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Mineralogy and autoradiography of selected mineral-spring precipitates in the Western United States

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Abstract

X-ray diffaction analysis of 236 precipitate or sediment samples from 97 mineral-spring sites in nine Western States showed the presence of 25 minerals, some precipitated and some detrital. Calcite and (or) aragonite are the most common of all the precipitated minerals. Gypsum and (or) anhydrite, as well as barite and native sulfur, are less common but are also believed to be precipitated minerals. Precipitated manganese and iron oxides, including romanechite, manganite, pyrolusite, goethite, and hematite, were found in some of the samples. Various salts of sodium, including halite and thenardite, were also identified. Dolomite and an unknown type of siliceous material are present in some of the samples and were possibly precipitated at the spring sites. Quartz, feldspar, and mica are present in many of the samples and are believed to be detrital contaminants.

An autoradiographic and thin section study of 11 samples from nine of the most radioactive spring sites showed the radioactivity, which is due primarily to radium, to be directly associated with mineral phases containing barium, manganese, iron, and (or) calcium as major constituents. Furthermore, the radioactivity has an exclusive affinity for the manganese-bearing minerals, which in these samples contain a substantial amount of barium, even if calcite or iron oxides are present. Where calcite predominates and manganese- and barium-bearing minerals are absent, the radioactivity shows a close association with the iron oxides present, especially hematite, but also shows a moderate association with the calcite and (or) aragonite cementing phases. In other samples composed predominantly of calcite but lacking iron oxides, the radioactivity is preferentially associated with an early stage of calcite development and is considerably lower in the later cementing stages. The radioactivity observed in all these samples is believed to be caused by radium

substituting for barium in mineral lattices, filling irregularities in other crystal structures, or adsorbing on the surfaces of precipitated molecules.

Introduction

Purpose of study

Mineral springs have fascinated mankind for centuries and have long been used for medicinal purposes. Only recently has modern science sought to determine the origin of such springs and found ways to utilize the water or precipitates for various other commercial purposes. Thermal springs have been studied as possible geothermal energy sources. Minerals precipitated by spring waters have been mined for the metals they contain or for their quality as ornamental stone. Some mineral springs have provided insights into the nature of hydrothermal ore-forming solutions.

The present study was undertaken to examine the geochemical environment of radioactive mineral springs. Data on numerous radioactive and nonradioactive parameters for both water and precipitates from a variety of springs were gathered and interpreted.

This report presents the data pertaining to the mineralogy of the precipitates at the springs studied. It discusses the identity of minerals in all the sampled precipitates as determined by X-ray diffraction and describes the relationships among the identified minerals in a selected number of samples as determined with the petrographic microscope, use of the scanning electron microscope (SEM), and determinations of organic content. Special emphasis is placed on the relationship between radioactivity and mineralogy as determined by autoradiography for the selected samples.

Area of study

From 1975 to 1980, 171 spring sites in nine Western States were visited. Water samples were collected and (or) measurements were taken at 156 sites; precipitate or sediment samples were taken at 97 sites. The distribution of sites by State is shown in the following table:

State	Total sites	Water sites	Precipitate sites
Arizona	18	10	14
California	10	10	4
Colorado	28	23	22
Idaho	6	6	4
Montana	14	14	6
Nevada	36	35	17
New Mexico	5	5	2
Utah	44	43	20
Wyoming	10	10	8
All States	171	156	97

Mineral-spring sites visited during this study are shown on figure 1 and listed in table 1. Fifteen sites in Arizona were visited by J. E. Peterson, S. E. Buell, and C. S. Spirakis (Peterson and others, 1977), who collected samples along the Colorado River in the Grand Canyon. All other sites were visited by J. K. Felmlee and R. A. Cadigan, who took various on-site measurements and collected water or precipitate samples where appropriate. Two of the sites (one in Idaho and one in Nevada) are not shown on the map because the samples were taken with the permission of the property owners on the condition that the sample locations be considered confidential.

Precipitate sample localities are shown on figure 2. As mentioned above, this report discusses only the data pertaining to the mineralogy of the precipitates at the mineral-spring sites visited.

Previous work

Several workers have studied the mineralogy of spring precipitates, but very few have investigated the radioactivity associated with some of the precipitates.

Weissberg, Browne, and Seward (1979) reported on mineralogy of hot-spring deposits around the world. Callaghan and Thomas (1939) studied manganiferous spring deposits at a spring in Utah. Wollenberg (1976) examined radioactivity in several calcareous and siliceous precipitates in Nevada.

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Methods of study

A split of each precipitate sample was reduced to a fine powder for X-ray study. The individual samples were pack-powder mounted on flat aluminum sample holders. The X-ray analysis was accomplished using a standard X-ray diffraction unit utilizing a long fine-focus copper X-ray tube and a focusing monochromator. Eleven selected samples were analyzed by optical microscopy, SEM, and electron microprobe. The carbonate terminology used to describe the textures follows Folk (1962, 1973).

An autoradiographic study was performed on the 11 samples from which standard thin sections had been made. Two types of autoradiographic techniques (both specific for alpha radioactivity) were employed. One type involved the production of a "radioluxograph," as described by Dooley (1958); the other involved the use of a nuclear track-recording plastic "CR-39," as discussed by Cartwright and Shirk (1978).

Analysis for weight percent of organic carbon was performed on 3 of the 11 samples from which thin sections had been made. This involved the determination of the following: (1) total carbon in the whole sample by use of an induction furnace combustion carbon analyzer, (2) organic carbonate carbon by combustion after hydrochloric acid removal of carbonate carbon, and (3) carbonate carbon after the burning at 450°C to remove organic carbon.

Results of X-ray diffraction study

Mineral identification of 236 precipitate samples taken from 97 spring sites in the course of this study was confirmed by X-ray diffraction analysis. All of these samples consisted of hard or soft cryptocrystalline or amorphous material which was not identifiable by megascopic examination or, in many instances, by microscopic examination. The results of the X-ray analysis are summarized in tables 2 and 3 and are discussed below. Mineralogic and selected semiquantitative emission spectrographic data and equivalent uranium (actually daughters of uranium, mainly radium-226) are listed with their respective spring sites in tables 2 and 3.

In table 2 the "Minerals identified" listing includes those minerals that were positively or tentatively identified. The criterion for positive identification was the presence of three or more of the strongest X-ray diffracton peak locations characteristic of that particular mineral. Tentative identification was based on one or two peaks. Mineral identification was further facilitated by reference to values of key elements shown in the spectrographic data. In the ensuing text discussion the number of samples or sites for which a mineral was positively identified is listed first, while the number of samples or sites for which identification was questionable follows in parentheses.

Calcite is the most common mineral identified in the precipitate samples. X-ray analysis revealed that 193 (3) of the 236 samples examined contain calcite. Calcite was identified at all spring sites except AZ4, AZ5, AZ10, AZ11, AZ13, CO1, CO11, CO23, NV10, NV29 and WY10. Aragonite was identified in 26 (2) of the precipitates from 14 (1) of the spring sites where calcite was found. Both minerals form hard or soft, very light gray to yellowish-gray precipitates indistinguishable from each other in the field.

Quartz, feldspar, mica, clay, and other accessory minerals were identified in many of the samples. These minerals are common detrital contaminants in mineral-spring precipitates and were therefore omitted in table 3. Because only eleven thin sections were prepared, it is impossible to positively determine whether all the quartz identified by X-ray analysis is detrital or whether some was authigenically precipitated as chalcedony. Primary precipitated silica was not identified in any of the thin sections, but detrital quartz was found in nearly all of them; therefore, most of the quartz identified in non-sectioned samples is thought to be detrital.

Very broad peaks or "humps" were observed in the X-ray diffraction patterns of seven samples from five spring localities (NV10, NV11, NV12, NV26, and MT5). These anomalous patterns probably represent varying amounts of amorphous siliceous material present within the sample and are designated "siliceous material" in tables 2 and 3. In six of these samples the "humps" on the X-ray diffractogram ranged from approximately 18^{o} 2θ to 30^{o} 2θ; the "hump" from the remaining diffraction pattern spread from approximately 18^{o} 2θ to 32^{o} 2θ. Semiquantitative spectrographic analysis shows greater than 20 percent silicon in six of these samples and 10 percent in the other sample. Wollenberg (1974) described the NV10 and NV11 sites as predominantly depositing or having deposited silica. In a report by Mariner,Rapp, Willey, and Presser (1974) the NV11 site is described as containing spring deposits primarily of silica, and the NV12 and NV26 sites are listed as having traces of silica. In the present study, cristobalite was tentatively identified in two other samples from NV12. Mariner, Presser, and Evans (1976b) commented that the MT5 spring has water temperatures which may be in equilibrium with alpha-cristobalite. Plots of water temperature versus silica content of the sampled waters (data from Felmlee and Cadigan, 1982) show that only the NV11 site falls on or near the saturation curve for amorphous silica established by Kithara in 1960 (from Fournier and Rowe, 1966). The other four sites plot considerably below the curve established by Kithara. Because areal variations in water temperature were not recorded at each spring site, the evidence is inconclusive as to what type of siliceous material the X-ray patterns at these four sites can be attributed--amorphous silica, amorphous silica in combination with other elements, or some other phase of silica or silica-bearing mineral which has not crystallized. The siliceous material in all seven samples occurs with various other cryptocrystalline white to yellowish- or pinkish-gray minerals and is indistinguishable from them in the field.

Gypsum was identified in 34(2) of the samples from 22(2) of the spring localities. Anhydrite is present in 2 samples from 2 of the sites where gypsum was found. Both minerals form hard or soft white to yellowish- or pinkish-gray precipitates or encrustations.

Dolomite occurs in 25(12) of the precipitate samples from 23(7) different sites. As in the case of quartz, it is difficult to assess whether the dolomite minerals are primary precipitates, diagenetic products of magnesium substitution in the original calcite, or detrital grains. Although the question concerning primary precipitation of dolomite is still disputed, Barnes and O'Neil (1971) have cited evidence for the primary precipitation of dolomite in Holocene travertines and conglomerate cements in fresh-water stream channels of the Coast Ranges of California. Also, Krauskopf (1967, p. 85) stated that small amounts of dolomite have been observed forming, probably as a primary precipitate, in present-day hot springs. All the samples containing dolomite, except one, also have calcite, but many of these samples also contain detrital feldspar, quartz, or clay. Samples containing only calcite and dolomite are light olive gray and do not show any megascopic difference between the two minerals.

Iron oxide or iron sulfide minerals were identified in 10(1) of the samples. Goethite was identified in 7(1) springs sampled, while hematite was found in 2 springs. Pyrite was identified in one of the samples, a black precipitate, from the CO12 spring site. Although 37 samples contain greater than 5 percent iron, only 10(1) displayed X-ray diffraction patterns typical of crystalline iron-bearing minerals. Many of the 27 samples containing greater than 5 percent iron but having no detectable crystalline iron minerals were soft dark-orange-brown precipitates and probably contain amorphous iron oxy-hydroxides. Semiquantitative spectrographic analysis showed that 11 of the precipitates containing greater than 5 percent iron also contain greater than 5 percent arsenic; however, as evidenced by X-ray diffraction, none of the samples apparently contain crystalline arsenic-bearing minerals, and only one sample contains any crystalline iron-bearing minerals. The arsenic may be present in arsenate molecules held by adsorption on the amorphous iron hydroxide precipitates, as suggested by Hem (1970).

Barite was identified in 9(1) of the samples from 4 different spring localities. Native sulfur was found in 9 of the samples from 6 sites. Only one sample contains both barite and native sulfur. More commonly the barite and native sulfur occur in different samples at the same site, or native sulfur occurs at sites having no barite. Most of the samples containing barite were collected as soft precipitates having a yellowish-gray color; only a few of the samples were hard porous precipitates. Samples containing native sulfur were soft grayish- or greenish-yellow precipitates.

Romanechite (a variety of psilomelane), pyrolusite, and manganite identified in 3(1), 1, and 1(2) of the precipitates, respectively, from a total of 3(3) sites. Two samples displayed X-ray diffraction patterns most probably attributed to a poorly crystalline manganese mineral. Five samples containing greater than 5 percent manganese according to the spectrographic data did not show any X-ray patterns attributable to manganese minerals; these samples probably contain amorphous manganese oxide or hydroxide precipitates analogous to the amorphous iron hydroxide precipitates. All of the manganese minerals form hard porous grayish-black precipitates.

Fluorite was found in 4 of the precipitate samples from site C017. Romanechite accompanies fluorite in all 4 of these samples. The fluorite is not megascopically visible, and the samples retain the grayish-black color of the manganese oxide minerals.

Thenardite was identified in 4 samples from 3 sites, and halite was identified in 3 samples from 3 sites. These samples contain other minerals and form white to pinkish-gray encrustations. One of the samples from spring site C013 contains greater than 5 percent aluminum. In this particular sample, which formed a white encrustation around a seep, soda alum was positively identified, while alunogen and halotrichite were tentatively identified.

Results of thin-section study

A thin-section study was undertaken on 11 samples from 9 of the spring sites, as shown on figure 2. These samples were collected late in the study from some of the most radioactive spring sites and are listed by site in the following table:

Site	Sample	Predominant minerals
C011--------------	80KF-6	Barite
C012--------------	80KF-5	Calcite
C014--------------	80KF-1	Calcite, iron oxide
C015--------------	80KF-3	Calcite, iron oxide
C017--------------	80KF-4	Manganese oxide
	80KF-7	Manganese oxide
	CD80-1	Manganese oxide
C022--------------	CD80-2	Manganese oxide
NV6---------------	80KF-50	Calcite, iron oxide
NV18--------------	CD80-69	Calcite
UT9---------------	CD76-11B	Barite

The samples fall into three general categories based solely on mineralogy: (1) samples dominated by calcite, (2) samples dominated by barite, and (3) samples dominated by manganese minerals.

The first and largest group includes those samples in which the mineralogy is dominated by calcite. Included in this category are samples 80KF-1, 80KF-3, 80KF-5, 80KF-50, and CD80-69. With the exception of sample 80KF-50, the framework of these samples consists chiefly of authigenic allochemical micritic or microspar grains and micritic peloids and micrite intraclasts which account for approximately 20 percent (80KF-1) to 80 percent (CD80-69) of each sample. Vugs or open space constitute approximately 25-50 percent of each sample. Detrital grains consisting of quartz, microcline, orthoclase, plagioclase, biotite, and muscovite, as well as igneous rock fragments, account for about 5-10 percent of the material present in the majority of the samples. In general, the micritic grains are ellipsoidal to spherical, sometimes having concentric micrite bands around the peripheries (fig. 3). Primary precipitated microspar grains only appear in sample 80KF-5 and are similar in size and morphology to the micritic grains. Small, dominantly angular detrital grains are often observed within the authigenic and detrital micritic grains and were probably the initial focii of the micrite nucleation. Both authigenic and detrital micritic grains range from about 0.1 mm to nearly 2 mm in width and up to 4 mm in length. In several of the samples a few of the micritic grains are distinctly angular and without difficulty were determined to be intraclasts. However, some of the more rounded grains were also determined to be intraclasts with the aid of autoradiography. (See section on "Autoradiographic study.") Authigenic micrite also occurs around the detrital grains and rock fragments where it has formed in irregular patches, especially where there is an accumulation of detrital grains (figs. 4A, B).

