	-0.794
71I	250972	-0.445	-0.453	-1.296	-0.643	-0.218	-0.372	-0.541	200.000
71J	101072	-0.377	-0.361	-1.264	-0.599	-0.156	-0.324	-0.511	200.000
71K	271072	-0.416	-0.641	-1.269	-0.620	-0.194	-0.356	-0.490	200.000
71L	131172	-0.479	-0.533	-1.328	-0.680	-0.325	-0.481	-0.477	200.000
71M	271172	-0.456	-0.517	-1.306	-0.659	-0.291	-0.453	-0.487	200.000
71N	180173	-0.570	-0.613	-1.417	-0.772	-0.358	-0.560	-0.518	200.000
710	160373	-0.651	-0.726	-1.435	-0.871	-0.527	-0.661	-0.541	200.000
71P	40473	-0.378	-0.434	-1.257	-0.595	-0.213	-0.375	-0.564	200.000
71Q	230473	-0.547	-0.566	-1.349	-0.726	-0.366	-0.484	-0.629	200.000
71R	70573	-0.466	-0.473	-1.269	-0.645	-0.282	-0.412	-0.625	200.000
71S	240573	0.083	0.057	-0.775	-0.124	0.256	0.134	-0.616	200.000
71T	70673	-0.401	-0.454	-1.256	-0.606	-0.259	-0.382	-0.593	200.000
71U	220673	-0.391	-0.429	-1.252	-0.599	-0.224	-0.365	-0.627	200.000
71V	20873	-0.374	-0.353	-1.202	-0.566	-0.097	-0.320	-0.604	-1.050

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
71A	290672	-1.936	-3.940	-0.072	-1.691	-6.323	-5.917	-5.761	-2.115
71B	130772	-1.420	-3.645	-0.409	-2.028	-6.578	-6.142	-5.679	-1.901
71C	240772	-1.973	-3.761	-0.136	-1.755	-6.191	-5.757	-5.319	-1.954
71D	60872	-1.709	-3.741	200.000	200.000	200.000	200.000	200.000	-1.959
71E	200872	-2.065	-4.043	200.000	200.000	200.000	200.000	200.000	-2.155
71F	290872	-1.525	-3.741	200.000	200.000	200.000	200.000	200.000	-1.888
71G	70972	-1.634	-3.838	200.000	200.000	200.000	200.000	200.000	-2.026
71H	160972	-1.532	-3.736	200.000	200.000	200.000	200.000	200.000	-1.840
71I	250972	200.000	-3.728	200.000	200.000	200.000	200.000	200.000	-1.889
71J	101072	200.000	-3.709	200.000	200.000	200.000	200.000	200.000	-1.835
71K	271072	200.000	-3.725	200.000	200.000	200.000	200.000	200.000	-1.870
71L	131172	200.000	-3.796	200.000	200.000	200.000	200.000	200.000	-1.902
71M	271172	200.000	-3.778	200.000	200.000	200.000	200.000	200.000	-1.914
71N	180173	200.000	-3.886	200.000	200.000	200.000	200.000	200.000	-2.005
71O	160373	200.000	-3.957	200.000	200.000	200.000	200.000	200.000	-2.148
71P	40473	200.000	-3.677	200.000	200.000	200.000	200.000	200.000	-1.854
71Q	230473	200.000	-3.782	200.000	200.000	200.000	200.000	200.000	-2.059
71R	70573	200.000	-3.704	200.000	200.000	200.000	200.000	200.000	-1.967
71S	240573	200.000	-3.767	200.000	200.000	200.000	200.000	200.000	-1.944
71T	70673	200.000	-3.711	200.000	200.000	200.000	200.000	200.000	-2.006
71U	250673	200.000	-3.716	200.000	200.000	200.000	200.000	200.000	-2.024
71V	20873	-1.910	-3.682	-0.220	-1.909	-6.441	-5.992	-5.564	-1.979

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	GAM-K	MGM-K	ILL-K
71A	290672	-4.070	-4.345	-2.331	-3.744	-3.469	-0.791	-0.773	-1.935
71B	130772	-3.775	-4.026	-2.094	-3.446	-3.135	-0.465	-0.448	-1.629
71C	240772	-3.882	-4.145	-2.210	-3.591	-3.265	-0.593	-0.586	-1.766
71D	60872	-3.870	-4.145	-2.191	-3.588	-3.269	-0.591	-0.573	-1.759
71L	200872	-4.171	-4.337	-2.488	-3.888	-3.357	-0.694	-0.667	-2.004
71F	290872	-3.868	-4.078	-2.199	-3.545	-3.174	-0.533	-0.517	-1.721
71G	70972	-3.963	-4.187	-2.296	-3.689	-3.277	-0.616	-0.602	-1.840
71H	160972	-3.863	-4.046	-2.184	-3.506	-3.133	-0.510	-0.494	-1.692
71I	250972	-3.854	-4.065	-2.176	-3.566	-3.139	-0.476	-0.460	-1.715
71J	101072	-3.819	-4.027	-2.156	-3.529	-3.088	-0.413	-0.416	-1.678
71K	271072	-3.852	-4.046	-2.172	-3.572	-3.107	-0.446	-0.432	-1.708
71L	131172	-3.925	-4.106	-2.242	-3.615	-3.146	-0.477	-0.460	-1.754
71M	271172	-3.905	-4.084	-2.224	-3.630	-3.121	-0.452	-0.436	-1.752
71N	180173	-4.015	-4.207	-2.332	-3.715	-3.250	-0.573	-0.556	-1.851
71O	160373	-4.067	-4.376	-2.407	-3.787	-3.491	-0.770	-0.771	-1.961
71P	40473	-3.795	-4.086	-2.125	-3.508	-3.194	-0.476	-0.475	-1.674
71Q	230473	-3.939	-4.209	-2.230	-3.710	-3.320	-0.626	-0.586	-1.833
71R	70573	-3.859	-4.136	-2.152	-3.612	-3.253	-0.559	-0.520	-1.747
71S	240573	-3.298	-3.700	-1.681	-3.066	-2.937	-0.235	-0.223	-1.272
71T	70673	-3.839	-4.162	-2.161	-3.627	-3.300	-0.583	-0.569	-1.771
71U	250673	-3.841	-4.180	-2.166	-3.636	-3.328	-0.604	-0.594	-1.784
71V	20873	-3.823	-4.099	-2.131	-3.519	-3.216	-0.527	-0.500	-1.689

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

EQUILIBRIUM PE

SAMP	DATE	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	PPCO2	ERROR	I.STR.
71A	290672	4.395	-0.480	-1.731	-1.326	-0.870	-1.164	-6.702	0.02407
71B	130772	3.294	-1.563	-2.057	-1.621	-1.158	-1.457	-6.898	0.02433
71C	240772	3.829	-1.029	-1.956	-1.521	-1.084	-1.355	-9.062	0.02399
71D	60872	3.795	-1.061	-1.960	-1.523	-1.077	-1.359	-7.099	0.02427
71E	200872	4.678	-0.178	-1.616	-1.223	-0.765	-1.062	-7.573	0.02433
71F	290872	3.774	-1.081	-1.957	-1.520	-1.066	-1.360	-7.735	0.02488
71G	70972	4.049	-0.806	-1.841	-1.419	-0.962	-1.257	-6.487	0.02502
71H	160972	3.787	-1.068	-1.955	-1.514	-1.064	-1.405	-6.173	0.02539
71I	250972	3.710	-1.144	-1.953	-1.515	200.000	-1.402	-5.192	0.02569
71J	101072	3.524	-1.263	-1.968	-1.528	200.000	-1.418	0.047	0.02663
71K	271072	3.921	-0.936	-1.957	-1.535	200.000	-1.332	-5.772	0.02747
71L	131172	3.980	-0.876	-1.855	-1.434	200.000	-1.301	-5.753	0.02806
71M	271172	3.927	-0.929	-1.880	-1.454	200.000	-1.318	-5.327	0.02773
71N	180173	4.238	-0.618	-1.758	-1.342	200.000	-1.213	-2.482	0.02679
71O	160373	4.426	-0.430	-1.706	-1.306	200.000	-1.188	-2.391	0.02537
71P	40473	3.556	-1.303	-2.038	-1.593	200.000	-1.491	-4.002	0.02463
71Q	230473	3.935	-0.924	-1.834	-1.469	200.000	-1.373	-0.654	0.02354
71R	70573	3.646	-1.174	-1.984	-1.548	200.000	-1.450	-1.438	0.02363
71S	240573	2.002	-2.856	-2.637	-2.122	200.000	-2.025	-7.449	0.02302
71T	70673	3.681	-1.178	-1.998	-1.563	200.000	-1.418	-5.416	0.02417
71U	250673	3.678	-1.180	-1.991	-1.554	200.000	-1.404	-0.217	0.02346
71V	20873	3.564	-1.293	-2.038	-1.559	-1.131	-1.417	-2.969	0.02440

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

APPENDIX VIe SATURATION INDEX PROGRAM OUTPUT FOR THE PERIODICAL DATA FROM SAMPLE SITE 72

TOTAL MOLARITY*

SAMP	DATE	CA	MG	ALK	S	NA	K	CL	FE
72A	290672	-2.066	-2.462	-2.209	-1.894	-3.298	-3.950	-4.501	-2.897
72B	130772	-2.072	-2.452	-2.211	-1.934	-3.294	-3.980	-4.705	-2.925
72C	240772	-2.069	-2.457	-2.211	-1.908	-3.302	-3.970	-4.758	-3.016
72D	60872	-2.065	-2.435	-2.224	-1.932	-3.273	-3.950	-4.787	-2.876
72E	200872	-2.067	-2.455	-2.234	-1.954	-3.272	-3.980	-4.626	-2.882
72F	290872	-2.085	-2.455	-2.228	-1.938	-3.313	-3.991	-4.606	-2.879
72G	70972	-2.072	-2.441	-2.229	-1.919	-3.321	-3.991	-4.587	-2.873
72H	160972	-2.067	-2.447	-2.265	-1.946	-3.302	-3.940	-4.675	-2.867
72I	250972	-2.050	-2.437	-2.276	-1.883	-3.287	-3.940	-4.676	-2.850
72J	101072	-2.050	-2.404	-2.257	-1.880	-3.291	-3.950	-4.420	-2.848
72K	271072	-2.065	-2.423	-2.306	-1.923	-3.294	-3.921	-4.591	-2.857
72L	131172	-2.072	-2.456	-2.270	-1.946	-3.321	-3.970	-4.616	-2.900
72M	271172	-2.066	-2.442	-2.280	-1.929	-3.317	-3.970	-4.564	-2.892
72N	181272	-2.060	-2.447	-2.270	-1.908	-3.317	-3.960	-4.559	-2.903
72O	160373	-2.055	-2.485	-2.264	-1.938	-3.313	-3.970	-4.564	-2.895
72P	40473	-2.055	-2.489	-2.268	-1.919	-3.306	-3.972	-4.587	-2.898
72Q	230473	-2.065	-2.435	-2.292	-1.919	-3.313	-4.027	-4.551	-2.912
72R	70573	-2.061	-2.431	-2.306	-1.938	-3.305	-4.013	-4.596	-2.909
72S	250573	-2.059	-2.459	-2.228	-1.919	-3.313	-4.008	-4.529	-2.903
72T	70673	-2.052	-2.459	-2.211	-1.927	-3.313	-4.013	-4.509	-2.906
72U	250673	-2.052	-2.460	-2.210	-1.942	-3.313	-4.025	-4.551	-2.905
72V	20773	-2.052	-2.428	-2.205	-1.894	-3.283	-4.025	-4.404	-2.881