The matrix or cement, ranging from 20 percent (CD80-69) to 75 percent (80KF-1) of each sample, consists dominantly of a sparry calcite mosaic and an earlier finer grained calcite mud with less distinct morphology (fig. 5). Aragonite and (or) fibrous crystals of probably high magnesian calcite (X-ray diffraction indicated no aragonite, table 2); occur as cement and open space filling in samples 80KF-1 and 80KF-3 (fig. 6).

The sparry calcite cement is generally a mosaic of subequant to equant, subhedral crystals ranging from about 0.025 mm to 0.4 mm in diameter. Relatively euhedral, equant to slightly elongate (0.1 to 0.25 mm) crystals of drusy calcite have grown, often radially, into open space and frequently display prismatic terminations at one end. The bladed acicular crystals of aragonite and calcite are dominantly euhedral, have widths of a few micrometers and lengths up to 0.04 mm, and define one of the latest stages of cementation. In sample 80KF-1 dominantly elongate, angular to subangular medium crystalline calcite interfingers with the tiny bladed calcite crystals which at one time had grown into open space.

Although sample 80KF-50 is composed almost entirely of calcite, it is unique in the absence of micritic or microspar grains. Coarsely crystalline, optically continuous calcite containing brown semi-opaque outlines of previous crystals and stages of calcite growth are prevalent thoughout the sample (fig. 7). The semi-opaque brown material is probably some type of organic material that had thinly lined the margins of crystal growth. Calcite also occurs in aggregates of elongated or bladed crystals 0.25-0.5 mm long with irregular margins arranged in fan-like groups (fig. 8).

Limonite and hematite occur in samples 80KF-1, 80KF-3, and 80KF-50. Both minerals are present in varying percentages and form several different textures. They were observed to (1) border or coat detrital grains, rock fragments, micritic grains, and intraclasts, (2) occur in thin concentric rings around micritic and detrital grains and intraclasts, (3) bound stages of calcite cement and line cavities or what once were cavities (fig. 5), (4) bound and be interspersed throughout irregular micrite patches, (5) randomly coat calcite, and (6) coat calcite growing within spherical cavities. All of these textures indicate that the iron oxides precipitated concurrently with or, more commonly, following calcite precipitation. The orange-brown limonite is more prevalent in these samples than the dark-reddish-brown hematite.

A variety of organic material was observed in several of the samples. The organic substance in sample 80KF-50 accounted for 2.1 percent by weight of the sample (table 4). An SEM photograph shows an accumulation of ostracod shells (fig. 10), and ostracod casts are prevalent throughout the thin section. Some other forms of organic material in sample 80KF-50 include nematode eggs, a nematode, xylem fragments, rotifer amictic eggs, and possibly some casts of blue-green algal filaments (J. H. Bushnell and R. W. Pennak, written commun., 1981). Masses of radially striated material observed in samples 80KF-5 and 80KF-50 possibly represent former blue-green algae or diatom mucus (J. H. Bushnell and R. W. Pennak, written commun., 1981). Organic material accounted for 2.0 percent by weight of sample 80KF-5 (table 4). Several diatoms and diatom casts were found in samples CD80-69 and 80KF-5 (fig. 10).

The second group of thin sections, those in which barite is the predominant mineralogical phase, includes samples 80KF-6 and CD-76-11B. Both samples show various stages and degrees of crystallization.

At least three successive stages of barite crystallization are observed in sample 80KF-6 (fig. 11). The initial stage of crystallization is depicted by tiny barite needles disseminated throughout a matrix of clay and other fine-grained constituents. Intermediate-stage barite is observed as relatively euhedral, feathery to thin bladed crystals and needles often in aggregates of crystals alined parallel to one another or in radiating groups. The individual crystals are 0.25-3 mm in length and about 0.01 mm in width. The third period of barite development is characterized by groups or aggregates of radiating crystals, similar to the intermediate stage, lining open space and cavities. These crystals are 0.1-0.2 mm in length and about 0.01 mm in width. Several angular intraclasts ranging in size from 3 1/2 to 4 1/2 mm in width are present and contain sand in a matrix of clay and fine-grained constituents. Voids account for about 20 percent of the thin section.

A photomicrograph of thin section CD-76-11B is shown in figure 12. A study utilizing the petrographic microscope, SEM, and whole rock X-ray diffraction determined that barite is the only crystalline phase present in this sample. Two periods of crystallization are apparent. The initial stage is characterized by cryptocrystalline barite occurring in subellipsoidal to subspheroidal clumps or patches which constitute the main part of the sample. These clumps range in diameter from 0.06 mm to 0.34 mm. In transmitted light they are semi-opaque brown to red brown. Examination by an SEM equipped with an energy dispersive analyzer revealed these patches to be predominantly barium and sulfur with no crystalline structure observable under 1,000 times magnification (fig. 13). Semiquantitative spectrographic analysis of this sample has shown it to be very low in iron and manganese (less than 0.05 percent, data from Cadigan and Felmlee, 1982) in relation to the other thin sections which display a red to brown coloration. This particular sample contained 2.1 percent organic carbon by weight (table 4) which may account for the darkening of these areas.

The second stage of barite growth in sample CD-76-11B is characterized by subhedral to euhedral, feathery to thinly bladed barite crystals occurring dominantly in aggregates or masses which have grown radially inward into vugs and open space from the cryptocrystalline barite patches (fig. 14). These individual crystals are 0.02-0.09 mm in length and about 0.006 mm in width. The vugs are approximately 0.1 mm to 1 mm in diameter and constitute about 5-10 percent of the thin section.

The third group of thin sections is distinguished by the presence of manganese-bearing minerals. Included within this category are samples 80KF-4, 80KF-7, and CD80-1 from spring site C017 and CD80-2 from site C022. The manganese minerals are opaque in transmitted light and form cryptocrystalline masses which have an irregular and contorted morphology (fig. 15). Romanechite was identified by X-ray diffraction in two of the samples from site C017 (one was not X-rayed) but not in the sample from site C022.

Although fluorite was identified by X-ray diffraction in all of the samples containing romanechite, it was not seen in thin section. However, a further investigation by SEM revealed euhedral crystals of fluorite, dominantly cubes and cubes with dodecahedrons, ranging in diameter from 10 to 30 μ m. The fluorite has grown on botryoidal masses of romanenchite, and, less commonly, the romanechite has grown on the fluorite (figs. 16A, B). The individual mossy globules or spheres of romanechite vary from 30 to 50 μm microns in diameter.

A photomicrograph of thin section 80KF-7 (fig. 17) depicts cryptocrystalline romanechite crystallized around and embaying coarsely crystalline, optically continuous calcite. Although the calcite is coarsely crystalline, often displaying rhombohedral cleavage, its morphology is extremely ragged, suggesting that it has been partially dissolved and etched by solutions. Further support of this hypothesis is shown in an SEM photograph (fig. 18) of a detrital quartz grain contained within sample 80KF-7, which displays a considerable amount of solution etching.

Positive identification of the species of manganese mineral present in sample CD-80-2 from site C022 was not ascertained by any of the methods employed in this study. Although its appearance in thin section is similar to the romanechite identified in the other samples, its X-ray diffraction pattern does not correspond to romanechite or to any of the other relatively common crystalline manganese minerals. An elemental analysis by an energy dispersive unit interlinked with the SEM indicated that this material is composed primarily of manganese but also contains barium, as romanechite does. The manganese minerals present in this sample appear as botryoidal globular masses similar to romanechite, but the size of the individual spheres is considerably larger, ranging up to about 500 μm in diameter (fig. 19).

Limonite was observed in minor amounts in all of the samples in this category, and hematite appears in sample CD-80-2. The iron-bearing minerals are cryptocrystalline and are found coating the manganese phase and lining open space and vugs. Although gypsum was identified by X-ray diffraction, it was not observed in thin section or by SEM.

The porosity of all of the samples in this group is very high, with vugs and cavities accounting for an estimated 20-40 percent of each sample. Detrital grains and rock fragments are abundant and constitute 10-20 percent of each sample. The detrital grains are dominantly quartz, feldspar, and biotite, whereas the rock fragments are primarily from fine-grained igneous rocks.

Autoradiographic study

An autoradiographic study implementing a nuclear track-recording plastic "CR-39" and the radioluxograph technique was performed on the 11 selected samples from which thin sections were obtained. This study was undertaken to determine which mineral phases and (or) paragenetic sequences are associated with the radioactivity inherent in these samples. As shown in table 2, 9 out of 11 of these samples have greater than or equal to 0.01 percent eU. The samples and their eU values (Cadigan and Felmlee, 1982) are listed below:

Sample	eU(pct)
80KF-6	0.4
80KF-5	.03
80KF-1	.007
80KF-3	.06
80KF-4	.06

80KF-7	.06
CD-80-1	.4
CD-80-2	.1
80KF-50	<.001
CD-80-69	.08
CD-76-11B	1.0

The radioactivity in these samples is due primarily to the presence of radium-226 (C. M. Bunker, oral commun., 1978).

Radioactivity in the examined samples was found to be associated with mineral phases containing barium, manganese, iron, and (or) calcium as principal elements. The radioactivity occurs with different intensities in the various minerals and was observed to have a preference for some mineral phases over others in the same samples.

Autoradiography shows that the radioactivity in some samples has an intimate association with barite (figs. 20 A, B, and 21 A, B). Barite is the only mineral present in sample CD-76-11B, and it constitutes the main precipitated mineral phase in sample 80KF-6. Several barite-barren intraclasts contained within sample 80KF-6 are composed of sand in a matrix of clay and other fine-grained constituents and appear to be barren of radioactivity.

Autoradiography also displays the intimate association of radioactivity with manganese- and barium-bearing precipitate phases and shows that radium-226 has an affinity for the manganese- and barium-bearing minerals over calcite and some iron-bearing minerals. In a photomicrograph and complementary autoradiograph of sample CD80-1, alpha tracks are abundant and distributed evenly throughout the manganese- and barium-bearing phase (figs. 22 A,B). Alpha-tracks are similarly distributed in sample 80KF-4 composed predominantly of romanechite. Also in sample CD80-2, where the manganese- and barium-bearing mineral coexists with hematite, radium-226 selectively associates with the manganese- and barium-bearing mineral (figs. 23 A,B). In sample 80KF-7, where calcite and romanechite coexist, radium-226 was observed to be distributed uniformly and abundantly throughout the romanechite; the calcite is essentially barren (figs. 24 A, B).

In some samples, namely 80KF-1 and 80KF-3, the radioactivity shows a close affinity with iron-bearing minerals, especially hematite (figs. 25 A,B and 26 A,B). Two observations have been made regarding this association. First, the iron minerals have a close relationship with radium-226 in those samples where calcite predominates and manganese- and barium-bearing minerals are absent. Second, when hematite is very close to or partially coating a coarsely to very coarsely crystalline phase of calcite, the radium is almost entirely associated with the hematite, leaving the uncoated portions of the calcite nearly barren of radioactivity (figs. 26 A, B). On the other hand, when hematite is observed to wholly or partially coat a finely to medium crystalline phase of calcite, the uncoated calcite still retains a low to background level of radioactivity. These relationships possibly indicate that the radium was expelled or excluded from the coarsely crystalline calcite because coprecipitation became limited. The radium in the hematite was probably the result of adsorption on hydrous iron oxide molecules which later dehydrated to form hematite.

In samples 80KF-1 and 80KF-3, composed chiefly of calcite, a moderate accumulation of alpha tracks was observed in the calcite and (or) aragonite cementing phases. Angular micritic grains which were determined to be intraclasts were devoid of radioactivity. Also, several rounded micritic grains and peloids were devoid of radioactivity and were therefore determined to be intraclasts (figs. 25 A,B and 27 A,B). On the other hand, authigenic micrite which has nucleated around detrital grains and masses of detrital grains shows a density of alpha tracks similar to the calcium carbonate cementing phases or background (figs. 28 A,B). As observed in all the other samples, the detrital grains are devoid of radioactivity.

In samples CD80-69 and 80KF-5, also composed predominantly of calcite, the radioactivity is preferentially associated with an early phase of micrite or microspar. The radioactivity in sample CD80-69 is mostly associated with a primary stage of calcite represented by irregular shaped, subequant to elongate authigenic micritic grains (figs. 29 A,B). A later cementing stage involving micrite and a finely crystalline calcite phase shows a much lower concentration of alpha tracks. Similarly, in sample 80KF-5 the bulk of the radioactivity is associated with early subrounded, subequant grains composed of microspar which makes up the framework of the sample (fig. 30). Considerably lower levels of radioactivity were seen in the later microspar cementing phase. In both samples very little difference in grain size and texture between stages of calcium carbonate was observed. Although both of these samples contain relatively high values of barium, electron microprobe data showed both samples to be relatively homogeneous with respect to the distribution of barium in the various phases of calcite. Apparently, the radioactivity in these samples is controlled more by the stages of development of the precipitate than by the morphology or the chemical composition.

In the samples containing barite, radium is believed to substitute for barium in the barite lattice. Barium and radium are alkaline-earth elements having the same ionic charge (+2) and very similar ionic radii (Ba, 1.35Å and Ra, 1.40Å), properties which account for the well-known phenomenon of coprecipitation commonly used in laboratory techniques for elemental analysis of radium in water. The radium associated with the manganese minerals may be held by adsorption on the surfaces of the manganese oxide; however, the manganese minerals in these samples contain a substantial amount of barium and more probably the radium is substituting for barium in the mineral structure. Substitution of radium for barium in the manganese mineral structure would explain why the radium exclusively associates with the manganese-bearing mineral phases over calcite or hematite when both occur in the same sample. The radium apparently prefers barium sites in the manganese mineral over calcium sites, and radium is being held only by adsorption to the surfaces of the iron oxides. The radioactivity in the calcium carbonate is probably not due to substitution of radium for calcium in the calcite and (or) aragonite lattices due to the fact that the ionic radii of Ca (1.40Å) and RA (1.99Å) are relatively far apart. Krauskopf (1967 p. 145) states, "substitution is not common between elements whose ionic radii differ by more than 15 percent." However, he also mentions that substitution of Si (0.42Å) and Al (0.51Å) is common and is one of the many exceptions to the rule that substitution is limited to elemental pairs which differ in ionic radius by less than 15 percent. Although "coprecipitation" of radium with calcium carbonates does occur and has been noted by Tokarev and Scherbakov (1960), they do not state whether the "coprecipitation" phenomenon takes place by substitution of radium for calcium, radium being held in interstitial sites created by irregularities in the calcite crystal structure, or a combination of both. The fact that substitution of radium for barium occurs in barite whereas substitution of radium for calcium in calcite is improbable could easily explain why the levels of radioactivity observed in calcite are much less than levels observed in barite.

Summary

Mineral identification of 236 precipitate or sediment samples from 97 mineral-spring sites in nine Western States was done by X-ray diffraction analysis. Twenty-five minerals, some precipitated and some thought to be detrital, were identified. Calcite and (or) aragonite are the most common of all the precipitated minerals. Gypsum and (or) anhydrite, as well as barite and sulfur, are less common but are also believed to be precipitated minerals. Precipitated manganese and iron oxides, including romanechite, manganite, pyrolusite, goethite, and hematite, were found in some of the samples. Various salts of sodium, including halite and thenardite, were also identified. An unknown type of siliceous material as well as dolomite were identified in some of the samples and were possibly precipitated at the spring sites. Quartz, feldspar, and mica are present in many of the samples and are believed to be detrital contaminants.

A descriptive thin-section study was done on 11 of the 236 samples from nine of the most radioactive spring sites. These 11 samples were grouped into three categories based solely on mineralogy: (1) samples dominated by calcite, (2) samples dominated by barite, and (3) samples dominated by manganese minerals.

An autoradiographic study utilizing a nuclear track recording plastic "CR-39" and the radioluxograph technique was performed on the 11 thin-section samples, 9 of which have greater than or equal to 0.01 percent eU. This study was undertaken to determine the paragenesis of the mineral phases and what mineral phases and paragenetic sequences are associated with the radioactivity, which is due primarily to the presence of radium.

The autoradiography results showed the radioactivity to be directly associated with the mineral phases containing barium, manganese, iron, and (or) calcium as principal elements. In the samples containing barite, the radioactivity occurs exclusively with the barite phase. Samples containing manganese-bearing precipitate phases show an intimate association of radioactivity with the manganese minerals and show that the radium has an exclusive affinity for the manganese-bearing minerals, which contain a substantial amount of barium in these samples, when calcite or iron oxides are present within the same sample. In two of the samples where calcite predominates and manganese- and barium-bearing minerals are absent, the radioactivity shows a close association with the iron oxides present, especially hematite, but also shows a moderate association with the calcite and (or) aragonite cementing phases. In two other samples also composed predominantly of calcite but nearly devoid of iron oxides, the radioactivity is preferentially associated with an early stage of microspar development and is considerably lower in the later cementing stages.

The radioactivity observed in the 11 samples studied by autoradiography is believed to be caused by radium substituting for barium in barite and manganese- and barium-bearing mineral lattices, occupying defects in calcium-bearing mineral phases, or adsorbing on the surfaces of precipitated iron oxy-hydroxide molecules. Radium, as an alkaline-earth element, has an ionic charge (+2) equivalent to barium allowing it to substitute in the barite lattice but has an ionic radius (1.40Å) much more similar to barium (1.35Å) than to calcium (0.99Å) allowing it to substitute in the barite lattice but not in the calcite lattice. Because radium can substitute for barium and probably not for calcium, it shows a preference for barium sites, whether in barite or in the barium-bearing manganese minerals such as romanechite, even if calcite is present. This preference is apparent even when iron oxides are present. Radium is probably held by adsorption on iron oxides, and although substitution for barium apparently takes precedence over adsorption, adsorption on iron oxides apparently takes precedence over physical coprecipitation with calcium. Where calcite is virtually the only mineral phase present, the radium shows a preference for early micrite or microspar phases, the distribution probably being controlled by the stages of development and the availability of radium.

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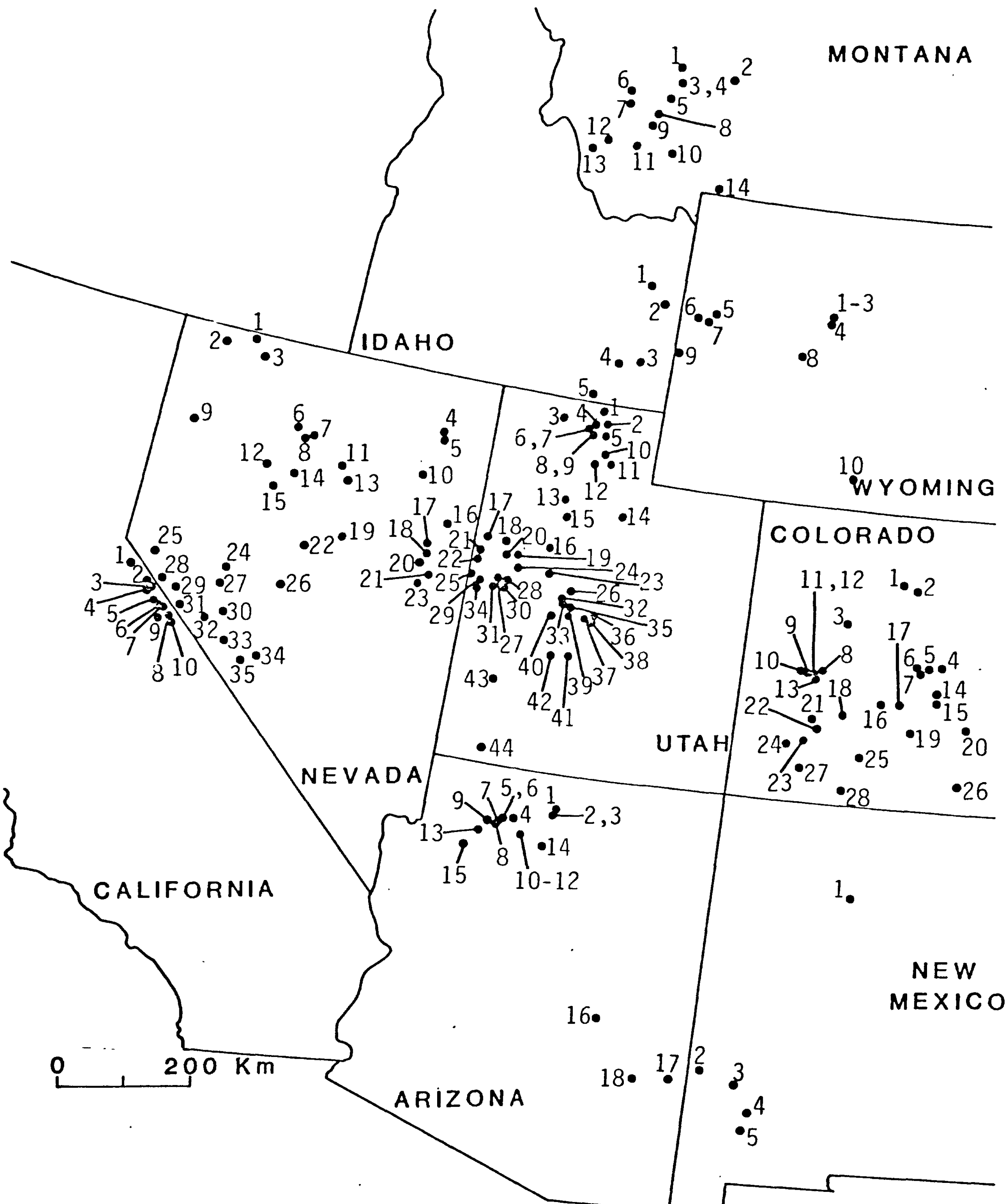

Figure 1.-- Mineral-springs sites visited during this study. Numbers in each state correspond to sites described in table 1.

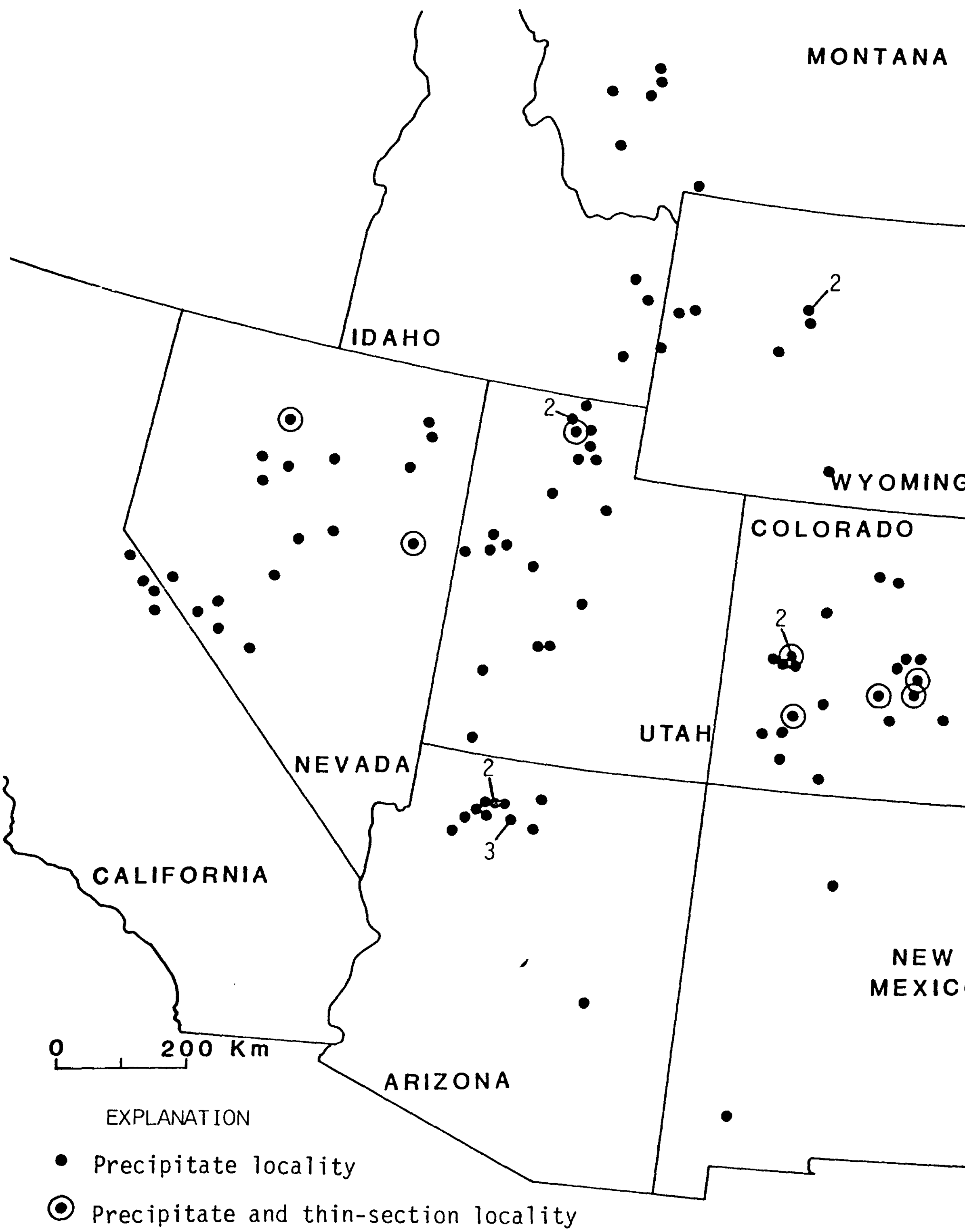

Figure 2.--Precipitate sample localities and localities from which thin sections were obtained. Numbers denote more than one locality represented by dot.

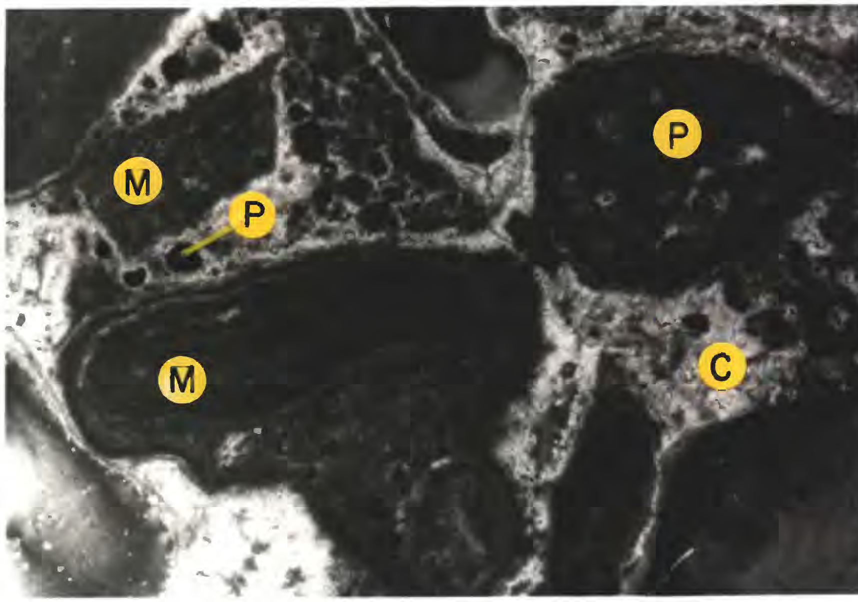

Figure 3.--Micritic grains (M) and peloids (P) in a cement consisting of a fine to medium crystalline calcite (C). Sample CD-80-69. Plane light. Field of view 5.1mm.

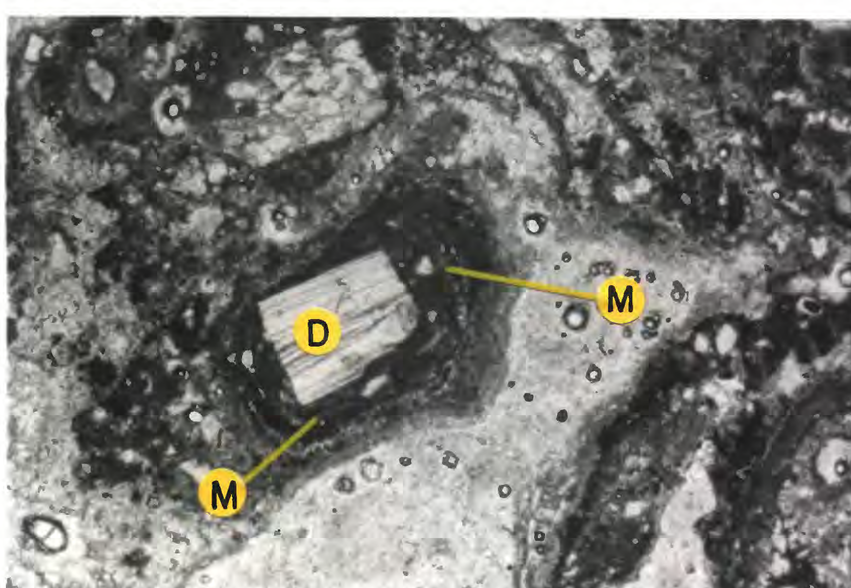

Figure 4A.--Micrite (M) which has nucleated somewhat concentrically around a detrital muscovite grain (D). Sample 80KF-3. Plane light. Field of view 5.1mm.