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED

TOTAL MOLARITY*

SAMP	DATE	CU	ZN	MN	HASTOA	TDS	PH	PE	TEMP C
72A	290672	-5.880	-5.144	-3.928	-3.640	0.333	6.400	3.191	7.900
72B	130772	-6.804	-5.109	-3.915	-3.610	0.309	6.500	3.335	7.900
72C	240772	-6.222	-5.144	-3.928	-3.616	0.321	6.400	2.779	7.900
72D	60872	-6.105	-5.053	-3.915	-3.616	0.311	6.300	300.000	7.800
72E	200872	-5.763	-4.624	-3.915	-3.627	0.293	6.400	300.000	7.900
72F	290872	-6.523	-5.135	-3.915	-3.655	0.303	6.400	300.000	7.900
72G	70972	-6.503	-5.135	-3.915	-3.627	0.316	6.300	300.000	8.000
72H	160972	-6.503	-5.135	-3.915	-3.725	0.295	6.400	300.000	8.100
72I	230972	100.000	-5.126	-3.915	-3.707	0.333	6.380	300.000	7.900
72J	101072	100.000	-5.117	-3.908	-3.671	0.340	6.400	300.000	8.000
72K	271072	100.000	-5.024	-3.915	-3.671	0.304	6.380	300.000	7.900
72L	131172	100.000	-5.153	-3.961	-3.630	0.292	6.330	300.000	8.000
72M	271172	100.000	-5.144	-3.935	-3.671	0.302	6.460	300.000	8.000
72N	180173	100.000	-5.076	-3.935	-3.655	0.316	6.330	300.000	7.800
72O	160373	100.000	-5.126	-3.941	-3.679	0.293	6.390	300.000	7.900
72P	40473	100.000	-4.953	-3.941	-3.671	0.309	6.450	300.000	7.600
72Q	230473	100.000	-5.173	-3.948	-3.679	0.305	6.500	300.000	7.700
72R	70573	100.000	-5.173	-3.948	-3.667	0.293	6.410	300.000	7.700
72S	250573	100.000	-5.163	-3.941	-3.679	0.316	6.400	300.000	7.700
72T	70673	100.000	-5.084	-3.941	-3.683	0.316	6.460	300.000	7.900
72U	250673	100.000	-5.135	-3.948	-3.679	0.308	6.450	300.000	7.700
72V	20873	-7.106	-5.173	-3.928	-3.667	0.338	6.380	3.766	7.800

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED
300 = NO MEASURMENT PERFORMED

IONIC MOLARITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
72A	290672	-2.212	-2.625	-2.220	-2.047	-3.308	-3.959	-4.001	-3.028
72B	130772	-2.208	-2.604	-2.223	-2.092	-3.303	-3.989	-4.705	-3.047
72C	240772	-2.212	-2.617	-2.222	-2.061	-3.311	-3.979	-4.758	-3.144
72D	60872	-2.200	-2.606	-2.236	-2.092	-3.281	-3.958	-4.787	-2.997
72E	200872	-2.198	-2.600	-2.265	-2.117	-3.281	-3.988	-4.626	-2.998
72F	290872	-2.221	-2.606	-2.239	-2.095	-3.322	-4.000	-4.606	-3.000
72G	70972	-2.211	-2.596	-2.240	-2.077	-3.330	-4.000	-4.587	-2.997
72H	160972	-2.199	-2.594	-2.277	-2.109	-3.310	-3.988	-4.675	-2.985
72I	290972	-2.196	-2.597	-2.287	-2.042	-3.296	-3.949	-4.676	-2.982
72J	101672	-2.196	-2.565	-2.270	-2.040	-3.300	-3.959	-4.420	-2.978
72K	271072	-2.202	-2.573	-2.319	-2.085	-3.303	-3.930	-4.591	-2.990
72L	131172	-2.205	-2.597	-2.282	-2.107	-3.330	-3.978	-4.616	-3.019
72M	271172	-2.203	-2.593	-2.292	-2.090	-3.326	-3.979	-4.564	-3.015
72N	180173	-2.201	-2.603	-2.282	-2.066	-3.326	-3.969	-4.509	-3.030
72O	160373	-2.189	-2.634	-2.275	-2.099	-3.322	-3.978	-4.564	-3.016
72P	40473	-2.194	-2.642	-2.279	-2.076	-3.315	-3.981	-4.587	-3.024
72Q	230473	-2.204	-2.587	-2.304	-2.078	-3.322	-4.036	-4.551	-3.037
72R	70573	-2.195	-2.577	-2.319	-2.101	-3.314	-4.022	-4.596	-3.029
72S	250573	-2.197	-2.613	-2.239	-2.077	-3.322	-4.017	-4.523	-3.027
72T	70673	-2.189	-2.611	-2.223	-2.087	-3.322	-4.022	-4.509	-3.028
72U	250673	-2.185	-2.609	-2.221	-2.104	-3.322	-4.033	-4.551	-3.023
72V	20873	-2.196	-2.587	-2.217	-2.052	-3.293	-4.034	-4.404	-3.019

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
72A	290672	-6.298	-5.415	-4.389	-3.640	-5.507	-3.877	-5.004	-4.947
72B	130772	-7.266	-5.361	-4.356	-3.610	-5.502	-3.856	-5.040	-4.913
72C	240772	-6.620	-5.410	-4.384	-3.616	-5.507	-3.870	-5.018	-4.942
72D	60872	-6.470	-5.304	-4.353	-3.616	-5.506	-3.871	-5.019	-4.924
72E	200872	-6.155	-5.166	-4.341	-3.627	-5.533	-3.893	-5.041	-4.938
72F	290872	-6.910	-5.386	-4.354	-3.655	-5.530	-3.874	-5.061	-4.926
72G	70972	-6.869	-5.393	-4.360	-3.627	-5.526	-3.867	-5.054	-4.936
72H	160972	-6.892	-5.380	-4.343	-3.725	-5.550	-3.900	-5.063	-4.953
72I	250972	200.000	-5.398	-4.370	-3.707	-5.561	-3.919	-4.990	-4.997
72J	101072	200.000	-5.390	-4.364	-3.671	-5.546	-3.870	-4.994	-4.975
72K	271072	200.000	-5.278	-4.349	-3.679	-5.593	-3.922	-5.035	-5.003
72L	131172	200.000	-5.400	-4.333	-3.630	-5.558	-3.907	-5.079	-5.007
72M	271172	200.000	-5.397	-4.370	-3.679	-5.567	-3.914	-5.061	-4.996
72N	180173	200.000	-5.339	-4.382	-3.655	-5.556	-3.916	-5.040	-5.000
72O	160373	200.000	-5.376	-4.375	-3.679	-5.535	-3.937	-5.064	-4.983
72P	40473	200.000	-5.211	-4.375	-3.679	-5.541	-3.950	-5.036	-4.988
72Q	230473	200.000	-5.431	-4.398	-3.679	-5.577	-3.921	-5.046	-5.027
72R	70573	200.000	-5.421	-4.376	-3.667	-5.581	-3.925	-5.059	-5.028
72S	250573	200.000	-5.421	-4.387	-3.679	-5.507	-3.883	-5.046	-4.961
72T	70673	200.000	-5.338	-4.383	-3.683	-5.484	-3.865	-5.056	-4.941
72U	250673	200.000	-5.381	-4.382	-3.679	-5.475	-3.860	-5.071	-4.938
72V	70873	-7.513	-5.440	-4.384	-3.667	-5.489	-3.839	-4.996	-4.941

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
72A	290672	-9.412	-5.615	-8.530	-5.760	-8.731	-8.807	-6.337	-5.934
72B	130772	-9.276	-5.685	-8.426	-5.677	-9.596	-8.650	-6.240	-5.930
72C	240772	-9.405	-5.646	-8.535	-5.875	-9.050	-8.800	-6.339	-5.939
72D	60872	-9.478	-5.657	-8.619	-5.831	-9.004	-8.798	-6.454	-5.922
72E	200872	-9.359	-5.708	-8.546	-5.727	-8.583	-8.555	-6.382	-5.950
72F	230872	-9.373	-5.698	-8.561	-5.729	-9.339	-8.775	-6.356	-5.965
72G	70972	-9.477	-5.683	-8.670	-5.824	-9.395	-8.880	-6.456	-5.976
72H	160972	-9.354	-5.659	-8.584	-5.706	-9.312	-8.761	-6.391	-5.991
72I	250972	-9.414	-5.603	-8.608	-5.735	200.000	-8.812	-6.424	-5.992
72J	101072	-9.385	-5.612	-8.573	-5.709	200.000	-8.780	-6.385	-5.979
72K	271072	-9.330	-5.621	-8.643	-5.730	200.000	-8.683	-8.456	-6.027
72L	131172	-9.427	-5.686	-8.629	-5.761	200.000	-8.804	-6.418	-6.015
72M	271172	-9.326	-5.672	-8.557	-5.680	200.000	-8.723	-6.347	-6.022
72N	180173	-9.477	-5.643	-8.681	-5.835	200.000	-8.804	-6.470	-6.014
72O	160373	-9.404	-5.685	-8.606	-5.755	200.000	-8.775	-6.402	-6.000
72P	40473	-9.357	-5.665	-8.548	-5.716	200.000	-8.563	-6.349	-5.999
72Q	230473	-9.317	-5.721	-8.530	-5.675	200.000	-8.729	-6.324	-6.031
72R	70573	-9.394	-5.728	-8.625	-5.756	200.000	-8.808	-6.428	-6.036
72S	250573	-9.326	-5.702	-8.475	-5.676	200.000	-8.730	-6.269	-5.967
72T	70673	-9.344	-5.715	-8.486	-5.693	200.000	-8.668	-6.279	-5.950
72U	250673	-9.361	-5.744	-8.477	-5.711	200.000	-8.730	-6.291	-5.948
72V	20573	-9.432	-5.698	-8.535	-5.777	-9.970	-8.858	-6.356	-5.918

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
72A	290672	-6.520	-3.483	-5.791	-6.647	-4.181	-2.611	-3.026	-11.839
72B	130772	-6.498	-3.539	-5.773	-7.651	-4.185	-2.644	-3.043	-11.704
72C	240772	-6.512	-3.608	-5.794	-6.977	-4.185	-2.620	-3.028	-11.833
72D	60872	-6.614	-3.491	-5.719	-6.857	-4.185	-2.638	-3.048	-11.916
72E	200872	-6.534	-3.512	-5.600	-6.561	-4.191	-2.654	-3.060	-11.829
72F	290872	-6.515	-3.493	-5.800	-7.296	-4.184	-2.657	-3.046	-11.817
72G	70972	-6.607	-3.478	-5.794	-7.242	-4.178	-2.635	-3.022	-11.926
72H	160972	-6.538	-3.492	-5.807	-7.291	-4.187	-2.649	-3.046	-11.841
72I	230972	-6.582	-3.436	-5.773	200.000	-4.162	-2.594	-2.998	-11.910
72J	101072	-6.512	-3.435	-5.766	200.000	-4.157	-2.595	-2.966	-11.967
72K	271072	-6.584	-3.468	-5.687	200.000	-4.174	-2.633	-3.008	-11.914
72L	131172	-6.566	-3.522	-5.823	200.000	-4.232	-2.651	-3.046	-11.916
72M	271172	-6.494	-3.505	-5.858	200.000	-4.197	-2.636	-3.029	-11.826
72N	100173	-6.629	-3.501	-5.730	200.000	-4.190	-2.616	-3.021	-11.963
72O	160373	-6.588	-3.513	-5.771	200.000	-4.209	-2.630	-3.078	-11.884
72P	40473	-6.547	-3.502	-5.611	200.000	-4.190	-2.617	-3.070	-11.833
72Q	230473	-6.466	-3.517	-5.832	200.000	-4.206	-2.628	-3.016	-11.821
72R	70573	-6.559	-3.529	-5.842	200.000	-4.214	-2.639	-3.026	-11.912
72S	250573	-6.438	-3.509	-5.823	200.000	-4.205	-2.622	-3.043	-11.766
72T	70673	-6.447	-3.513	-5.743	200.000	-4.211	-2.623	-3.049	-11.773
72U	250673	-6.455	-3.529	-5.808	200.000	-4.225	-2.634	-3.063	-11.782
72V	20873	-6.503	-3.484	-5.826	-7.871	-4.186	-2.604	-2.999	-11.855

*LOG TO THE BASE 10
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
72A	200672	-9.362	-5.882	-6.230
72B	130772	-9.177	-5.776	-7.095
72C	240772	-9.476	-5.881	-6.550
72D	60872	-9.536	-5.983	-6.514
72E	200872	-9.327	-5.906	-6.125
72F	290872	-9.329	-5.904	-6.854
72G	70972	-9.520	-5.997	-6.917
72H	160972	-9.297	-5.917	-6.872
72I	250972	-96357	-5.956	200.000
72J	101072	-9.307	-5.918	200.000
72K	271072	-9.351	-5.987	200.000
72L	131172	-9.378	-5.948	200.000
72M	271172	-9.216	-5.878	200.000
72N	180173	-9.510	-6.003	200.000
72O	160373	-9.365	-5.918	200.000
72P	40473	-9.278	-5.874	200.000
72Q	230473	-9.183	-5.857	200.000
72R	70573	-9.354	-5.951	200.000
72S	250573	-9.195	-5.797	200.000
72T	70673	-9.240	-5.799	200.000
72U	250673	-9.270	-5.805	200.000
72V	20873	-9.403	-5.887	-7.465

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
72A	290672	-2.409	-2.887	-2.298	-2.360	-3.386	-4.043	-4.085	-3.315
72B	130772	-2.492	-2.864	-2.300	-2.400	-3.380	-4.071	-4.788	-3.331
72C	240772	-2.497	-2.877	-2.300	-2.371	-3.389	-4.062	-4.841	-3.429
72D	60872	-2.484	-2.906	-2.313	-2.402	-3.359	-4.041	-4.870	-3.281
72E	200872	-2.479	-2.858	-2.342	-2.423	-3.358	-4.070	-4.708	-3.280
72F	290872	-2.503	-2.864	-2.316	-2.402	-3.399	-4.082	-4.688	-3.283
72G	70972	-2.497	-2.857	-2.318	-2.388	-3.408	-4.083	-4.670	-3.282
72H	180972	-2.482	-2.853	-2.354	-2.416	-3.387	-4.030	-4.758	-3.268
72I	250972	-2.486	-2.862	-2.366	-2.357	-3.375	-4.034	-4.760	-3.271
72J	101072	-2.487	-2.930	-2.349	-2.357	-3.380	-4.044	-4.505	-3.269
72K	271072	-2.486	-2.933	-2.396	-2.395	-3.381	-4.013	-4.674	-3.264
72L	131172	-2.487	-2.955	-2.359	-2.413	-3.406	-4.060	-4.698	-3.301
72M	271172	-2.486	-2.852	-2.369	-2.398	-3.403	-4.061	-4.646	-3.298
72N	180173	-2.487	-2.864	-2.360	-2.377	-3.404	-4.052	-4.592	-3.316
72O	160373	-2.472	-2.892	-2.352	-2.406	-3.399	-4.060	-4.646	-3.299
72P	40473	-2.478	-2.902	-2.356	-2.386	-3.392	-4.063	-4.669	-3.308
72Q	230473	-2.488	-2.847	-2.382	-2.388	-3.400	-4.119	-4.633	-3.321
72R	70573	-2.477	-2.836	-2.396	-2.409	-3.391	-4.104	-4.678	-3.312
72S	250573	-2.483	-2.874	-2.317	-2.388	-3.400	-4.099	-4.612	-3.313
72T	70673	-2.474	-2.873	-2.399	-2.398	-3.400	-4.105	-4.592	-3.314
72U	250673	-2.469	-2.869	-2.299	-2.413	-3.399	-4.116	-4.633	-3.307
72V	20873	-2.485	-2.851	-2.296	-2.367	-3.372	-4.119	-4.489	-3.309

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CU++	ZN++	MN++	HASIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
72A	290672	-6.586	-5.702	-4.676	-3.640	-5.586	-3.955	-5.082	-5.025
72B	130772	-7.549	-5.644	-4.639	-3.610	-5.580	-3.934	-5.117	-4.990
72C	240772	-6.904	-5.695	-4.669	-3.616	-5.585	-3.947	-5.096	-5.020
72D	60872	-6.754	-5.583	-4.638	-3.616	-5.584	-3.949	-5.097	-5.001
72E	200872	-6.437	-5.448	-4.622	-3.627	-5.609	-3.970	-5.117	-5.015
72F	290872	-7.192	-5.669	-4.636	-3.655	-5.607	-3.950	-5.138	-5.003
72G	70972	-7.154	-5.678	-4.645	-3.627	-5.604	-3.945	-5.132	-5.014
72H	160972	-7.175	-5.663	-4.625	-3.725	-5.626	-3.977	-5.140	-5.030
72I	250972	200.000	-5.688	-4.560	-3.707	-5.640	-3.998	-5.069	-5.076
72J	101072	200.000	-5.681	-4.655	-3.671	-5.625	-3.949	-5.073	-5.035
72K	271072	200.000	-5.563	-4.634	-3.679	-5.670	-3.999	-5.112	-5.080
72L	131172	200.000	-5.682	-4.674	-3.690	-5.635	-3.984	-5.156	-5.083
72M	271172	200.000	-5.681	-4.654	-3.679	-5.644	-3.991	-5.138	-5.073
72N	180173	200.000	-5.624	-4.667	-3.655	-5.633	-3.993	-5.117	-5.077
72O	160373	200.000	-5.658	-4.658	-3.679	-5.612	-4.014	-5.141	-5.060
72P	40473	200.000	-5.695	-4.659	-3.679	-5.618	-4.028	-5.113	-5.065
72Q	230473	200.000	-5.715	-4.673	-3.679	-5.655	-3.939	-5.123	-5.105
72R	70573	200.000	-5.704	-4.659	-3.667	-5.658	-4.001	-5.136	-5.105
72S	250573	200.000	-5.706	-4.672	-3.679	-5.584	-3.961	-5.124	-5.039
72T	70673	200.000	-5.623	-4.668	-3.683	-5.562	-3.942	-5.134	-5.019
72U	250673	200.000	-5.666	-4.666	-3.679	-5.553	-3.937	-5.148	-5.016
72V	20873	-7.802	-5.730	-4.673	-3.667	-5.568	-3.917	-5.075	-5.020

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION.

IONIC ACTIVITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
72A	200672	-9.490	-5.693	-8.608	-5.888	-8.809	-8.886	-6.414	-5.934
72B	130772	-9.353	-5.762	-8.503	-5.754	-9.673	-9.728	-6.316	-5.930
72C	240772	-9.483	-5.724	-8.612	-5.953	-9.128	-8.878	-6.416	-5.939
72D	60872	-9.555	-5.734	-8.636	-5.908	-9.081	-8.876	-6.530	-5.922
72E	200872	-9.436	-5.784	-8.622	-5.803	-8.660	-8.631	-6.458	-5.950
72F	200872	-9.450	-5.775	-8.637	-5.806	-9.415	-8.852	-6.432	-5.965
72G	70972	-9.555	-5.760	-8.748	-5.901	-9.473	-8.937	-6.533	-5.976
72H	160972	-9.431	-5.736	-8.661	-5.783	-9.389	-8.838	-6.467	-5.991
72I	250972	-9.493	-5.681	-8.686	-5.814	200.000	-8.891	-6.502	-5.992
72J	101072	-9.464	-5.691	-8.653	-5.788	200.000	-8.859	-6.464	-5.979
72K	271072	-9.468	-5.699	-8.720	-5.808	200.000	-8.766	-6.532	-6.027
72L	131172	-9.504	-5.763	-8.706	-5.839	200.000	-8.881	-6.493	-6.015
72M	271172	-9.403	-5.747	-8.634	-5.757	200.000	-8.800	-6.424	-6.022
72N	180173	-9.555	-5.720	-8.759	-5.913	200.000	-8.881	-6.547	-6.014
72O	160373	-9.481	-5.757	-8.693	-5.832	200.000	-8.852	-6.478	-6.000
72P	40473	-9.434	-5.742	-8.625	-5.793	200.000	-8.641	-6.426	-5.998
72Q	230473	-9.394	-5.799	-8.607	-5.752	200.000	-8.806	-6.400	-6.031
72R	70573	-9.471	-5.805	-8.702	-5.833	200.000	-8.883	-6.504	-6.036
72S	250573	-9.404	-5.780	-8.553	-5.754	200.000	-8.807	-6.345	-5.967
72T	70673	-9.422	-5.793	-8.564	-5.777	200.000	-8.746	-6.356	-5.950
72U	250673	-9.438	-5.821	-8.574	-5.789	200.000	-8.807	-6.367	-5.948
72V	20873	-9.511	-5.777	-8.614	-5.856	-10.049	-8.937	-6.433	-5.918

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
72A	290672	-6.520	-3.483	-5.791	-6.647	-4.181	-2.611	-3.026	-11.839
72B	130772	-6.398	-3.539	-5.773	-7.651	-4.185	-2.644	-3.043	-11.704
72C	240772	-6.512	-3.608	-5.794	-6.977	-4.185	-2.620	-3.028	-11.833
72D	60872	-6.614	-3.491	-5.719	-6.857	-4.185	-2.638	-3.048	-11.916
72E	200872	-6.534	-3.512	-5.600	-6.561	-4.191	-2.654	-3.060	-11.829
72F	290872	-6.515	-3.493	-5.800	-7.296	-4.184	-2.657	-3.046	-11.917
72G	70972	-6.607	-3.478	-5.794	-7.242	-4.178	-2.635	-3.022	-11.926
72H	160972	-6.538	-3.492	-5.807	-7.291	-4.187	-2.649	-3.046	-11.841
72I	250972	-6.582	-3.436	-5.773	200.000	-4.162	-2.594	-2.993	-11.910
72J	101072	-6.512	-3.435	-5.766	200.000	-4.157	-2.595	-2.966	-11.867
72K	271072	-6.584	-3.468	-5.687	200.000	-4.174	-2.633	-3.008	-11.914
72L	131172	-6.566	-3.522	-5.823	200.000	-4.232	-2.651	-3.046	-11.916
72M	271172	-6.494	-3.505	-5.808	200.000	-4.197	-2.636	-3.029	-11.826
72N	180173	-6.629	-3.501	-5.730	200.000	-4.190	-2.616	-3.021	-11.963
72O	160373	-6.589	-3.513	-5.793	200.000	-4.209	-2.630	-3.078	-11.884
72P	40473	-6.547	-3.502	-5.611	200.000	-4.190	-2.617	-3.070	-11.833
72Q	230473	-6.466	-3.517	-5.832	200.000	-4.206	-2.628	-3.016	-11.821
72R	70573	-6.559	-3.529	-5.842	200.000	-4.214	-2.639	-3.026	-11.912
72S	250573	-6.438	-3.509	-5.823	200.000	-4.205	-2.622	-3.043	-11.766
72T	70673	-6.447	-3.519	-5.749	200.000	-4.211	-2.623	-3.049	-11.773
72U	250673	-6.455	-3.529	-5.808	200.000	-4.225	-2.634	-3.063	-11.782
72V	20873	-6.503	-3.484	-5.826	-7.871	-4.186	-2.604	-2.999	-11.855

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
72A	290672	-9.362	-5.882	-6.230
72B	130772	-9.177	-5.776	-7.095
72C	240772	-9.476	-5.881	-6.550
72D	60872	-9.536	-5.983	-6.514
72E	200872	-9.327	-5.906	-6.125
72F	270872	-9.329	-5.904	-6.854
72G	70972	-9.520	-5.997	-6.917
72H	160972	-9.297	-5.917	-6.872
72I	250972	-9.357	-5.956	200.000
72J	101072	-9.307	-5.918	200.000
72K	271072	-9.351	-5.987	200.000
72L	131172	-9.378	-5.946	200.000
72M	271172	-9.216	-5.878	200.000
72N	180173	-9.510	-6.003	200.000
72O	160373	-9.365	-5.918	200.000
72P	40473	-9.278	-5.874	200.000
72Q	230473	-9.183	-5.857	200.000
72R	70573	-9.354	-5.951	200.000
72S	250573	-9.195	-5.797	200.000
72T	70673	-9.240	-5.799	200.000
72U	250673	-9.270	-5.803	200.000
72V	20873	-9.403	-5.887	-7.465