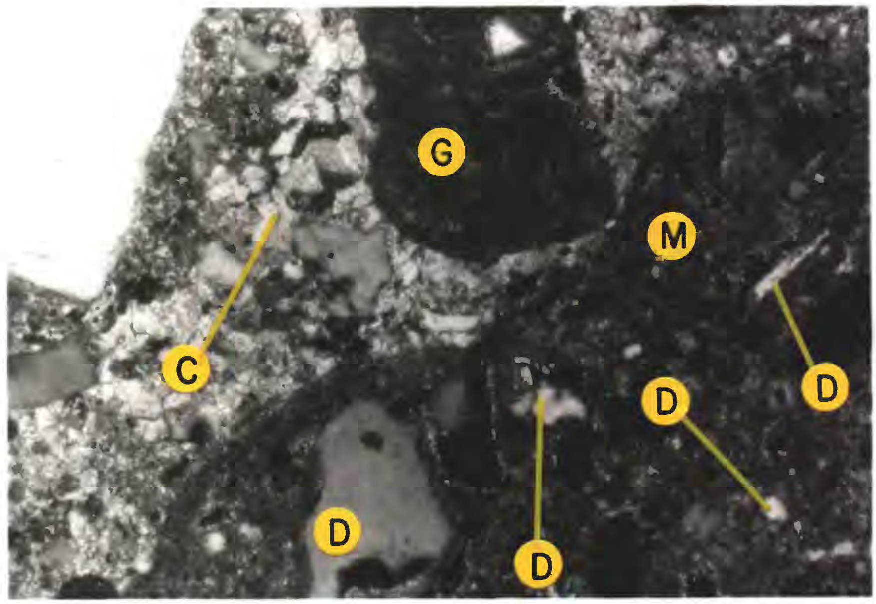

Figure 4B.--Irregular shaped patch of micrite (M) which has formed around a cluster of detrital grains (D). At the top a micritic grain (G) is shown within a matrix of sparry calcite mosaic (C). Sample 80KF-3. Crossed polars. Field of view 2.48mm.

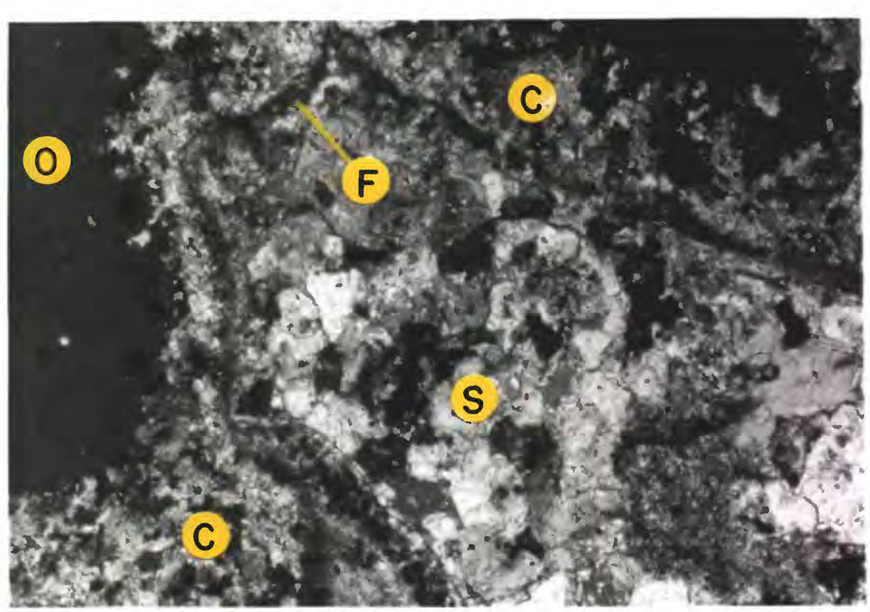

Figure 5.--Sparry calcite mosaic (S) and an earlier stage of microcrystalline calcite development (C) separated by a rim of iron oxide (F). O, open space. Sample 80KF-1. Crossed polars. Field of view 1.0mm.

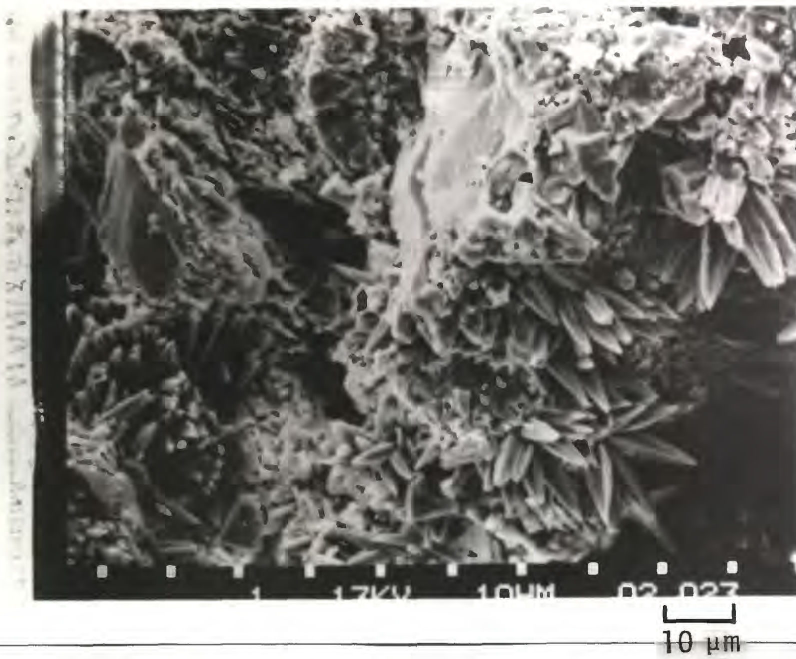

Figure 6.--Aragonite crystals which have grown into open space. Sample 80KF-3

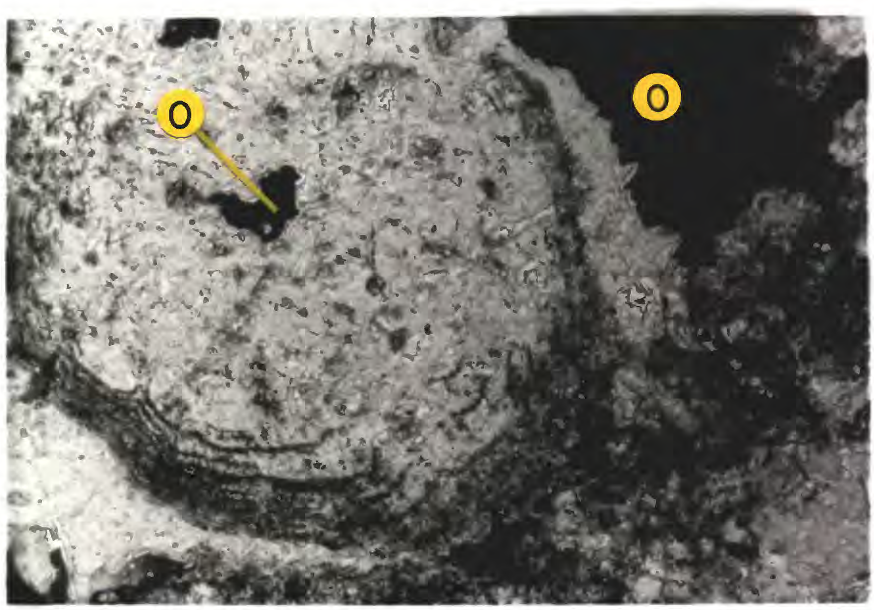

Figure 7.--Coarsely crystalline calcite displaying semi-opaque outlines of previous stages of crystal growth. The semi-opaque material is probably organic. O, open space. Sample 80KF-50. Plane light Field of view 5.1mm.

Figure 8.--Calcite occurring in aggregates of elongate, bladed crystals arranged in fan-like groups. O, open space. Sample 80KF-50. Nicols crossed. Field of view 1.0mm.

Figure 9.--An accumulation of ostracode shells within sample 80KF-50. 100x magnification.

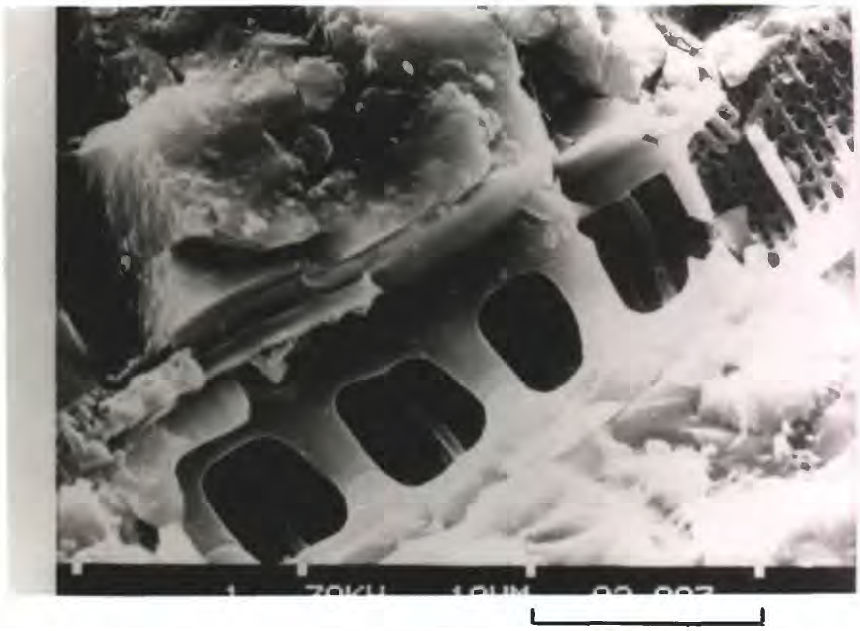

Figure 10.--A single diatom within sample CD-80-69. 3,000x magnification.

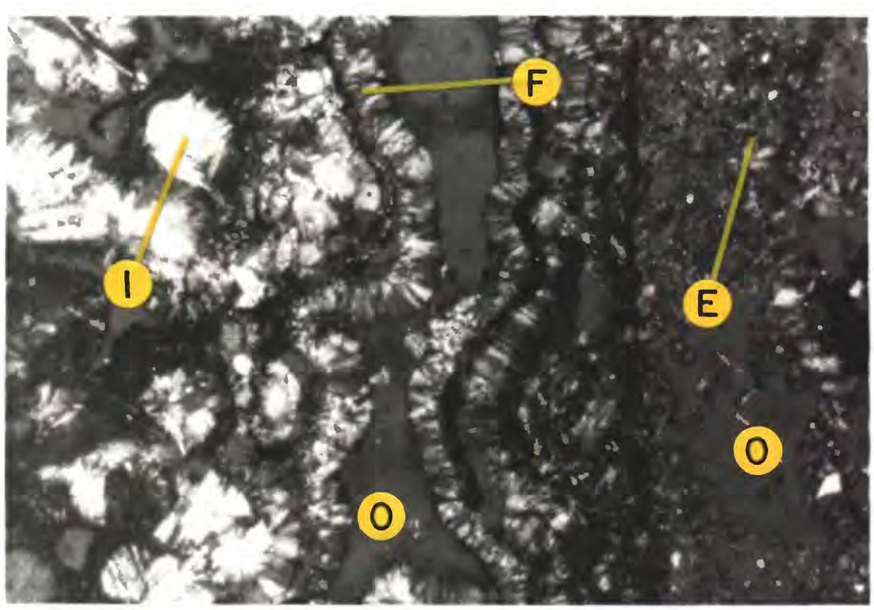

Figure 11.--Three stages of barite crystallization: early stage (E); intermediate stage (I); and final stage (F), showing barite lining open space (O). Sample 80KF-6. Crossed polars. Field of view 5.1mm.

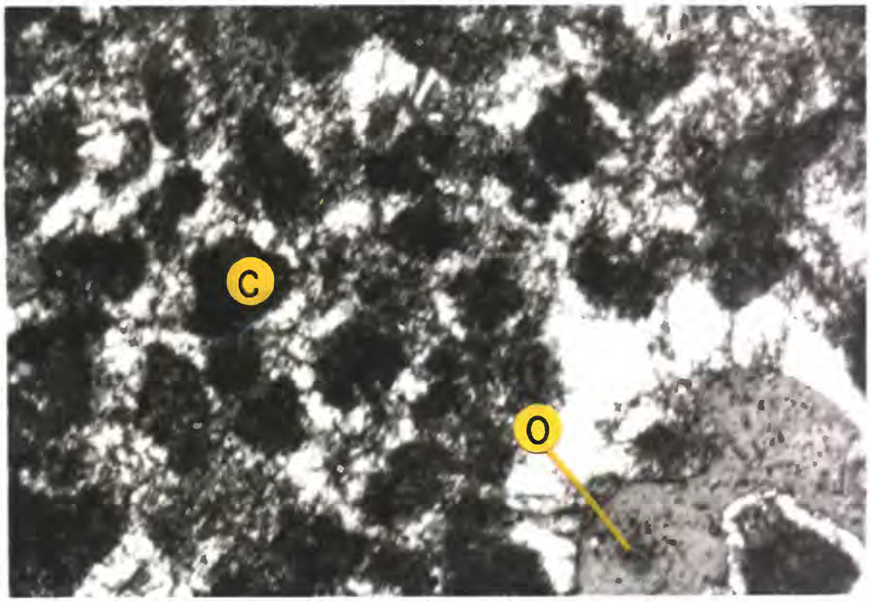

Figure 12.--Barite morphologies, (C), clumps; O, open space. Sample CD-76-11B. Crossed polars. Field of view 2.48mm.

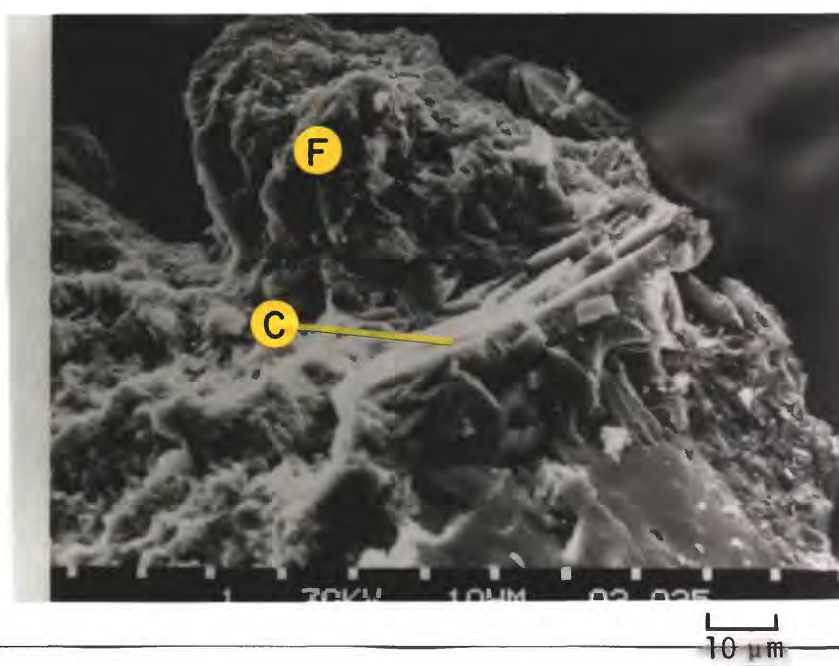

Figure 13.--Very fine grained phase (F) and coarser grained phase (C) of barite. Sample CD-76-11B.

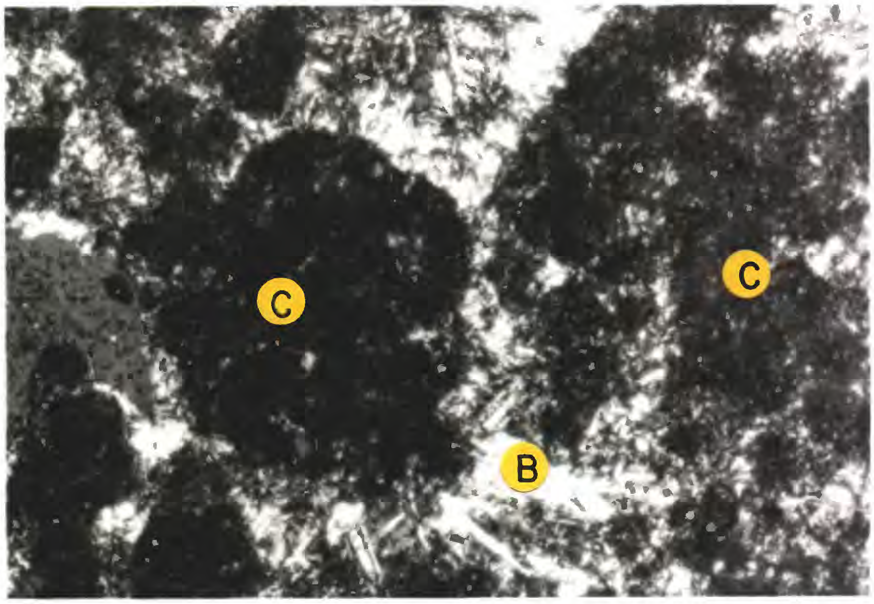

Figure 14.--Bladed barite crystals (B) which have grown radially into open space from semi-opaque cryptocrystalline barite clumps (C). Sample CD-76-11B. Crossed polars. Field of view 5.1mm.

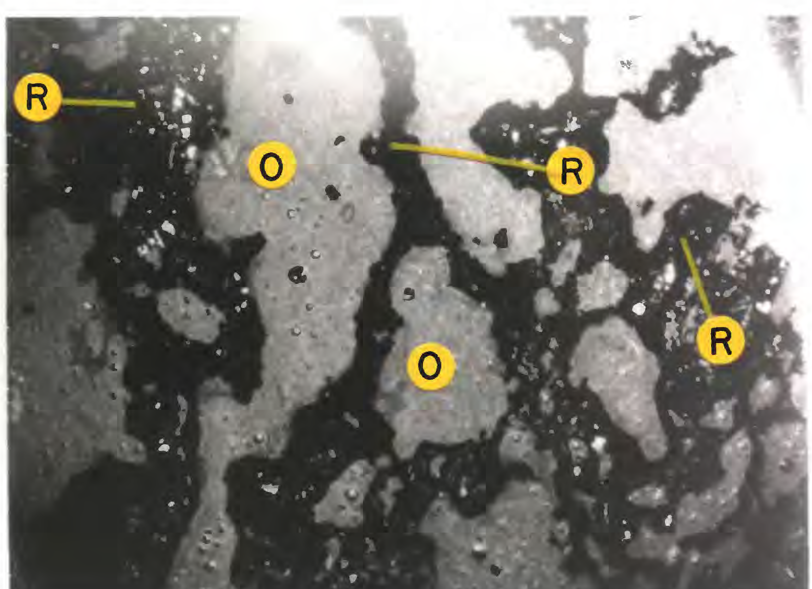

Figure 15.--Cryptocrystalline phase of romanechite (R). O, open space. Sample CD-80-1. Crossed polars. Field of view 5.1mm.

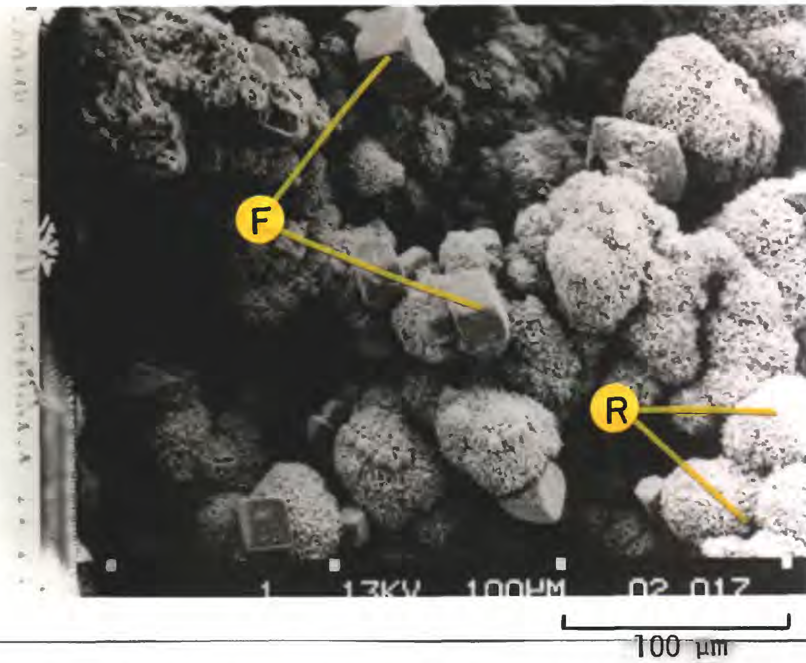

Figure 16A.--Fluorite crystals (F) which have apparently grown on botryoidal masses of romanechite (R). Sample 80KF-4.

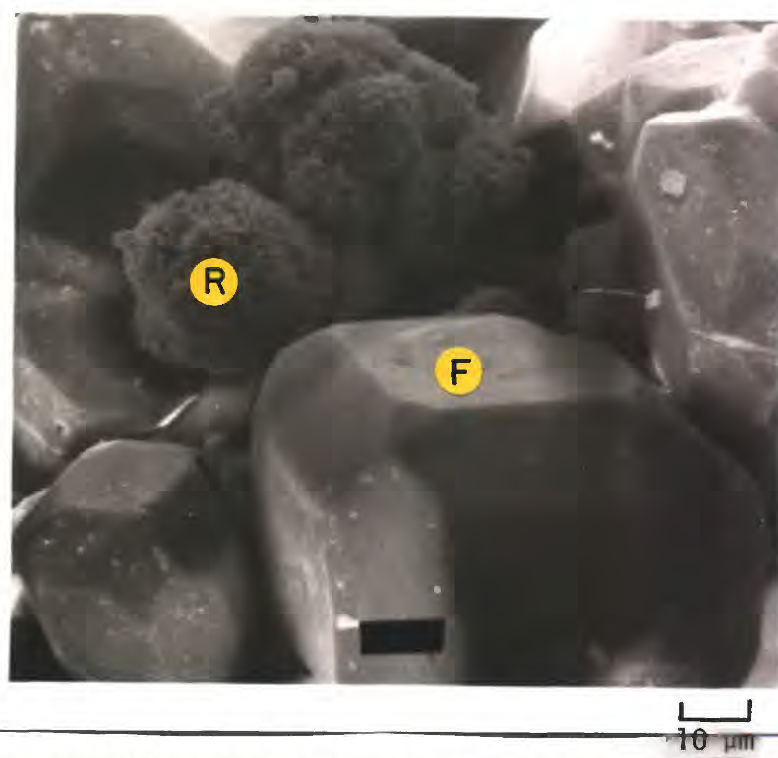

Figure 16B.--Romanechite (R) which has apparently grown on fluorite crystals (F). Sample 80KF-4.

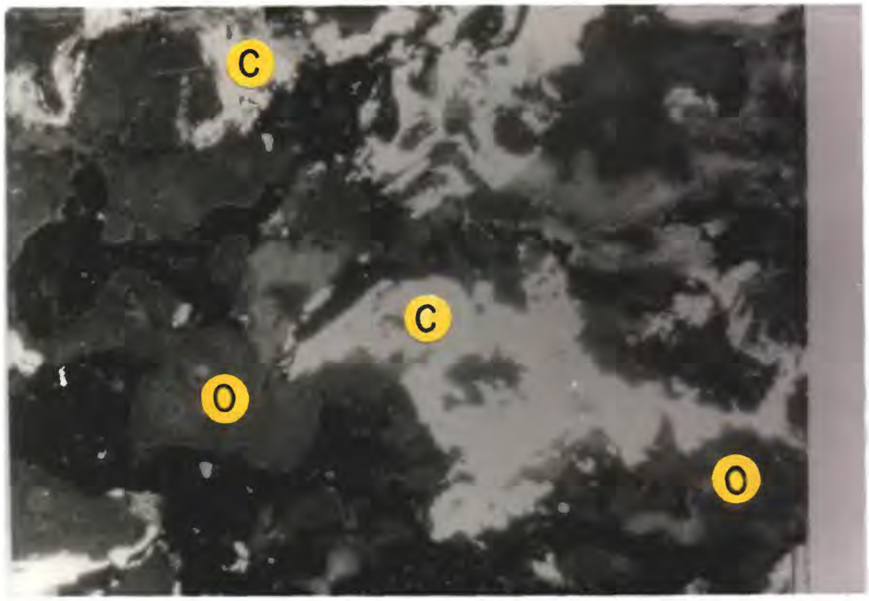

Figure 17.--Cryptocrystalline romanechite (R) which has crystallized around and embayed calcite (C). O, open space. Sample 80KF-7. Crossed polars. Field of view 5.1mm.

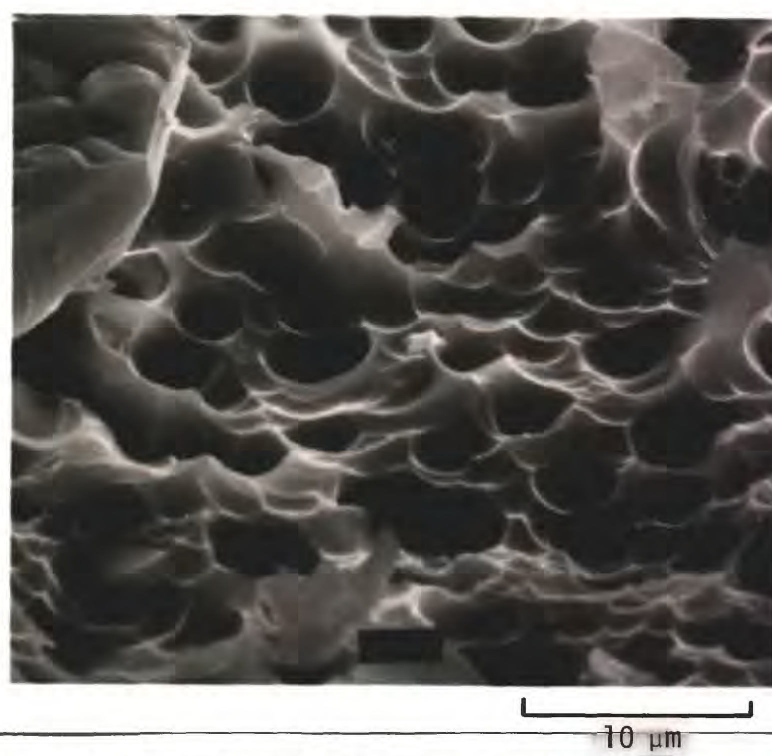

Figure 18.--Etched and dissolved detrital quartz grain in sample CD-80-2.

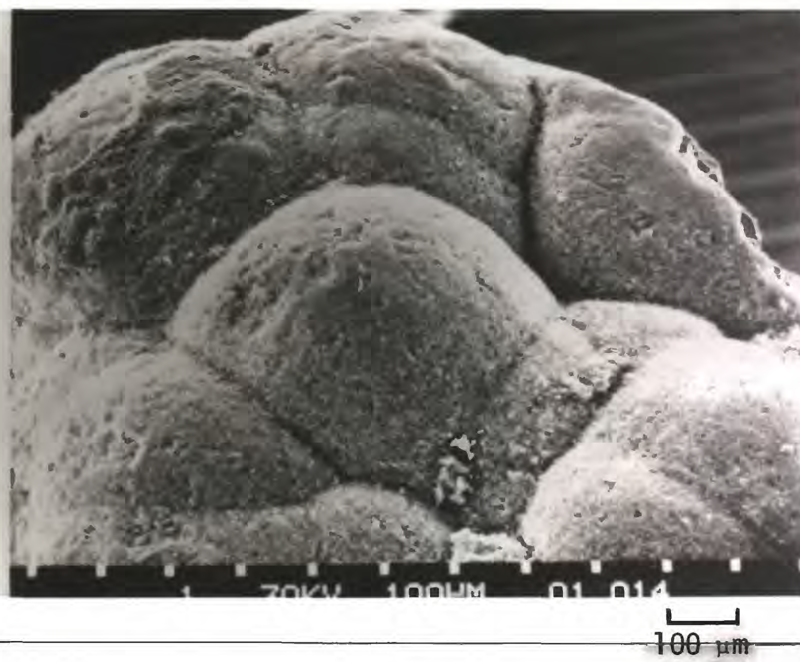

Figure 19.--Botryoidal manganese mineral in sample CD-80-2.