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
72A	290672	-8.914	-9.729	-9.301	-18.215	-12.117	-11.091	-4.859	-6.786
72B	130772	-8.808	-9.646	-9.180	-17.987	-11.960	-10.955	-4.892	-8.415
72C	240772	-8.913	-9.845	-9.293	-18.206	-12.111	-11.085	-4.868	-7.425
72D	60872	-9.015	-9.811	-9.396	-18.410	-12.119	-11.168	-4.886	-7.438
72E	200872	-8.937	-9.738	-9.316	-18.253	-11.906	-11.080	-4.903	-6.539
72F	290872	-8.935	-9.715	-9.296	-18.232	-12.100	-11.068	-4.906	-8.016
72G	70972	-9.029	-9.815	-9.389	-18.419	-12.211	-11.178	-4.884	-8.240
72H	160972	-8.949	-9.735	-9.320	-18.269	-12.130	-11.093	-4.898	-8.017
72I	250972	-8.988	-9.783	-9.364	-18.352	-12.190	-11.162	-4.843	200.000
72J	101072	-8.961	-9.733	-9.294	-18.245	-12.144	-11.119	-4.844	200.000
72K	271072	-9.019	-9.797	-9.365	-18.384	-12.095	-11.166	-4.882	200.000
72L	131172	-8.990	-9.794	-9.348	-18.329	-12.175	-11.168	-4.900	200.000
72M	271172	-8.910	-9.722	-9.276	-18.185	-12.104	-11.077	-4.895	200.000
72N	180173	-9.034	-9.863	-9.411	-18.445	-12.171	-11.214	-4.864	200.000
72O	160373	-8.950	-9.776	-9.370	-18.320	-12.136	-11.135	-4.878	200.000
72P	40473	-8.904	-9.734	-9.328	-18.232	-11.921	-11.095	-4.864	200.000
72Q	230473	-8.888	-9.721	-9.247	-18.135	-12.115	-11.073	-4.876	200.000
72R	70573	-8.992	-9.816	-9.340	-18.328	-12.208	-11.163	-4.886	200.000
72S	250573	-8.828	-9.658	-9.219	-18.047	-12.051	-11.017	-4.870	200.000
72T	70673	-8.830	-9.670	-9.228	-18.059	-11.979	-11.025	-4.871	200.000
72U	250673	-8.836	-9.675	-9.236	-18.072	-12.033	-11.034	-4.882	200.000
72V	20871	-9.018	-9.742	-9.285	-18.203	-12.163	-11.107	-4.852	-9.278

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF=K
72A	290672	-19.796	9.913	15.885	15.885	7.888	7.408	7.314	-4.922
72B	130772	-22.280	10.136	16.169	16.169	8.009	7.506	7.480	-4.792
72C	240772	-20.745	9.923	15.771	15.771	7.898	7.408	7.342	-4.893
72D	60872	-20.722	9.734	15.619	15.619	7.777	7.299	7.227	-4.972
72E	200872	-19.426	9.942	15.920	15.920	7.895	7.384	7.310	-4.923
72F	290872	-21.640	9.936	15.917	15.917	7.892	7.409	7.355	-4.991
72G	70972	-21.927	9.743	15.617	15.617	7.776	7.308	7.251	-5.036
72H	160972	-21.658	9.947	15.932	15.932	7.893	7.410	7.355	-5.080
72I	230972	200.000	9.998	15.869	15.869	7.862	7.386	200.000	-5.069
72J	131072	200.000	9.970	15.931	15.931	7.885	7.405	200.000	-4.986
72K	271072	200.000	9.927	15.876	15.876	7.867	7.375	200.000	-4.991
72L	131172	200.000	9.905	15.839	15.839	7.872	7.392	200.000	-5.059
72M	271172	200.000	10.068	16.082	16.082	7.961	7.470	200.000	-4.959
72N	180173	200.000	9.796	15.674	15.674	7.811	7.336	200.000	-5.032
72O	160373	200.000	9.888	15.871	15.871	7.882	7.399	200.000	-5.029
72P	40473	200.000	9.999	16.042	16.042	7.949	7.435	200.000	-4.972
72Q	230473	200.000	10.153	16.179	16.179	8.007	7.513	200.000	-4.977
72R	70573	200.000	9.984	15.918	15.918	7.906	7.424	200.000	-5.028
72S	250573	200.000	10.106	16.157	16.157	7.995	7.502	200.000	-4.968
72T	70673	200.000	10.048	16.066	16.066	7.962	7.463	200.000	-5.012
72U	250673	200.000	10.031	16.043	16.043	7.952	7.460	200.000	-5.024
72V	20873	-23.513	9.909	15.831	15.831	7.866	7.392	7.370	-5.072

*LOG TO THE BASE 10
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
72A	290672	10.301	-4.265	45.925	2.357	-11.544	-18.816	-19.204	-0.475
72B	130772	10.508	-4.101	47.071	2.429	-11.322	-18.375	-18.747	-0.341
72C	240772	10.303	-4.220	45.907	2.338	-11.452	-18.623	-19.003	-0.455
72D	60872	10.116	-4.290	45.056	2.259	-11.522	-18.810	-19.191	-0.550
72E	200872	10.321	-4.211	46.084	2.330	-11.464	-18.691	-19.070	-0.468
72F	290872	10.297	-4.309	46.023	2.318	-11.618	-18.943	-19.304	-0.511
72G	70972	10.103	-4.361	45.090	2.217	-11.614	-18.909	-19.269	-0.586
72H	160972	10.318	-4.437	46.012	2.370	-11.886	-19.480	-19.851	-0.561
72I	250972	10.274	-4.409	45.786	2.346	-11.823	-19.381	-19.756	-0.566
72J	101072	10.313	-4.321	46.177	2.356	-11.663	-19.054	-19.398	-0.499
72K	271072	10.274	-4.359	45.955	2.367	-11.717	-19.159	-19.506	-0.513
72L	131172	10.273	-4.405	45.836	2.320	-11.784	-19.243	-19.611	-0.559
72M	271172	10.434	-4.301	46.660	2.399	-11.659	-18.999	-19.365	-0.458
72N	180173	10.173	-4.384	45.326	2.278	-11.694	-19.067	-19.443	-0.570
72O	160373	10.308	-4.367	45.759	2.330	-11.725	-19.124	-19.545	-0.545
72P	00473	10.422	-4.300	46.311	2.387	-11.658	-19.011	-19.434	-0.483
72Q	230473	10.512	-4.258	47.085	2.381	-11.616	-18.920	-19.280	-0.444
72R	70573	10.343	-4.315	46.253	2.306	-11.648	-18.992	-19.350	-0.521
72S	250573	10.497	-4.268	46.851	2.391	-11.626	-18.935	-19.327	-0.454
72T	70673	10.446	-4.306	46.555	2.355	-11.673	-19.020	-19.418	-0.495
72U	230673	10.431	-4.307	46.478	2.334	-11.665	-19.001	-19.401	-0.507
72V	20873	10.275	-4.325	45.876	2.261	-11.659	-19.060	-19.426	-0.566

*LOG TO THE BASE 10
200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
72A	290672	-0.512	0.654	-1.461	-0.763	-1.413	-0.684	-0.234	-0.808
72B	130772	-0.406	0.737	-1.339	-0.651	-1.257	-0.549	-0.267	-1.622
72C	240772	-0.512	0.538	-1.453	-0.761	-1.407	-0.679	-0.243	-1.127
72D	60872	-0.613	0.572	-1.557	-0.863	-1.412	-0.762	-0.261	-1.134
72E	200872	-0.536	0.645	-1.475	-0.784	-1.203	-0.674	-0.278	-0.681
72F	290872	-0.534	0.669	-1.456	-0.773	-1.397	-0.662	-0.281	-1.423
72G	70972	-0.628	0.571	-1.547	-0.866	-1.504	-0.776	-0.259	-1.535
72H	160972	-0.547	0.652	-1.476	-0.790	-1.423	-0.690	-0.274	-1.423
72I	250972	-0.586	0.610	-1.523	-0.833	-1.487	-0.756	-0.218	200.000
72J	101072	-0.549	0.654	-1.482	-0.779	-1.437	-0.716	-0.219	200.000
72K	271072	-0.617	0.587	-1.525	-0.849	-1.392	-0.760	-0.257	200.000
72L	131172	-0.579	0.593	-1.506	-0.821	-1.468	-0.765	-0.275	200.000
72M	271172	-0.508	0.665	-1.434	-0.749	-1.397	-0.675	-0.260	200.000
72N	180173	-0.633	0.521	-1.572	-0.880	-1.464	-0.798	-0.239	200.000
72O	140373	-0.548	0.607	-1.529	-0.817	-1.433	-0.720	-0.253	200.000
72P	40473	-0.504	0.643	-1.491	-0.775	-1.214	-0.682	-0.233	200.000
72Q	230473	-0.487	0.659	-1.410	-0.726	-1.408	-0.667	-0.250	200.000
72R	70573	-0.591	0.564	-1.503	-0.819	-1.501	-0.757	-0.261	200.000
72S	250573	-0.427	0.722	-1.382	-0.682	-1.144	-0.611	-0.245	200.000
72T	70673	-0.429	0.713	-1.388	-0.687	-1.276	-0.618	-0.246	200.000
72U	230673	-0.435	0.705	-1.398	-0.694	-1.326	-0.628	-0.257	200.000
72V	20873	-0.517	0.642	-1.446	-0.753	-1.456	-0.700	-0.227	-2.054

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
72A	290672	-1.448	-4.019	0.043	-1.575	-4.682	-4.508	-3.425	-2.073
72B	130772	-2.695	-3.907	-0.093	-1.718	-4.947	-4.750	-4.135	-1.942
72C	240772	-1.928	-4.014	0.219	-1.400	-4.280	-4.097	-3.442	-2.044
72D	60872	-1.916	-4.112	200.000	200.000	200.000	200.000	200.000	-2.121
72E	200872	-1.268	-4.005	200.000	200.000	200.000	200.000	200.000	-2.074
72F	290872	-2.375	-4.008	200.000	200.000	200.000	200.000	200.000	-2.142
72G	70972	-2.519	-4.100	200.000	200.000	200.000	200.000	200.000	-2.189
72H	160972	-2.384	-3.995	200.000	200.000	200.000	200.000	200.000	-2.235
72I	250972	200.000	-4.026	200.000	200.000	200.000	200.000	200.000	-2.218
72J	101072	200.000	-3.987	200.000	200.000	200.000	200.000	200.000	-2.139
72K	271072	200.000	-4.012	200.000	200.000	200.000	200.000	200.000	-2.141
72L	131172	200.000	-4.019	200.000	200.000	200.000	200.000	200.000	-2.212
72M	271172	200.000	-3.938	200.000	200.000	200.000	200.000	200.000	-2.112
72N	180173	200.000	-4.081	200.000	200.000	200.000	200.000	200.000	-2.180
72O	160373	200.000	-4.032	200.000	200.000	200.000	200.000	200.000	-2.179
72P	40473	200.000	-3.989	200.000	200.000	200.000	200.000	200.000	-2.116
72Q	230473	200.000	-3.907	200.000	200.000	200.000	200.000	200.000	-2.123
72R	70573	200.000	-3.941	200.000	200.000	200.000	200.000	200.000	-2.174
72S	250573	200.000	-3.930	200.000	200.000	200.000	200.000	200.000	-2.114
72T	70673	200.000	-3.952	200.000	200.000	200.000	200.000	200.000	-2.162
72U	250673	200.000	-3.967	200.000	200.000	200.000	200.000	200.000	-2.170
72V	20873	-3.311	-4.025	-0.128	-1.747	-5.232	-5.065	-4.454	-2.221