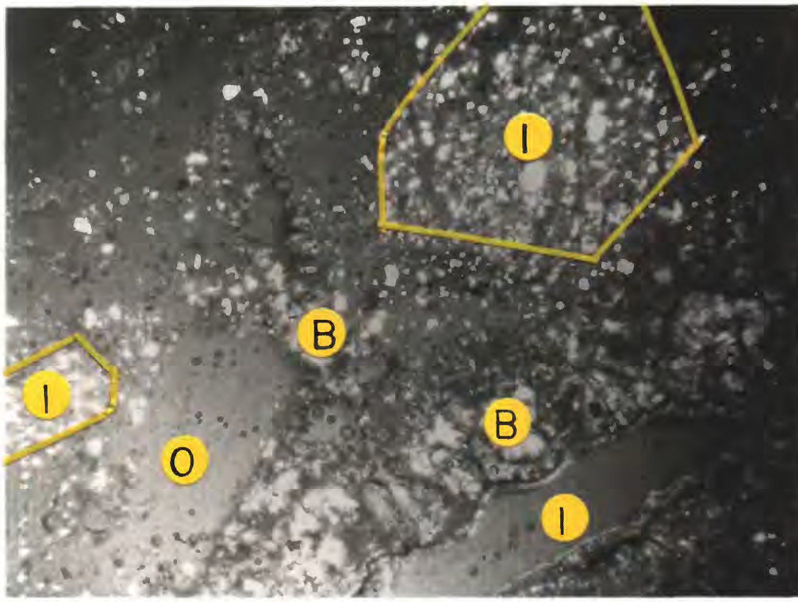

Figure 20A.--Barite (B) and intraclasts (I). O, open space. Sample 80KF-6. Crossed polars. Field of view 5.1mm.

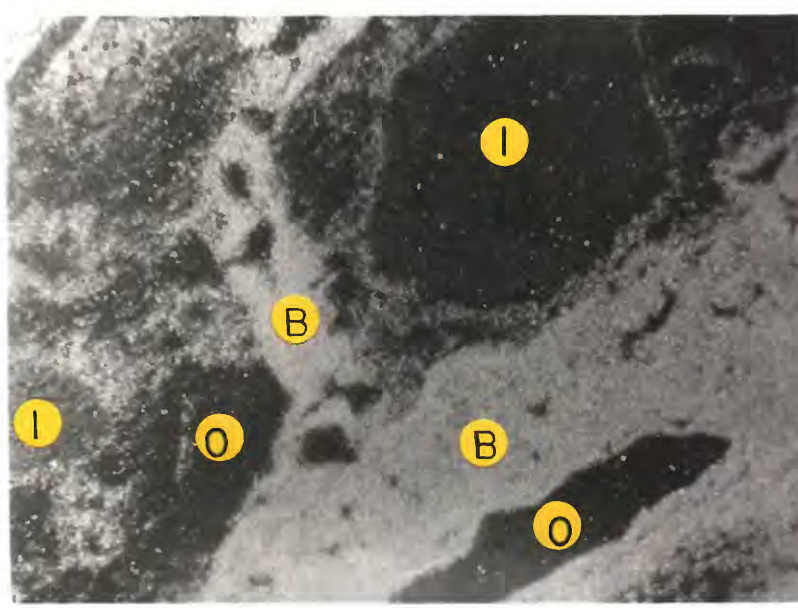

Figure 20B.--Autoradiograph complementary to figure 20A, showing radioactivity exclusively associating with the barite phase (B). The intraclasts (I) are barren of radioactivity. O, open space.

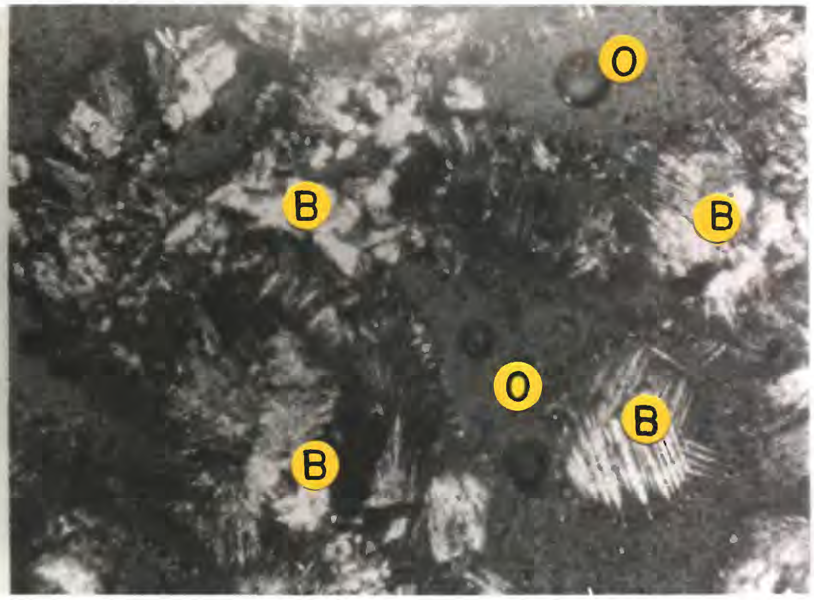

Figure 21A.--Intermediate stage of barite (B). O, open space. Sample 80KF-6. Crossed polars. Field of view 2.48mm.

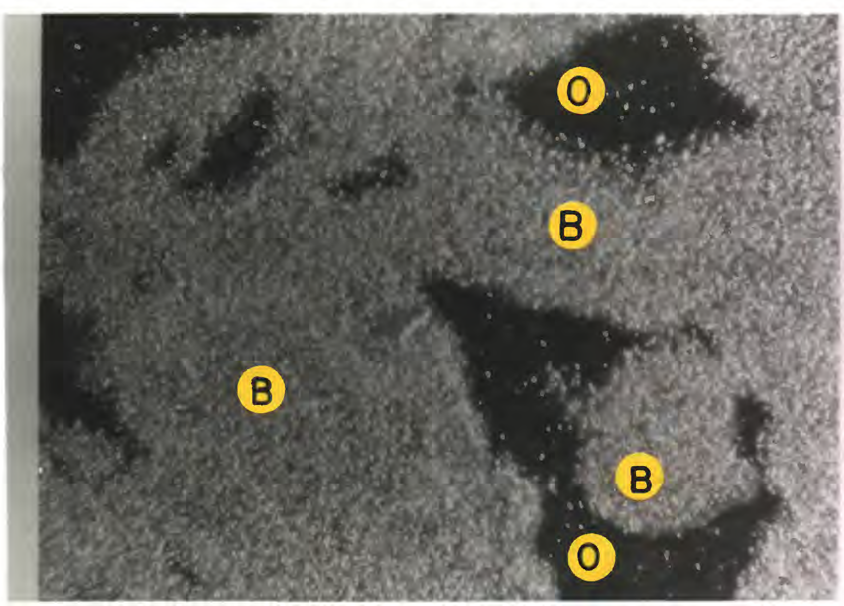

Figure 21B.--Autoradiograph complementary to figure 21A, showing a dense accumulation of alpha tracks associated with the barite (B). O, open space.

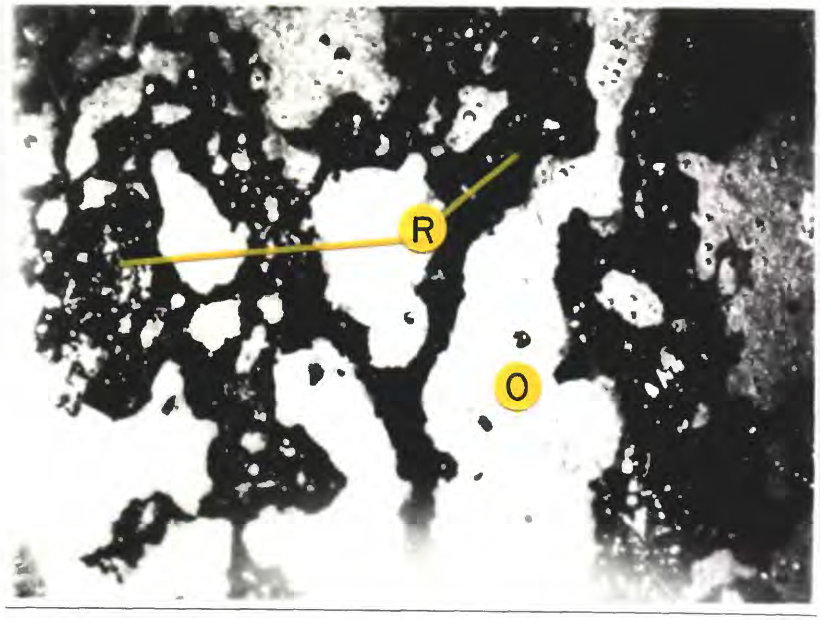

Figure 22A.--Cryptocrystalline phase of romanechite (R). O, open space. Sample CD-80-1. Crossed polars. Field of view 5.1mm.

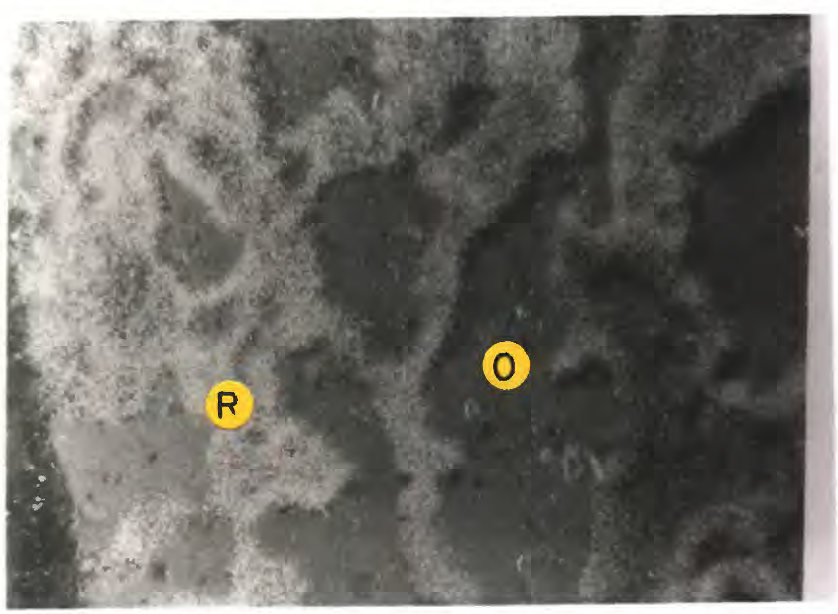

Figure 22B.--Autoradiograph complementary to figure 22A, showing a dense accumulation of alpha tracks associated with romanechite (R). O, open space.

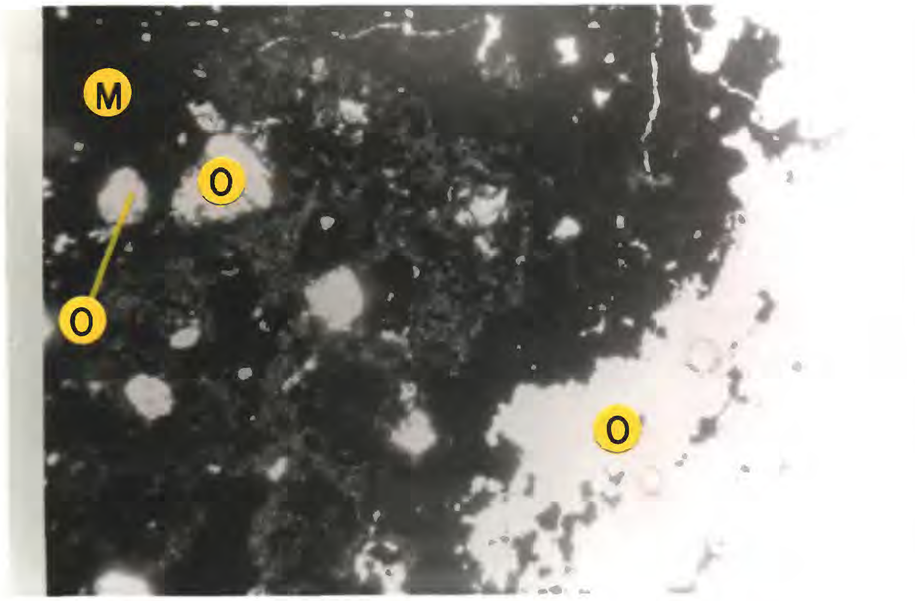

Figure 23A.--Barium-bearing manganese mineral (M) around hematite (light gray area). O, open space. Sample CD-80-1. Plane light. Field of view 1.0mm.

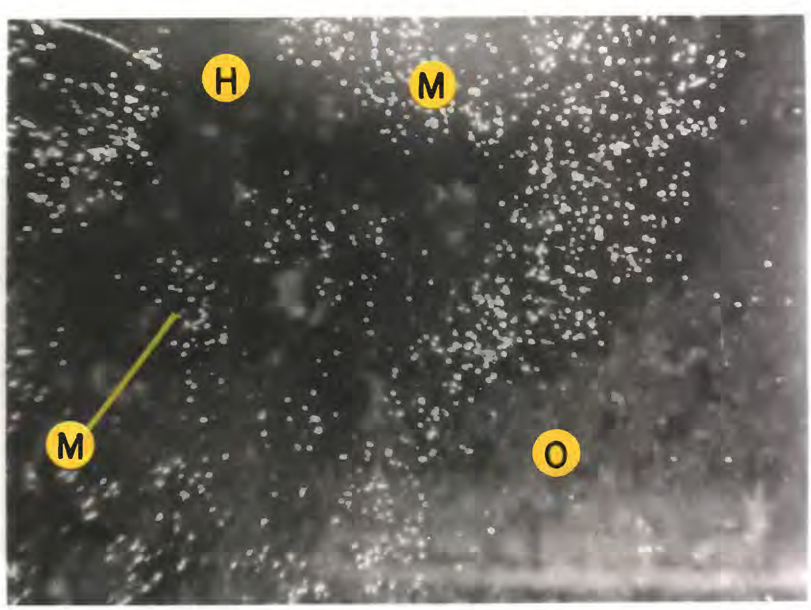

Figure 23B.--Autoradiograph complementary to figure 23A, showing radioactivity associating exclusively with the barium-bearing manganese mineral (M). Hematite (H) is devoid of radioactivity. O, open space.