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
72A	290672	-4.096	-4.327	-2.477	-3.541	-3.608	-1.134	-1.167	-1.948
72B	130772	-3.992	-4.163	-2.363	-3.470	-3.385	-0.913	-0.939	-1.826
72C	240772	-4.093	-4.282	-2.470	-3.561	-3.515	-1.037	-1.067	-1.930
72D	60872	-4.123	-4.351	-2.568	-3.641	-3.583	-1.130	-1.161	-2.016
72E	200872	-4.086	-4.272	-2.462	-3.569	-3.527	-1.072	-1.100	-1.942
72F	230872	-4.098	-4.320	-2.468	-3.580	-3.682	-1.197	-1.217	-1.981
72G	70972	-4.100	-4.323	-2.558	-3.680	-3.680	-1.181	-1.200	-2.048
72H	140972	-4.078	-4.439	-2.462	-3.525	-3.954	-1.468	-1.491	-2.025
72I	250972	-4.109	-4.471	-2.491	-3.552	-3.887	-1.416	-1.444	-2.031
72J	101072	-4.085	-4.391	-2.449	-3.541	-3.720	-1.254	-1.265	-1.969
72K	271072	-4.109	-4.420	-2.474	-3.531	-3.781	-1.305	-1.318	-1.982
72L	131172	-4.105	-4.407	-2.483	-3.577	-3.850	-1.348	-1.371	-2.024
72M	271172	-4.095	-4.363	-2.401	-3.498	-3.725	-1.226	-1.248	-1.932
72N	180173	-4.164	-4.445	-2.541	-3.622	-3.756	-1.258	-1.287	-2.035
72O	160374	-4.092	-4.429	-2.494	-3.560	-3.789	-1.288	-1.338	-2.012
72P	40473	-4.048	-4.361	-2.449	-3.517	-3.716	-1.229	-1.262	-1.957
72Q	230473	-3.999	-4.319	-2.368	-3.521	-3.676	-1.184	-1.205	-1.924
72R	70573	-4.084	-4.376	-2.451	-3.596	-3.708	-1.220	-1.240	-1.990
72S	250573	-4.006	-4.329	-2.391	-3.512	-3.686	-1.192	-1.228	-1.930
72T	70673	-4.023	-4.368	-2.414	-3.544	-3.737	-1.236	-1.275	-1.966
72U	250673	-4.049	-4.368	-2.429	-3.568	-3.725	-1.225	-1.265	-1.978
72V	20873	-4.113	-4.387	-2.486	-3.639	-3.721	-1.255	-1.278	-2.031

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

EQUILIBRIUM PE

SAMP	DATE	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	PPCO2	ERROR	I.STR.
72A	290672	3.321	-1.534	-1.491	-1.317	-0.634	-0.985	-9.765	0.04035
72B	130772	3.036	-1.819	-1.612	-1.415	-0.800	-1.087	-5.199	0.03981
72C	240772	3.435	-1.420	-1.501	-1.318	-0.663	-0.987	-9.438	0.03940
72D	60872	3.595	-1.261	-1.378	-1.206	-0.545	-0.900	-3.609	0.03918
72E	200872	3.286	-1.569	-1.498	-1.293	-0.631	-1.029	-0.345	0.03823
72F	290872	3.288	-1.566	-1.495	-1.318	-0.675	-1.003	-4.941	0.03840
72G	70972	3.580	-1.274	-1.381	-1.220	-0.574	-0.904	-5.465	0.03947
72H	160972	3.257	-1.596	-1.501	-1.324	-0.680	-1.040	-0.556	0.03849
72I	250972	3.337	-1.518	-1.465	-1.295	200.000	-1.033	-6.000	0.04111
72J	101072	3.267	-1.587	-1.490	-1.317	200.000	-1.035	-5.600	0.04171
72K	271072	3.330	-1.525	-1.470	-1.284	200.000	-1.063	-0.949	0.03934
72L	131172	3.358	-1.496	-1.477	-1.304	200.000	-1.025	-1.608	0.03915
72M	271172	3.116	-1.736	-1.667	-1.382	200.000	-1.115	-2.414	0.03988
72N	190173	3.539	-1.316	-1.411	-1.237	200.000	-0.977	-5.153	0.03971
72O	160373	3.334	-1.520	-1.485	-1.307	200.000	-1.029	-2.330	0.03857
72P	40473	3.188	-1.669	-1.543	-1.337	200.000	-1.094	-4.798	0.03912
72Q	250473	3.043	-1.814	-1.604	-1.418	200.000	-1.170	-3.299	0.03917
72R	70573	3.304	-1.553	-1.504	-1.329	200.000	-1.093	0.164	0.03866
72S	250573	3.065	-1.792	-1.592	-1.407	200.000	-1.095	-5.354	0.03955
72T	70673	3.139	-1.716	-1.565	-1.372	200.000	-1.047	-4.347	0.03957
72U	250673	3.179	-1.677	-1.550	-1.365	200.000	-1.037	-2.530	0.03912
72V	20773	3.382	-1.473	-1.466	-1.299	-0.688	-0.964	-7.141	0.04111

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

APPENDIX VIf SATURATION INDEX PROGRAM OUTPUT FOR THE PERIODICAL DATA FROM SAMPLE SITE 73

TOTAL MOLARITY*

SAMP	DATE	CA	MG	ALK	S	NA	K	CL	FE
73A	300672	-2.968	-2.939	-2.655	-2.821	-4.019	-4.822	-4.704	-4.747
73B	130772	-2.914	-2.978	-2.624	-2.840	-4.000	-4.822	-4.554	-4.747
73C	240772	-3.010	-2.964	-2.710	-2.933	-4.039	-4.868	-4.508	-4.706
73D	100872	-3.004	-2.976	-2.699	-2.941	-4.039	-4.876	-4.554	-4.866
73E	170872	-3.019	-2.976	-2.703	-2.961	-4.054	-4.902	-4.610	-4.497
73F	290872	-2.916	-2.895	-2.643	-2.810	-4.000	-4.852	-4.471	-4.756
73G	70972	-2.873	-2.847	-2.612	-2.752	-3.974	-4.822	-4.508	-4.756
73H	160972	-2.831	-2.782	-2.643	-2.688	-3.964	-4.729	-4.471	-4.687
73I	250972	-2.802	-2.780	-2.627	-2.648	-3.947	-4.717	-4.471	-4.592
73J	101072	-2.776	-2.746	-2.621	-2.569	-3.937	-4.760	-4.374	-4.369
73K	271072	-2.758	-2.729	-2.627	-2.564	-3.915	-4.747	-4.313	-4.592
73L	131172	-2.796	-2.766	-2.668	-2.615	-3.930	-4.760	-4.295	-4.640
73M	271172	-2.805	-2.782	-2.668	-2.663	-3.930	-4.754	-4.317	-4.607
73N	180173	-2.929	-2.899	-2.733	-2.792	-4.019	-4.844	-4.404	-4.779
73O	160373	-3.091	-3.015	-2.795	-2.996	-4.106	-4.911	-4.508	-4.849
73P	40473	-3.162	-3.058	-2.831	-3.085	-4.131	-4.969	-4.508	-4.941
73Q	230473	-3.263	-3.148	-2.827	-3.080	-4.106	-4.959	-4.508	-5.048
73R	70573	-3.126	-3.044	-2.790	-3.048	-4.106	-4.969	-4.471	-5.114
73S	240573	-3.156	-3.119	-2.777	-3.150	-4.158	-5.013	-4.471	-5.167
73T	70673	-3.099	-3.078	-2.740	-3.000	-4.139	-4.980	-4.436	-5.167
73U	230673	-3.042	-3.034	-2.703	-2.937	-4.106	-4.939	-4.404	-5.124
73V	20873	-2.929	-2.886	-2.643	-2.787	-4.019	-4.868	-4.309	-4.808

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED

TOTAL MOLARITY*

SAMP	DATE	CU	ZN	MN	H4SIO4	TDS	PH	PE	TEMP C
73A	300672	100.000	-4.271	-4.661	-3.805	-0.424	6.200	5.614	7.800
73B	130772	100.000	-4.206	-4.597	-3.807	-0.408	7.100	5.703	7.800
73C	240772	100.000	-4.327	-4.723	-3.830	-0.494	6.700	6.228	7.600
73D	100872	100.000	-4.308	-4.695	-3.822	-0.493	7.000	300.000	7.800
73E	170872	100.000	-4.327	-4.740	-3.819	-0.502	6.850	300.000	7.800
73F	290872	100.000	-4.188	-4.582	-3.802	-0.404	6.750	300.000	7.800
73G	70972	100.000	-4.126	-4.510	-3.796	-0.362	6.650	300.000	7.800
73H	160972	100.000	-4.082	-4.461	-3.783	-0.333	6.620	300.000	7.800
73I	250972	100.000	-4.064	-4.428	-3.781	-0.306	6.650	300.000	7.700
73J	101072	100.000	-4.014	-4.378	-3.778	-0.262	6.720	300.000	7.800
73K	271072	100.000	-3.986	-4.342	-3.765	-0.256	6.720	300.000	7.700
73L	131172	100.000	-4.035	-4.422	-3.778	-0.300	6.400	300.000	7.800
73M	271172	100.000	-4.022	-4.398	-3.765	-0.323	6.550	300.000	7.800
73N	180173	100.000	-4.180	-4.564	-3.807	-0.429	6.520	300.000	7.900
73O	160373	100.000	-4.304	-4.727	-3.862	-0.563	6.700	300.000	7.600
73P	40473	100.000	-4.362	-4.735	-3.870	-0.622	6.700	300.000	7.450
73Q	230473	100.000	-4.359	-4.719	-3.857	-0.635	6.620	300.000	7.400
73R	70573	100.000	-4.279	-4.731	-3.861	-0.586	6.860	300.000	7.400
73S	240573	100.000	-4.367	-4.826	-3.911	-0.627	6.910	300.000	7.400
73T	70673	100.000	-4.353	-4.744	-3.877	-0.553	6.860	300.000	7.400
73U	250673	100.000	-4.284	-4.679	-3.854	-0.504	6.730	300.000	7.500
73V	20873	100.000	-4.108	-4.564	-3.827	-0.396	6.750	6.443	7.800

*LOG TO THE BASE 10

100 = NOT DETECTED BY THE METHOD USED
300 = NO MEASURMENT PERFORMED

IONIC MOLARITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
73A	300672	-3.014	-2.993	-2.661	-2.893	-4.021	-4.823	-4.404	-4.788
73B	130772	-2.957	-2.930	-2.632	-2.920	-4.002	-4.823	-4.554	-4.789
73C	240772	-3.047	-3.009	-2.716	-3.004	-4.041	-4.870	-4.508	-4.741
73D	100872	-3.041	-3.021	-2.705	-3.011	-4.041	-4.878	-4.554	-4.903
73E	170872	-3.084	-3.019	-2.709	-3.031	-4.056	-4.904	-4.610	-4.531
73F	290872	-2.961	-2.949	-2.649	-2.888	-4.002	-4.854	-4.471	-4.798
73G	70972	-2.923	-2.905	-2.620	-2.835	-3.977	-4.824	-4.508	-4.801
73H	160972	-2.885	-2.844	-2.651	-2.777	-3.966	-4.732	-4.471	-4.736
73I	250972	-2.861	-2.846	-2.635	-2.738	-3.950	-4.720	-4.471	-4.694
73J	101072	-2.843	-2.820	-2.630	-2.661	-3.940	-4.763	-4.374	-5.030
73K	271072	-2.825	-2.802	-2.636	-2.659	-3.918	-4.750	-4.319	-4.653
73L	131172	-2.858	-2.835	-2.677	-2.706	-3.933	-4.763	-4.295	-4.626
73M	271172	-2.861	-2.846	-2.677	-2.754	-3.933	-4.756	-4.317	-4.659
73N	180173	-2.977	-2.953	-2.739	-2.870	-4.022	-4.846	-4.404	-4.822
73O	160373	-3.126	-3.055	-2.801	-3.060	-4.108	-4.912	-4.508	-4.882
73P	40473	-3.192	-3.093	-2.836	-3.144	-4.133	-4.970	-4.508	-4.969
73Q	230473	-3.294	-3.185	-2.831	-3.130	-4.108	-4.960	-4.508	-5.077
73R	70573	-3.157	-3.081	-2.795	-3.110	-4.108	-4.970	-4.471	-5.144
73S	240573	-3.182	-3.152	-2.782	-3.207	-4.159	-5.014	-4.471	-5.193
73T	70673	-3.134	-3.120	-2.745	-3.060	-4.141	-4.981	-4.436	-5.200
73U	230673	-3.080	-3.060	-2.708	-3.002	-4.108	-4.941	-4.404	-5.160
73V	20873	-2.977	-2.942	-2.649	-2.864	-4.022	-4.870	-4.309	-4.852