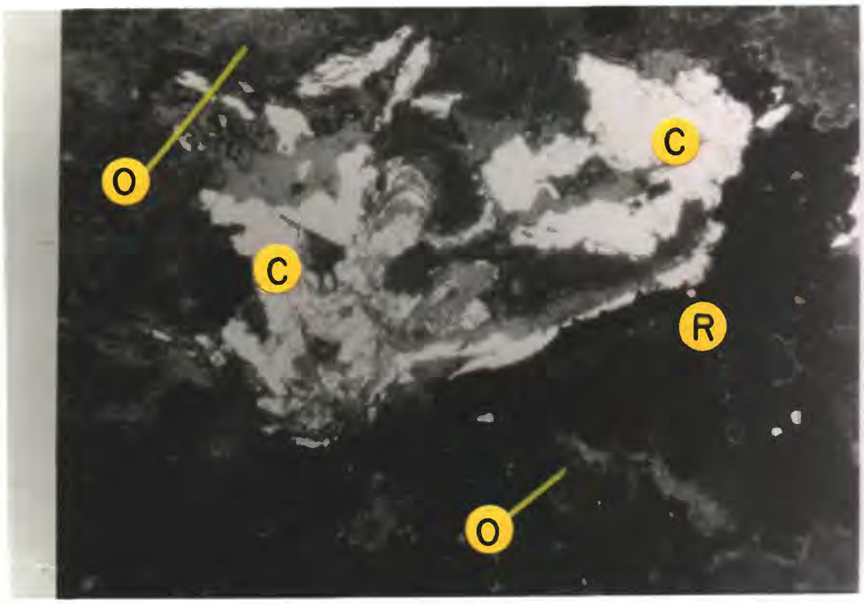

Figure 24A.--Calcite (C) coexisting with cryptocrystalline romanechite (R). O, open space. Sample 80KF-7. Crossed polars. Field of view 2.48mm.

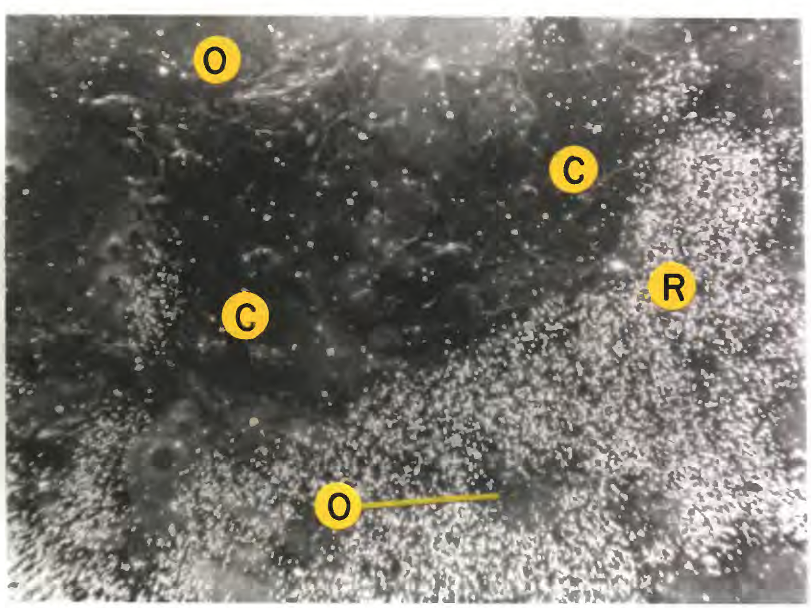

Figure 24B.--Autoradiograph complementary to figure 24A, showing radioactivity associating exclusively with romanechite (R). Calcite (C) is barren of radioactivity. O, open space.

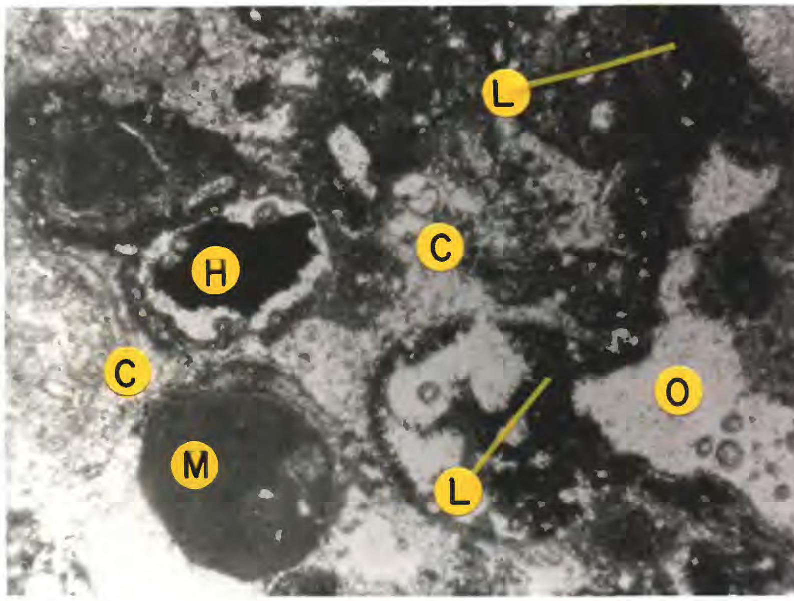

Figure 25A.--Micritic peloid intraclast (M) within cement consisiting of calcite (C). Hematite (H) is coating calcite. L, limonite. O, open space. Sample 80KF-3. Plane light. Field of view 2.48mm.

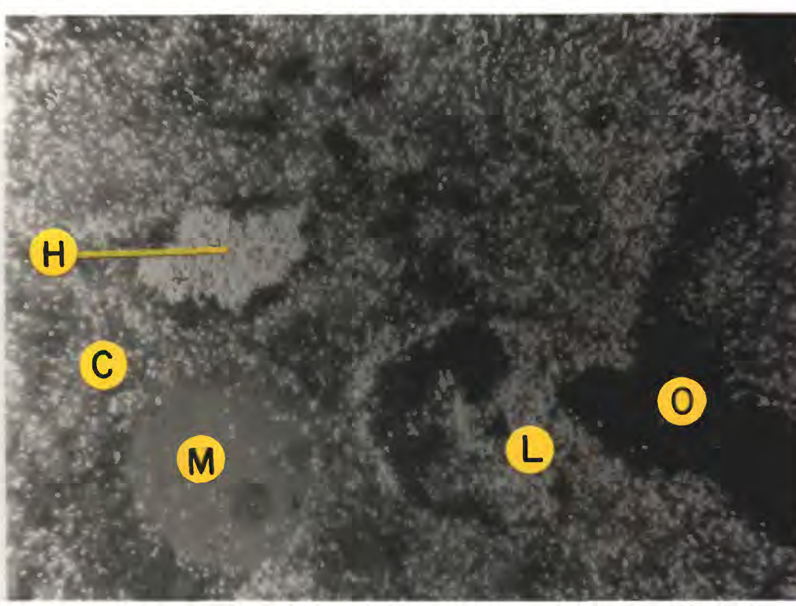

Figure 25B.--Autoradiograph complementary to figure 25A, showing the micritic intraclast (M) to be barren of radioactivity and the calcite cement (C) to have low to moderate levels of radioactivity. Hematite (H) shows a dense accumulation of alpha tracks, whereas the limonitic phase (L) shows alpha-track accumulations of intermediate density. O, open space.

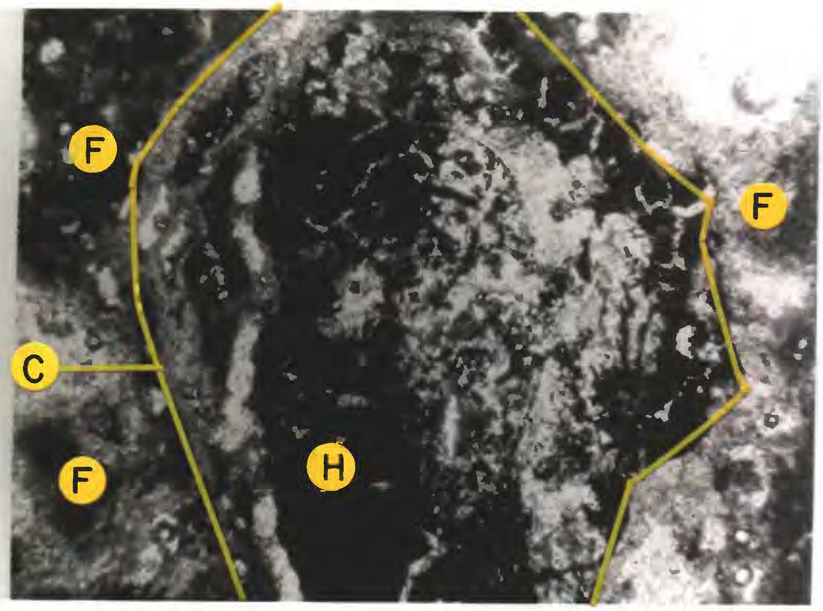

Figure 26A.--Coarsely crystalline calcite (C) partially coated by hematite (H) within relatively fine grained calcite cement (F). Sample 80KF-3. Plane light. Field of view 2.48mm.

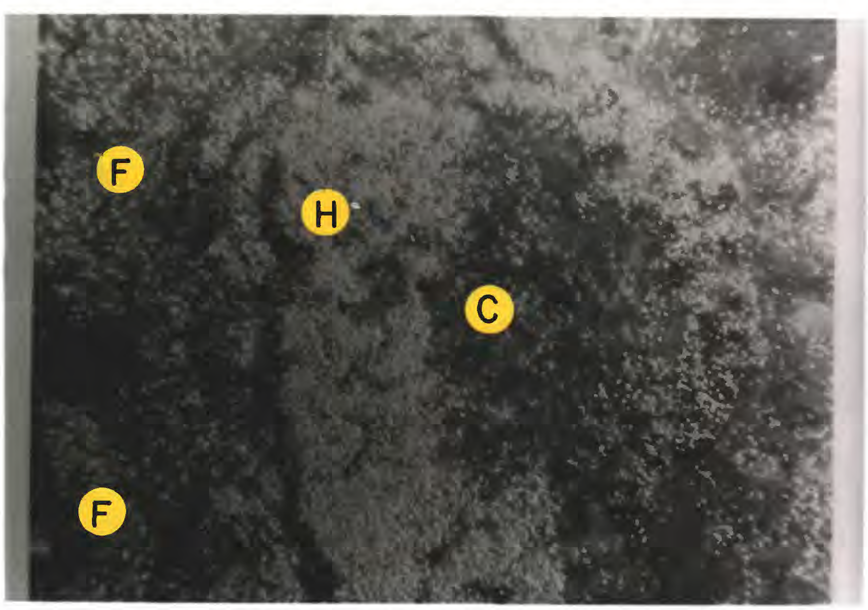

Figure 26B.--Autoradiograph complementary to figure 26A, showing dense accumulation of alpha tracks associated with hematite (H), whereas the portions of the coarsely crystalline calcite (C) not coated by hematite are relatively barren of radioactivity. The calcite cementing phase (F) shows a low to moderate accumulation of alpha tracks.

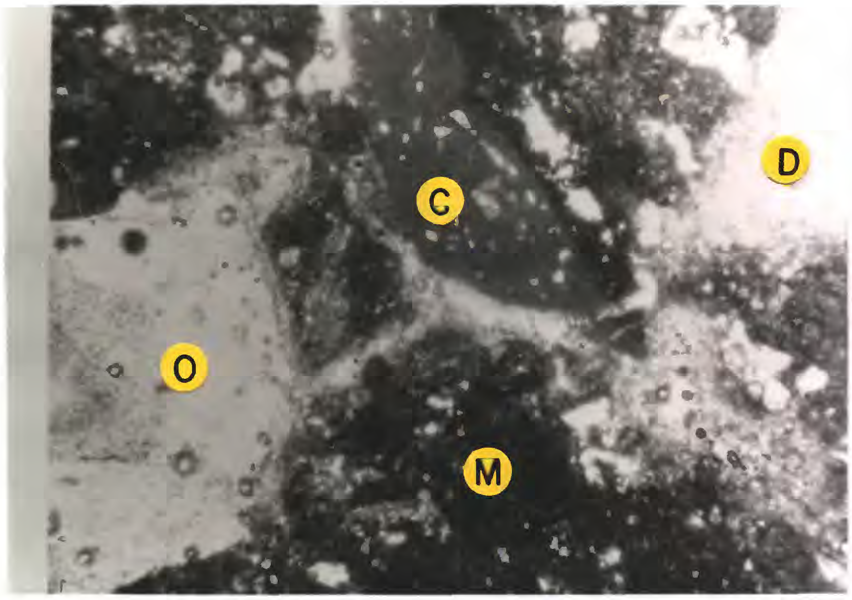

Figure 27A.--Micritic intraclast(M) within a very finely crystalline to micritic calcite cement (C). D, detrital grain. O, open space. Sample 80KF-3. Plane light. Field of view 2.48mm.

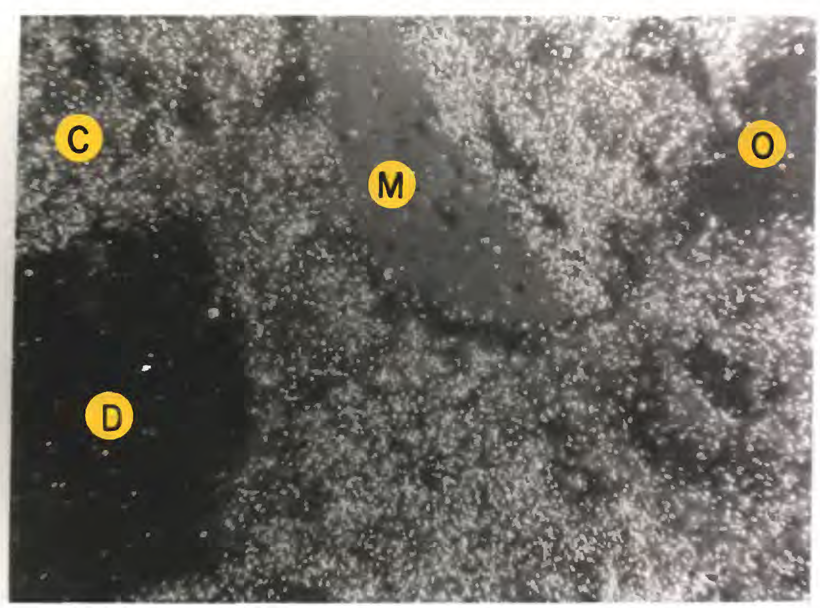

Figure 27B.--Autoradiograph complementary to figure 27A, showing micrite intraclast (M) barren of radioactivity. Calcite cementing phase (C) shows a moderate accumulation of alpha tracks. D, detrital grain. O, open space.