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
73A	300672	200.000	-4.339	-4.862	-3.805	-6.612	-4.568	-6.408	-5.724
73H	130772	200.000	-4.270	-4.790	-3.807	-6.530	-4.479	-6.420	-5.627
73C	240772	200.000	-4.382	-4.895	-3.830	-6.690	-4.631	-6.530	-5.804
73D	160872	200.000	-4.362	-4.866	-3.822	-6.676	-4.632	-6.537	-5.764
73E	170872	200.000	-4.379	-4.907	-3.819	-6.691	-4.633	-6.571	-5.807
73F	290872	200.000	-4.256	-4.792	-3.802	-6.552	-4.516	-6.388	-5.637
73G	70972	200.000	-4.201	-4.723	-3.796	-6.491	-4.449	-6.318	-5.555
73H	160972	200.000	-4.166	-4.685	-3.783	-6.471	-4.424	-6.257	-5.555
73I	230972	200.000	-4.141	-4.664	-3.781	-6.456	-4.414	-6.205	-5.521
73J	101072	200.000	-4.118	-4.636	-3.778	-6.438	-4.388	-6.125	-5.495
73K	271072	200.000	-4.090	-4.599	-3.765	-6.426	-4.378	-6.103	-5.466
73L	131172	200.000	-4.130	-4.664	-3.778	-6.495	-4.445	-6.159	-5.565
73M	271172	200.000	-4.110	-4.626	-3.765	-6.495	-4.453	-6.202	-5.523
73N	180173	200.000	-4.251	-4.764	-3.807	-6.658	-4.608	-6.388	-5.706
73O	160373	200.000	-4.353	-4.884	-3.842	-6.844	-4.754	-6.644	-5.869
73P	40473	200.000	-4.404	-4.936	-3.870	-6.937	-4.821	-6.744	-5.949
73Q	230473	200.000	-4.403	-4.865	-3.857	-7.027	-4.902	-6.699	-5.864
73R	70573	200.000	-4.322	-4.880	-3.861	-6.864	-4.771	-6.699	-5.855
73S	240573	200.000	-4.404	-4.960	-3.911	-6.868	-4.822	-6.830	-5.915
73T	70673	200.000	-4.403	-4.907	-3.877	-6.793	-4.762	-6.674	-5.834
73U	230673	200.000	-4.339	-4.855	-3.854	-6.710	-4.690	-6.590	-5.752
73V	20873	200.000	-4.180	-4.771	-3.827	-6.566	-4.510	-6.385	-5.626

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
73A	300672	-9.390	-7.167	-9.809	-7.627	200.000	-7.838	-6.979	-7.011
73B	130772	-9.022	-7.198	-8.862	-6.731	200.000	-6.872	-6.049	-6.965
73C	240772	-9.526	-7.316	-9.382	-7.081	200.000	-7.382	-6.536	-7.082
73D	100872	-9.189	-7.330	-9.068	-6.935	200.000	-7.054	-6.223	-7.071
73E	170872	-9.379	-7.375	-9.236	-6.712	200.000	-7.220	-6.376	-7.088
73F	290872	-9.364	-7.197	-9.230	-7.090	200.000	-7.208	-6.417	-6.983
73G	70972	-9.410	-7.121	-9.279	-7.198	200.000	-7.258	-6.487	-6.931
73H	160972	-9.407	-6.979	-9.333	-7.167	200.000	-7.257	-6.548	-6.956
73I	250972	-9.354	-6.932	-9.271	-7.045	200.000	-7.201	-6.502	-6.925
73J	101072	-9.265	-6.905	-9.191	-7.369	200.000	-7.117	-6.428	-6.914
73K	271072	-9.233	-6.894	-9.178	-6.997	200.000	-7.034	-6.435	-6.899
73L	131172	-9.610	-7.045	-9.549	-7.351	200.000	-7.445	-6.794	-6.951
73M	271172	-9.419	-6.982	-9.337	-7.162	200.000	-7.273	-6.644	-6.949
73N	180173	-9.579	-7.168	-9.567	-7.333	200.000	-7.428	-6.735	-7.091
73O	160373	-9.509	-7.406	-9.528	-7.216	200.000	-7.347	-6.621	-7.228
73P	40473	-9.561	-7.541	-9.587	-7.304	200.000	-7.399	-6.659	-7.285
73Q	230473	-9.566	-7.511	-9.634	-7.491	200.000	-7.476	-6.734	-7.251
73R	70573	-9.350	-7.511	-9.363	-7.324	200.000	-7.163	-6.458	-7.221
73S	240573	-9.375	-7.644	-9.347	-7.319	200.000	-7.189	-6.394	-7.254
73T	70673	-9.379	-7.474	-9.347	-7.382	200.000	-7.245	-6.408	-7.204
73U	250673	-9.457	-7.382	-9.410	-7.472	200.000	-7.312	-6.500	-7.139
73V	20873	-9.361	-7.192	-9.253	-7.152	200.000	-7.140	-6.420	-7.003

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
73A	300672	-7.373	-5.798	-5.269	200.000	-5.208	-3.967	-3.967	-12.778
73B	130772	-6.385	-5.834	-5.236	200.000	-5.172	-3.945	-3.939	-11.783
73C	240772	-6.938	-5.844	-5.406	200.000	-5.335	-4.095	-4.080	-12.359
73D	100872	-6.635	-6.013	-5.393	200.000	-5.313	-4.095	-4.097	-12.016
73E	170872	-6.786	-5.658	-5.428	200.000	-5.372	-4.126	-4.113	-12.209
73F	290872	-6.772	-5.811	-5.190	200.000	-5.132	-3.918	-3.926	-12.143
73G	70972	-6.807	-5.776	-5.097	200.000	-5.035	-3.841	-3.844	-12.163
73H	160972	-6.814	-5.567	-5.018	200.000	-4.953	-3.760	-3.738	-12.194
73I	250972	-6.773	-5.544	-4.961	200.000	-4.900	-3.704	-3.707	-12.131
73J	101072	-6.681	-5.865	-4.875	200.000	-4.809	-3.622	-3.617	-12.037
73K	271072	-6.673	-5.490	-4.849	200.000	-4.773	-3.606	-3.602	-12.010
73L	131172	-7.057	-5.566	-4.922	200.000	-4.872	-3.672	-3.668	-12.426
73M	271172	-6.914	-5.570	-4.942	200.000	-4.874	-3.717	-3.720	-12.233
73N	180173	-7.023	-5.814	-5.163	200.000	-5.092	-3.912	-3.909	-12.440
73O	160373	-7.039	-6.024	-5.416	200.000	-5.363	-4.212	-4.166	-12.422
73P	40473	-7.125	-6.180	-5.536	200.000	-5.483	-4.347	-4.274	-12.501
73Q	230473	-7.286	-6.262	-5.509	200.000	-5.384	-4.423	-4.341	-12.496
73R	70573	-6.918	-6.328	-5.428	200.000	-5.400	-4.286	-4.236	-12.250
73S	240573	-6.917	-6.460	-5.593	200.000	-5.564	-4.394	-4.391	-12.257
73T	70673	-6.909	-6.339	-5.463	200.000	-5.382	-4.217	-4.229	-12.229
73U	250673	-6.967	-6.253	-5.354	200.000	-5.285	-4.118	-4.142	-12.277
73V	20873	-6.770	-5.843	-5.092	200.000	-5.099	-3.913	-3.900	-12.135

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC MOLARITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
73A	300672	-11.393	-7.151	200.000
73B	130772	-9.599	-6.170	200.000
73C	240772	-10.354	-6.733	200.000
73D	100872	-9.809	-6.412	200.000
73E	170872	-9.826	-6.577	200.000
73F	290872	-10.308	-6.542	200.000
73G	70972	-10.517	-6.583	200.000
73H	160972	-10.519	-6.615	200.000
73I	230972	-10.363	-6.548	200.000
73J	141072	-10.623	-6.465	200.000
73K	271072	-10.255	-6.456	200.000
73L	131172	-10.024	-6.340	200.000
73M	271172	-10.584	-6.680	200.000
73N	180173	-10.782	-6.374	200.000
73O	160373	-10.486	-6.985	200.000
73P	40473	-10.579	-6.980	200.000
73Q	230473	-10.846	-7.150	200.000
73R	70573	-10.442	-6.750	200.000
73S	240573	-10.385	-6.702	200.000
73T	70673	-10.501	-6.679	200.000
73U	250673	-10.718	-6.725	200.000
73V	20873	-10.378	-6.563	200.000

LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CA++	MG++	HCO3-	SO4--	NA+	K+	CL-	FE++
73A	300672	-3.164	-3.136	-2.701	-3.050	-4.061	-4.864	-4.44	-4.939
73B	130772	-3.112	-3.077	-2.672	-3.082	-4.043	-4.865	-4.596	-4.944
73C	240772	-3.190	-3.145	-2.753	-3.152	-4.078	-4.908	-4.647	-4.883
73D	100872	-3.184	-3.157	-2.742	-3.160	-4.078	-4.916	-4.592	-5.045
73E	170872	-3.196	-3.154	-2.746	-3.179	-4.093	-4.942	-4.648	-4.672
73F	290872	-3.116	-3.096	-2.690	-3.050	-4.043	-4.896	-4.513	-4.953
73G	70972	-3.085	-3.059	-2.662	-3.005	-4.019	-4.868	-4.552	-4.963
73H	160972	-3.054	-3.004	-2.695	-2.954	-4.011	-4.777	-4.517	-4.904
73I	250972	-3.033	-3.009	-2.681	-2.919	-3.995	-4.767	-4.518	-4.917
73J	11072	-3.022	-2.988	-2.677	-2.849	-3.987	-4.812	-4.423	-5.208
73K	271072	-3.005	-2.972	-2.694	-2.843	-3.965	-4.800	-4.369	-4.833
73L	131172	-3.031	-2.999	-2.722	-2.889	-3.979	-4.810	-4.342	-4.869
73M	271172	-3.032	-3.007	-2.721	-2.933	-3.978	-4.803	-4.363	-4.829
73N	180173	-3.130	-3.099	-2.779	-3.030	-4.062	-4.888	-4.445	-4.976
73O	100373	-3.260	-3.184	-2.836	-3.200	-4.143	-4.948	-4.544	-5.016
73P	40473	-3.318	-3.214	-2.869	-3.276	-4.165	-5.004	-4.542	-5.095
73Q	280473	-3.415	-3.301	-2.862	-3.255	-4.139	-4.992	-4.540	-5.198
73R	70573	-3.288	-3.206	-2.829	-3.245	-4.142	-5.005	-4.505	-5.274
73S	240573	-3.305	-3.271	-2.814	-3.335	-4.191	-5.046	-4.503	-5.317
73T	70673	-3.266	-3.247	-2.780	-3.137	-4.175	-5.016	-4.471	-5.333
73U	250673	-3.219	-3.212	-2.744	-3.146	-4.144	-4.978	-4.441	-5.298
73V	20873	-3.133	-3.091	-2.690	-3.027	-4.062	-4.912	-4.352	-5.008

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	CU++	ZN++	MN++	H4SIO4	CAHCO3+	MGHCO3+	NASO4-	MNHCO3+
73A	300672	200.000	-4.490	-5.012	-3.805	-6.651	-4.607	-6.748	-5.763
73B	130772	200.000	-4.425	-4.945	-3.807	-6.570	-4.519	-6.461	-5.668
73C	240772	200.000	-4.524	-5.038	-3.830	-6.727	-4.669	-6.567	-5.841
73D	100872	200.000	-4.504	-5.008	-3.822	-6.713	-4.669	-6.574	-5.801
73E	170872	200.000	-4.520	-5.048	-3.819	-6.728	-4.670	-6.608	-5.844
73F	290872	200.000	-4.412	-4.937	-3.802	-6.593	-4.556	-6.422	-5.677
73G	70972	200.000	-4.363	-4.885	-3.796	-6.533	-4.491	-6.360	-5.597
73H	160972	200.000	-4.334	-4.854	-3.783	-6.535	-4.469	-6.301	-5.599
73I	250972	200.000	-4.313	-4.836	-3.781	-6.501	-4.459	-6.250	-5.567
73J	101072	200.000	-4.297	-4.815	-3.778	-6.485	-4.435	-6.172	-5.542
73K	271072	200.000	-4.271	-4.779	-3.765	-6.474	-4.426	-6.150	-5.513
73L	131172	200.000	-4.304	-4.838	-3.778	-6.540	-4.491	-6.204	-5.610
73M	271172	200.000	-4.280	-4.796	-3.765	-6.540	-4.498	-6.247	-5.568
73N	180173	200.000	-4.405	-4.917	-3.807	-6.698	-4.648	-6.428	-5.747
73O	160373	200.000	-4.487	-5.018	-3.842	-6.879	-4.789	-6.679	-5.904
73P	40473	200.000	-4.540	-5.062	-3.870	-6.969	-4.854	-6.777	-5.981
73Q	230473	200.000	-4.523	-4.986	-3.857	-7.058	-4.933	-6.730	-5.896
73R	70573	200.000	-4.453	-5.010	-3.861	-6.898	-4.805	-6.722	-5.889
73S	240573	200.000	-4.527	-5.083	-3.911	-6.900	-4.854	-6.862	-5.947
73T	70673	200.000	-4.535	-5.039	-3.877	-6.827	-4.796	-6.708	-5.869
73U	250673	200.000	-4.478	-4.994	-3.854	-6.746	-4.727	-6.626	-5.788
73V	20873	200.000	-4.336	-4.827	-3.827	-6.607	-4.551	-6.426	-5.667

*LOG TO THE BASE 10

20J = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MNOH+	KSO4-	NACO3-	FEOH+	CUOH+	ZNOH+	CO3--	NAHCO3
73A	300672	-10.030	-7.206	-9.848	-7.666	200.000	-7.877	-7.918	-7.011
73B	130772	-9.063	-7.239	-8.903	-6.771	200.000	-6.912	-6.089	-6.965
73C	240772	-9.563	-7.354	-9.419	-7.118	200.000	-7.419	-6.573	-7.082
73D	100872	-9.226	-7.367	-9.105	-6.972	200.000	-7.091	-6.260	-7.071
73L	170872	-9.416	-7.412	-9.272	-6.749	200.000	-7.257	-6.413	-7.088
73F	290872	-9.465	-7.237	-9.271	-7.130	200.000	-7.249	-6.457	-6.983
73G	70972	-9.452	-7.164	-9.321	-7.240	200.000	-7.300	-6.529	-6.931
73H	160972	-9.451	-7.223	-9.377	-7.212	200.000	-7.302	-6.592	-6.956
73I	250972	-9.399	-6.977	-9.317	-7.090	200.000	-7.246	-6.547	-6.925
73J	151072	-9.312	-6.952	-9.238	-7.416	200.000	-7.164	-6.474	-6.914
73K	271072	-9.281	-6.941	-9.225	-7.044	200.000	-7.142	-6.482	-6.899
73L	131172	-9.655	-6.991	-9.594	-7.337	200.000	-7.491	-6.840	-6.951
73M	271172	-9.464	-7.027	-9.441	-7.206	200.000	-7.318	-6.689	-6.949
73N	180173	-9.611	-7.209	-9.607	-7.379	200.000	-7.468	-6.775	-7.091
73O	150373	-9.544	-7.441	-9.563	-7.251	200.000	-7.382	-6.656	-7.228
73P	40473	-9.594	-7.574	-9.619	-7.337	200.000	-7.432	-6.691	-7.285
73Q	230473	-9.598	-7.542	-9.665	-7.522	200.000	-7.507	-6.765	-7.251
73R	70573	-9.384	-7.545	-9.397	-7.358	200.000	-7.197	-6.492	-7.221
73S	240573	-9.407	-7.676	-9.379	-7.351	200.000	-7.221	-6.426	-7.254
73T	70673	-9.413	-7.509	-9.381	-7.417	200.000	-7.279	-6.442	-7.204
73U	250673	-9.494	-7.418	-9.446	-7.508	200.000	-7.348	-6.535	-7.139
73V	20873	-9.402	-7.233	-9.293	-7.193	200.000	-7.181	-6.460	-7.003

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	MGCO3	FESO4	ZNSO4	CUSO4	MNSO4	CASO4	MGSO4	MNCO3
73A	300672	-7.373	-5.798	-5.269	200.000	-5.208	-3.967	-3.967	-12.778
73B	130772	-6.385	-5.834	-5.236	200.000	-5.172	-3.945	-3.939	-11.783
73C	240772	-6.938	-5.844	-5.406	200.000	-5.335	-4.095	-4.080	-12.359
73D	100872	-6.635	-6.013	-5.393	200.000	-5.313	-4.095	-4.097	-12.016
73E	170972	-6.796	-5.658	-5.428	200.000	-5.372	-4.126	-4.113	-12.209
73F	290872	-6.772	-5.811	-5.190	200.000	-5.132	-3.918	-3.926	-12.143
73G	70972	-6.807	-5.776	-5.097	200.000	-5.035	-3.841	-3.844	-12.163
73H	160972	-6.814	-5.667	-5.018	200.000	-4.953	-3.760	-3.738	-12.194
73I	250972	-6.773	-5.548	-4.961	200.000	-4.900	-3.704	-3.707	-12.131
73J	101072	-6.641	-5.865	-4.875	200.000	-4.809	-3.622	-3.617	-12.037
73K	271072	-6.673	-5.490	-4.849	200.000	-4.773	-3.606	-3.602	-12.010
73L	131172	-7.057	-5.566	-4.922	200.000	-4.872	-3.672	-3.668	-12.426
73M	271172	-6.914	-5.570	-4.942	200.000	-4.874	-3.717	-3.720	-12.233
73N	180473	-7.033	-5.814	-5.163	200.000	-5.092	-3.912	-3.909	-12.440
73O	160373	-7.059	-6.024	-5.416	200.000	-5.363	-4.212	-4.166	-12.422
73P	40473	-7.125	-6.180	-5.536	200.000	-5.483	-4.347	-4.274	-12.501
73Q	230473	-7.286	-6.262	-5.509	200.000	-5.384	-4.423	-4.341	-12.496
73R	70573	-6.918	-6.328	-5.428	200.000	-5.400	-4.286	-4.236	-12.250
73S	240573	-6.917	-6.460	-5.533	200.000	-5.564	-4.394	-4.391	-12.257
73T	70673	-6.909	-6.339	-5.483	200.000	-5.382	-4.217	-4.229	-12.229
73U	250673	-6.967	-6.253	-5.354	200.000	-5.285	-4.118	-4.142	-12.277
73V	20873	-6.770	-5.843	-5.092	200.000	-5.098	-3.913	-3.900	-12.135

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

IONIC ACTIVITY*

SAMP	DATE	FE(OH)2	CACO3	CUCO3
73A	300672	-11.393	-7.151	200.000
73B	130772	-9.599	-6.170	200.000
73C	240772	-10.354	-6.733	200.000
73D	100872	-9.899	-6.412	200.000
73E	170872	-9.826	-6.577	200.000
73F	290872	-10.308	-6.542	200.000
73G	70972	-10.517	-6.583	200.000
73H	160972	-10.519	-6.615	200.000
73I	230972	-10.363	-6.548	200.000
73J	101072	-10.623	-6.466	200.000
73K	271072	-10.255	-6.456	200.000
73L	131172	-10.324	-6.840	200.000
73M	271172	-10.584	-6.689	200.000
73N	180173	-10.782	-6.874	200.000
73O	160373	-10.496	-6.885	200.000
73P	40473	-10.579	-6.980	200.000
73Q	230473	-10.846	-7.156	200.000
73R	70573	-10.442	-6.750	200.000
73S	240573	-10.385	-6.702	200.000
73T	70673	-10.501	-6.679	200.000
73U	250673	-10.718	-6.725	200.000
73V	20873	-10.378	-6.563	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
73A	300672	-10.182	-11.957	-10.154	-20.336	-11.508	-12.030	-6.215	200.000
73B	130772	-9.201	-11.034	-9.167	-18.368	-10.515	-11.035	-6.193	200.000
73C	240772	-9.763	-11.456	-9.719	-19.482	-11.097	-11.611	-6.342	200.000
73D	100872	-9.443	-11.304	-9.416	-18.860	-10.764	-11.268	-6.343	200.000
73E	170872	-9.608	-11.085	-9.567	-19.176	-10.933	-11.461	-6.374	200.000
73F	290872	-9.574	-11.410	-9.553	-19.127	-10.869	-11.394	-6.166	200.000
73G	70972	-9.614	-11.492	-9.588	-19.202	-10.892	-11.414	-6.089	200.000
73H	160972	-9.646	-11.497	-9.536	-19.242	-10.927	-11.446	-6.008	200.000
73I	290972	-9.579	-11.363	-9.555	-19.135	-10.859	-11.382	-5.952	200.000
73J	101072	-9.496	-11.683	-9.462	-18.959	-10.771	-11.289	-5.871	200.000
73K	271072	-9.487	-11.315	-9.454	-18.941	-10.753	-11.261	-5.854	200.000
73L	131172	-9.871	-11.709	-9.838	-19.709	-11.144	-11.677	-5.920	200.000
73M	271172	-9.720	-11.518	-9.696	-19.416	-10.969	-11.485	-5.965	200.000
73N	180173	-9.906	-11.751	-9.874	-19.780	-11.180	-11.692	-6.161	200.000
73O	160373	-9.915	-11.671	-9.839	-19.754	-11.143	-11.674	-6.459	200.000
73P	40473	-10.009	-11.786	-9.965	-19.915	-11.222	-11.753	-6.594	200.000
73Q	230473	-10.179	-11.963	-10.066	-20.245	-11.288	-11.751	-6.670	200.000
73R	70573	-9.779	-11.766	-9.698	-19.477	-10.944	-11.502	-6.533	200.000
73S	240573	-9.732	-11.743	-9.697	-19.429	-10.953	-11.509	-6.641	200.000
73T	70673	-9.708	-11.775	-9.689	-19.397	-10.977	-11.481	-6.464	200.000
73U	250673	-9.755	-11.834	-9.748	-19.502	-11.014	-11.529	-6.365	200.000
73V	20873	-9.593	-11.468	-9.561	-19.144	-10.796	-11.387	-6.160	200.000

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
73A	300672	200.000	9.264	13.661	13.661	7.874	7.143	200.000	-6.273
73B	130772	200.000	11.123	16.356	16.356	8.908	8.038	200.000	-5.380
73C	240772	200.000	10.255	15.217	15.217	8.456	7.660	200.000	-5.869
73D	100872	200.000	10.843	15.955	15.955	8.812	7.958	200.000	-5.559
73E	170872	200.000	10.546	15.878	15.878	8.616	7.812	200.000	-5.729
73F	290872	200.000	10.404	15.297	15.297	8.504	7.683	200.000	-5.790
73G	70972	200.000	10.241	14.987	14.987	8.384	7.571	200.000	-5.811
73H	160972	200.000	10.238	14.955	14.955	8.338	7.531	200.000	-5.724
73I	250972	200.000	10.291	15.133	15.133	8.361	7.554	200.000	-5.678
73J	101072	200.000	10.452	14.952	14.952	8.459	7.613	200.000	-5.648
73K	271072	200.000	10.468	15.327	15.327	8.432	7.610	200.000	-5.610
73L	131172	200.000	9.801	14.331	14.331	8.075	7.299	200.000	-5.966
73M	271172	200.000	10.193	14.821	14.821	8.250	7.452	200.000	-5.783
73N	190173	200.000	9.941	14.584	14.584	8.240	7.449	200.000	-5.983
73O	160373	200.000	10.216	15.084	15.084	8.473	7.661	200.000	-5.933
73P	40473	200.000	10.186	15.005	15.005	8.489	7.676	200.000	-6.044
73Q	230473	200.000	9.939	14.662	14.662	8.402	7.592	200.000	-6.087
73R	70573	200.000	10.514	15.306	15.306	8.680	7.822	200.000	-5.866
73S	240573	200.000	10.549	15.413	15.413	8.753	7.893	200.000	-5.958
73T	70673	200.000	10.473	15.247	15.247	8.678	7.827	200.000	-5.910
73U	250673	200.000	10.248	14.892	14.892	8.519	7.683	200.000	-5.957
73V	20873	200.000	10.409	15.242	15.242	8.504	7.670	200.000	-5.817

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

ACTIVITY PRODUCT*

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
73A	300672	9.236	-5.470	42.513	1.336	-13.080	-21.202	-21.[illegible]74	-1.448
73B	130772	11.088	-4.558	51.806	2.235	-12.172	-19.371	-19.337	-0.447
73C	240772	10.210	-5.035	47.442	1.792	-12.700	-20.432	-20.388	-0.957
73D	100872	10.816	-4.721	50.395	2.084	-12.365	-19.756	-19.729	-0.625
73E	170872	10.504	-4.880	48.910	1.908	-12.517	-20.045	-20.004	-0.801
73F	290872	10.384	-4.897	48.217	1.854	-12.500	-20.032	-20.012	-0.849
73G	70972	10.215	-4.962	47.409	1.782	-12.555	-20.156	-20.131	-0.926
73H	160972	10.186	-4.957	47.309	1.843	-12.523	-20.079	-20.029	-0.875
73I	250972	10.207	-4.906	47.677	1.883	-12.467	-19.977	-19.953	-0.834
73J	101072	10.418	-4.823	48.480	1.908	-12.379	-19.805	-19.772	-0.776
73K	271072	10.435	-4.776	48.576	1.920	-12.306	-19.686	-19.653	-0.743
73L	131172	9.769	-5.135	45.228	1.590	-12.691	-20.455	-20.422	-1.129
73M	271172	10.068	-4.958	46.700	1.747	-12.488	-20.053	-20.028	-0.946
73N	180173	9.910	-5.157	45.807	1.632	-12.771	-20.550	-20.519	-1.104
730	160373	10.140	-5.127	47.239	1.752	-12.811	-20.597	-20.521	-1.006
73P	40473	10.082	-5.206	47.058	1.696	-12.946	-20.880	-20.776	-1.080
73Q	230473	9.825	-5.234	45.837	1.628	-12.949	-21.035	-20.921	-1.168
73R	70573	10.432	-5.003	48.709	1.855	-12.724	-20.453	-20.371	-0.891
73S	240673	10.515	-5.102	48.837	1.864	-12.923	-20.770	-20.735	-0.937
73T	70673	10.454	-5.068	48.489	1.844	-12.822	-20.560	-20.540	-0.927
73U	250673	10.241	-5.123	47.394	1.752	-12.832	-20.594	-20.588	-1.012
73V	20873	10.367	-4.967	48.220	1.838	-12.622	-20.252	-20.210	-0.888

*LOG TO THE BASE 10

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	CACO3	FECO3	MGCO3	DOLOMITE	ZNCO3	MNCO3	CASO4	MALACHITE
73A	300672	-1.781	-1.573	-2.315	-1.826	-0.801	-1.624	-1.590	200.000
73B	130772	-0.800	-0.650	-1.328	-0.842	0.192	-0.629	-1.568	200.000
73C	240772	-1.362	-1.079	-1.882	-1.400	-0.390	-1.209	-1.717	200.000
73D	100872	-1.042	-0.921	-1.577	-1.088	-0.057	-0.862	-1.718	200.000
73E	170872	-1.207	-0.701	-1.728	-1.246	-0.226	-1.055	-1.749	200.000
73F	290872	-1.172	-1.027	-1.714	-1.221	-0.162	-0.988	-1.541	200.000
73G	70972	-1.213	-1.109	-1.743	-1.259	-0.185	-1.008	-1.464	200.000
73H	160972	-1.245	-1.113	-1.757	-1.279	-0.220	-1.040	-1.383	200.000
73I	250972	-1.178	-0.980	-1.715	-1.225	-0.156	-0.976	-1.327	200.000
73J	101072	-1.095	-1.299	-1.623	-1.137	-0.064	-0.883	-1.245	200.000
73K	271072	-1.086	-0.935	-1.617	-1.129	-0.046	-0.865	-1.229	200.000
73L	131172	-1.470	-1.325	-1.999	-1.502	-0.437	-1.271	-1.295	200.000
73M	271172	-1.319	-1.134	-1.856	-1.366	-0.262	-1.079	-1.339	200.000
73N	180173	-1.504	-1.368	-2.034	-1.547	-0.477	-1.286	-1.536	200.000
73O	160373	-1.514	-1.294	-2.003	-1.537	-0.435	-1.271	-1.834	200.000
73P	40473	-1.609	-1.404	-2.071	-1.618	-0.515	-1.347	-1.968	200.000
73Q	230473	-1.779	-1.584	-2.233	-1.783	-0.585	-1.345	-2.044	200.000
73R	70573	-1.373	-1.387	-1.864	-1.399	-0.241	-1.095	-1.907	200.000
73S	240573	-1.331	-1.364	-1.864	-1.375	-0.250	-1.103	-2.015	200.000
73T	70673	-1.308	-1.396	-1.856	-1.359	-0.274	-1.075	-1.838	200.000
73U	250673	-1.354	-1.456	-1.913	-1.411	-0.307	-1.123	-1.740	200.000
73V	20873	-1.192	-1.091	-1.714	-1.231	-0.089	-0.984	-1.535	200.000

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AZURITE	MG(OH)2	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	KF-K
73A	300672	200.000	-4.348	-0.020	-1.639	-7.088	-6.663	200.000	-3.422
73B	130772	200.000	-3.418	-0.948	-2.567	-8.211	-7.640	200.000	-2.528
73C	240772	200.000	-3.860	-6.738	-2.357	-8.279	-7.789	200.000	-3.013
73D	100872	200.000	-3.558	200.000	200.000	200.000	200.000	200.000	-2.708
73E	170872	200.000	-3.707	200.000	200.000	200.000	200.000	200.000	-2.877
73F	290872	200.000	-3.777	200.000	200.000	200.000	200.000	200.000	-2.838
73G	70972	200.000	-3.859	200.000	200.000	200.000	200.000	200.000	-2.959
73H	160972	200.000	-3.861	200.000	200.000	200.000	200.000	200.000	-2.872
73I	230972	200.000	-3.930	200.000	200.000	200.000	200.000	200.000	-2.828
73J	101072	200.000	-3.754	200.000	200.000	200.000	200.000	200.000	-2.796
73K	271072	200.000	-3.743	200.000	200.000	200.000	200.000	200.000	-2.756
73L	131172	200.000	-4.173	200.000	200.000	200.000	200.000	200.000	-3.114
73M	271172	200.000	-3.938	200.000	200.000	200.000	200.000	200.000	-2.931
73N	180173	200.000	-4.005	200.000	200.000	200.000	200.000	200.000	-3.133
73O	160373	200.000	-3.879	200.000	200.000	200.000	200.000	200.000	-3.077
73P	40473	200.000	-3.899	200.000	200.000	200.000	200.000	200.000	-3.186
73Q	230473	200.000	-4.025	200.000	200.000	200.000	200.000	200.000	-3.227
73R	70573	200.000	-3.737	200.000	200.000	200.000	200.000	200.000	-3.006
73S	240573	200.000	-3.720	200.000	200.000	200.000	200.000	200.000	-3.098
73T	70673	200.000	-3.758	200.000	200.000	200.000	200.000	200.000	-3.050
73U	250673	200.000	-3.867	200.000	200.000	200.000	200.000	200.000	-3.099
73V	20873	200.000	-3.782	-0.818	-2.438	-8.542	-8.016	200.000	-2.964

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

SATURATION INDEX

SAMP	DATE	AN-K	AB-K	CHL-K	KMI-K	NAM-K	CAM-K	MGM-K	ILL-K
73A	300672	-4.633	-5.531	-2.822	-4.565	-5.141	-2.326	-2.152	-2.833
73B	130772	-3.706	-4.619	-1.893	-3.666	-4.234	-1.411	-1.234	-1.923
73C	240772	-4.154	-5.100	-2.335	-4.112	-4.757	-1.939	-1.759	-2.388
73D	100872	-3.842	-4.783	-2.034	-3.817	-4.426	-1.603	-1.430	-2.085
73E	170872	-3.998	-4.941	-2.182	-3.992	-4.579	-1.748	-1.567	-2.2[illegible]
73F	290872	-4.059	-4.958	-2.252	-4.046	-4.562	-1.741	-1.571	-2.288
73G	70972	-4.143	-5.023	-2.333	-4.118	-4.617	-1.803	-1.630	-2.359
73H	160972	-4.157	-5.018	-2.334	-4.058	-4.585	-1.764	-1.579	-2.312
73I	250972	-4.112	-4.968	-2.322	-4.016	-4.531	-1.714	-1.542	-2.274
73J	101072	-4.041	-4.884	-2.229	-3.992	-4.441	-1.628	-1.451	-2.222
73K	271072	-4.037	-4.837	-2.219	-3.982	-4.366	-1.567	-1.391	-2.198
73L	131172	-4.366	-5.136	-2.501	-4.311	-4.752	-1.952	-1.776	-2.543
73M	271172	-4.216	-5.019	-2.403	-4.153	-4.550	-1.751	-1.579	-2.377
73N	180173	-4.291	-5.218	-2.430	-4.266	-4.835	-2.001	-1.825	-2.520
73O	160373	-4.189	-5.188	-2.356	-4.152	-4.869	-2.022	-1.825	-2.432
73P	40473	-4.225	-5.266	-2.379	-4.211	-5.001	-2.162	-1.952	-2.501
73Q	230473	-4.355	-5.294	-2.503	-4.280	-5.003	-2.239	-2.025	-2.580
73R	70573	-4.052	-5.063	-2.215	-4.053	-4.778	-1.948	-1.750	-2.329
73S	240573	-4.011	-5.162	-2.203	-4.044	-4.977	-2.107	-1.932	-2.371
73T	70673	-4.041	-5.128	-2.237	-4.064	-4.876	-2.001	-1.934	-2.362
73U	250673	-4.143	-5.183	-2.345	-4.154	-4.888	-2.020	-1.858	-2.438
73V	20873	-4.076	-5.028	-2.258	-4.066	-4.680	-1.849	-1.670	-2.325

200 = INCOMPLETE INFORMATION TO PERFORM THE CALCULATION

EQUILIBRIUM PE

SAMP	DATE	FE(OH)3	FE2O3	FES2	ZNS	CUFES2	PPCO2	ERROR	I.STR.
73A	300672	5.553	0.697	-1.474	-1.050	200.000	-1.188	-5.36	0.00706
73B	130772	2.858	-1.098	-2.508	-1.945	200.000	-2.060	1.157	0.00840
73C	240772	4.013	-0.844	-2.051	-1.562	200.000	-1.742	1.105	0.00692
73D	100872	3.259	-1.597	-2.412	-1.865	200.000	-2.030	0.570	0.00688
73E	170872	3.336	-1.520	-2.216	-1.719	200.000	-1.883	1.650	0.00676
73F	290872	3.917	-0.939	-2.104	-1.590	200.000	-1.727	-1.121	0.00942
73G	70972	4.227	-0.629	-1.984	-1.478	200.000	-1.600	-1.188	0.00929
73H	160972	4.258	-0.597	-1.938	-1.439	200.000	-1.602	2.108	0.01024
73I	250972	4.073	-0.782	-1.964	-1.463	200.000	-1.617	0.096	0.01075
73J	151072	4.262	-0.593	-2.050	-1.520	200.000	-1.684	-3.570	0.01176
73K	271072	3.995	-0.862	-2.030	-1.515	200.000	-1.692	-1.147	0.01207
73L	131172	4.893	0.038	-1.675	-1.206	200.000	-1.410	0.119	0.01104
73M	271172	4.393	-0.463	-1.850	-1.359	200.000	-1.559	2.925	0.01054
73N	180173	4.621	-0.234	-1.843	-1.359	200.000	-1.586	0.938	0.00821
73O	160373	4.146	-0.712	-2.067	-1.563	200.000	-1.824	2.251	0.00609
73P	40473	4.239	-0.621	-2.080	-1.574	200.000	-1.859	3.358	0.00525
73Q	230473	4.585	-0.275	-1.992	-1.489	200.000	-1.772	-7.959	0.00473
73R	70573	3.941	-0.919	-2.270	-1.719	200.000	-1.979	1.610	0.00561
73S	240573	3.833	-1.026	-2.343	-1.790	200.000	-2.013	0.082	0.00497
73T	70673	3.999	-0.860	-2.267	-1.724	200.000	-1.929	-3.503	0.00581
73U	250673	4.347	-0.512	-2.112	-1.583	200.000	-1.763	-5.535	0.00651
73V	20873	3.988	-0.870	-2.099	-1.572	200.000	-1.729	-3.044	0.00854

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