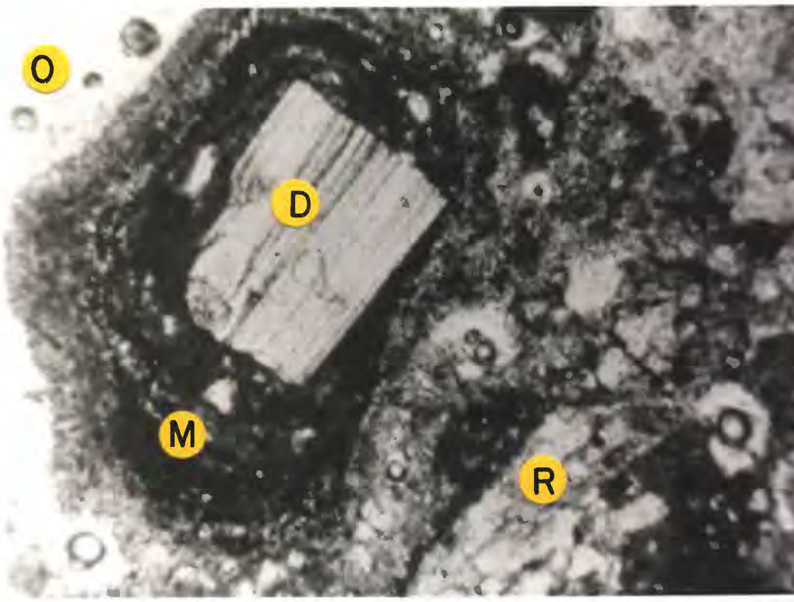

Figure 28A.--Detrital muscovite grain (D) surrounded by micrite (M). R, rock fragment. O, open space. Sample 80KF-3. Plane light. Field of view 2.48mm.

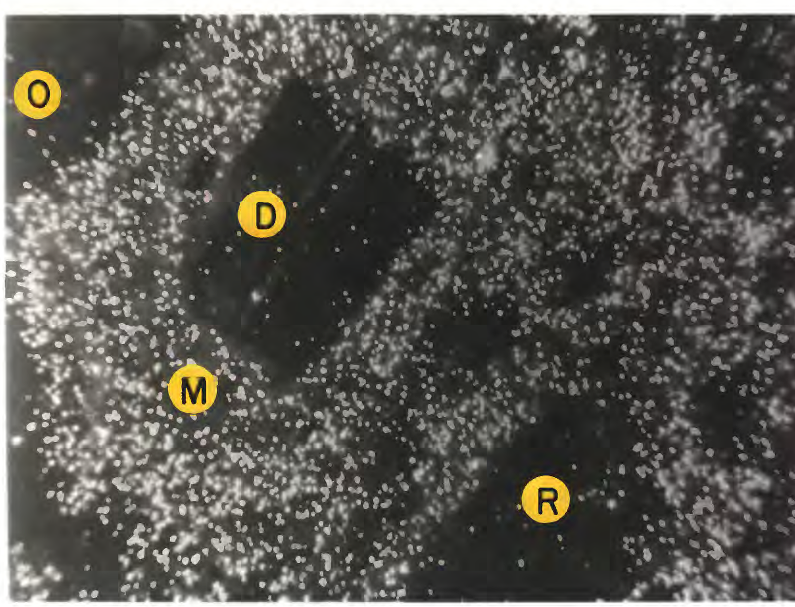

Figure 28B.--Autoradiograph complementary to figure 28A, showing radioactivity associating with the micrite (M) surrounding the muscovite (D), which is devoid of radioactivity. R, rock fragment. O, open space.

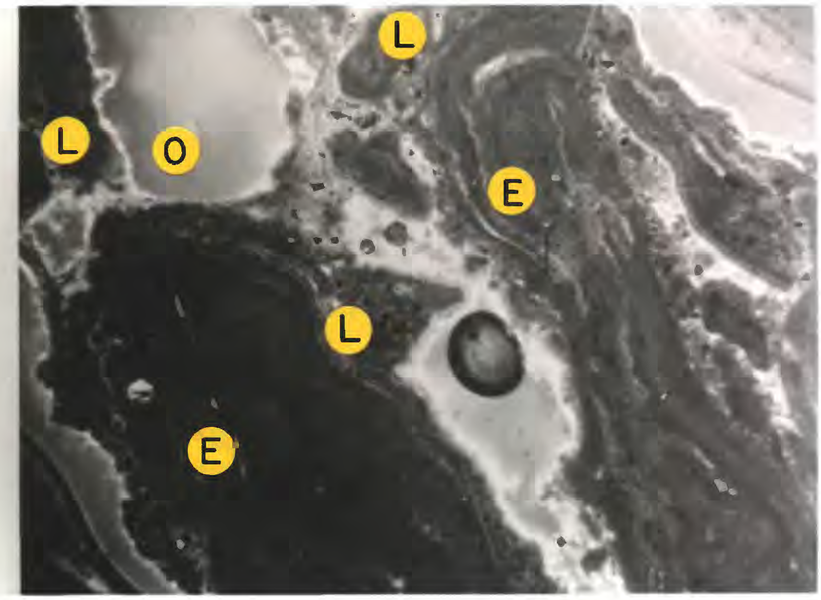

Figure 29A.--Early (E) and later stage (L) of micrite development. O, open space. Sample CD-80-69. Crossed polars. Field of view 5.1mm.

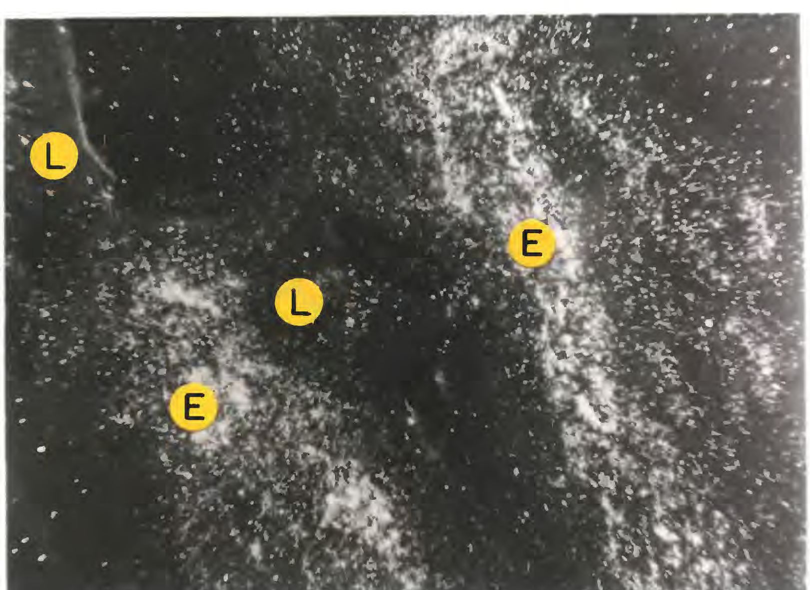

Figure 29B.--Autoradiograph complementary to figure 29A, showing the radioactivity dominantly associating with the early stage of micrite development(E). L, late stage of micrite development.

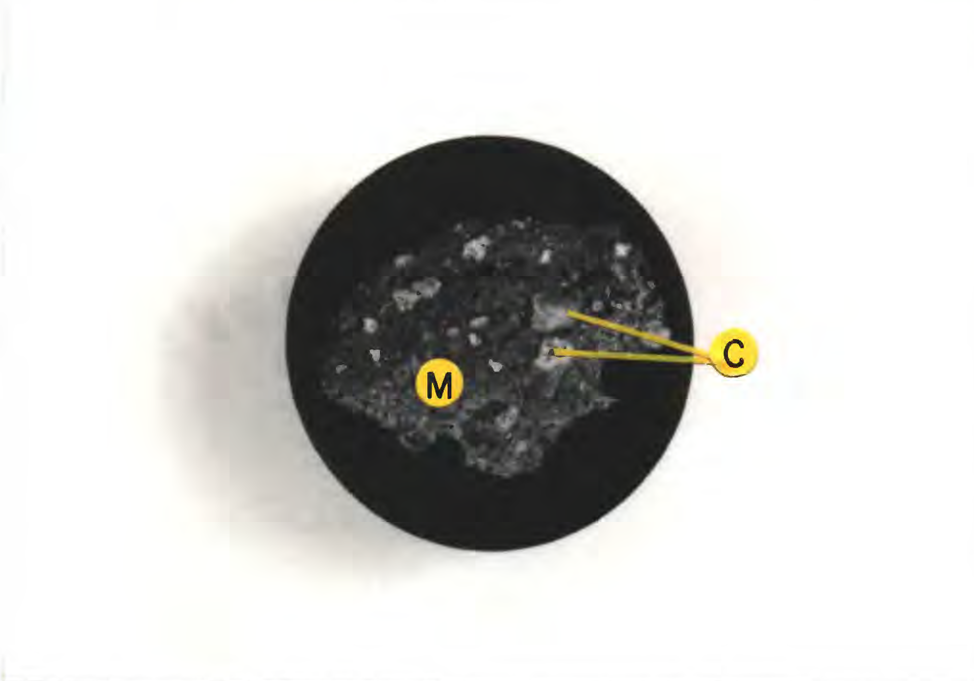

Figure 30A.--Polished section from sample 80KF-5 showing framework microspar grains (C) in a cement consisting of microspar (M).

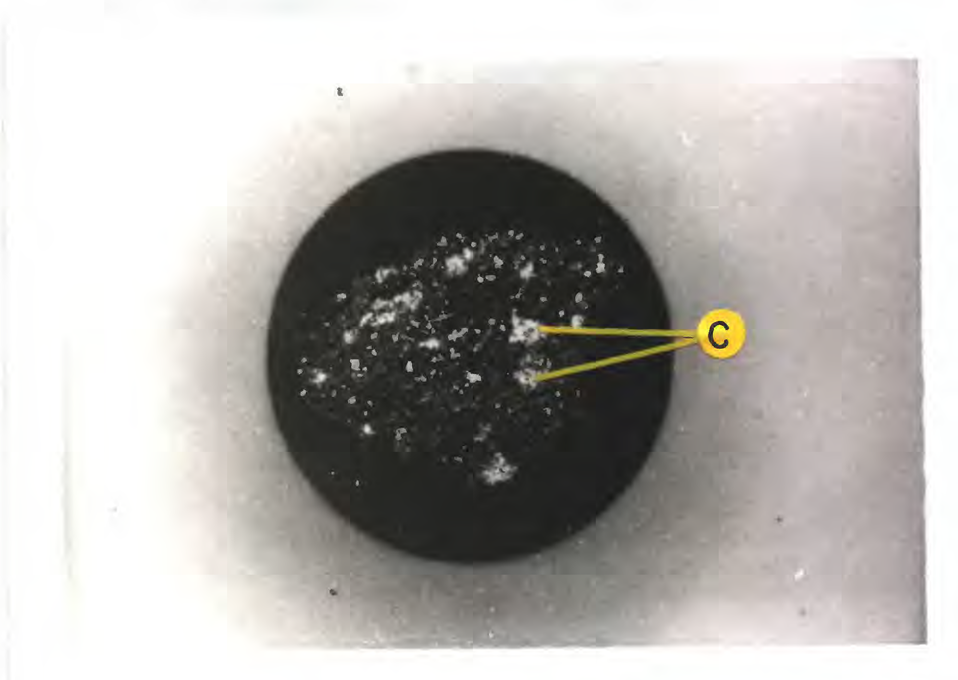

Figure 30B.--Radioluxograph complementary to figure 30A, showing radioactivity predominantly associating with the framework grains composed of microspar (C).

Table 1.--Sample site descriptions

W, water sample and (or) field measurements; S, precipitate or sediment sample.

Site No.	Site name	Sample type	Remarks
			Arizona
AZ 1	Vaseys Paradise spring in Grand Canyon	W	Spring issues on right bank of river facing downstream. Sampled at point of issue.
AZ 2	Grand Canyon at river mile 34.1	S	No spring. Travertine forms stalactite-like mass on rock outcrop on right bank of river facing downstream.
AZ 3	Spring in Grand Canyon at river mile 34.2	W	Springs issue in several places from rock outcrop on right bank of river facing downstream. Sampled from several points of issue.
AZ 4	Grand Canyon at river mile 136.7	S	No spring. Damp travertine at base of outcrop on left bank of river facing downstream.
AZ 5	Spring in Grand Canyon at river mile 151.5	W S	Spring issues from rock outcrop on right bank of river facing downstream. Sampled at point of issue. Travertine has formed.
AZ 6	Spring in Grand Canyon at river mile 147.9	W S	Spring issues from rock outcrop on right bank of river facing downstream. Sampled at point of issue. Travertine has formed.
AZ 7	Grand Canyon at river mile 155.8	S	Water seeps from rock ledge on right bank of river facing downstream. Travertine has formed near point of issue.
AZ 8	Havasu Canyon in Grand Canyon	S	Spring issues far upstream. Travertine has formed in creek bed to at least 400 m from mouth of creek on left bank of river facing downstream.
AZ 9	Spring at Fern Glen Canyon in Grand Canyon	W S	Springs issue from rock outcrops on right bank of river facing downstream. Sampled at main (lowest) spring. Travertine forms deposits.
AZ10	Grand Canyon at river mile 114.5	S	No spring. Damp travertine coats rocks on left bank of river facing downstream.
AZ11	Grand Canyon at river mile 115.5	S	No spring. Travertine coating on float boulder on left bank of river facing downstream.
AZ12	Grand Canyon at river mile 116.5	S	No spring. Travertine coating on float boulder at mouth of creek on left bank of river facing downstream.
AZ13	Lava Falls warm springs in Grand Canyon	W S	Springs issue over length of several hundred meters on left bank of river facing downstream. Sampled at several points of issue. Travertine forms deposits at several sites.
AZ14	Pumpkin Spring in Grand Canyon	W S	Spring issues in pool on travertine mound and flows out to river at upstream end of pool on left bank of river facing downstream. Sampled at pool. Travertine is forming around spring.
AZ15	Grand Canyon at river mile 77	S	No water. Inactive travertine at dry spring on left bank of river facing downstream.
AZ16	The Salt Banks springs	W S	Springs issue in three areas on north side of river along river bank. Sampled at easternmost spring area near river level, where water flows from older deposits. Extensive cliff-like travertine apron covers river bank for about 0.5 km. Deposits are actively forming where water rises in pools and overflows down apron as much as 30 m to river.
AZ17	Clifton Hot Spring	W	Springs seep from gravel in numerous places at river level on east bank of river. Sampled at one point of issue of high temperature.
AZ18	Indian Hot Springs	W	Springs issue in pools behind hotel building of old spa. Sampled at one pool. Water used for bathing.
			California
CA 1	Grovers Hot Springs	W S	Springs issue in numerous orifices near base of hillside. Sampled at main spring, which forms 1-m-diameter pool at crest of low travertine mound at west end of spring area. Travertine forms apron in areas where springs issue. Water used for swimming pool. State Park.
CA 2	Wild Horse Spring	W	Spring issues through horizontal metal pipe at least 1 m long. Sampled where water flows from pipe. Water used for stock.
CA 3	Lava Springs	W	Spring rises near base of outcrop at bend in road. Sampled at point of issue.
CA 4	Fales Hot Springs	W S	Spring rises in 3-m-diameter pool with vigorous bubbling of large-volume flow on south side of highway. Sampled at pool edge. Water flows down valley to west, where travertine is forming in places along the drainage. North of highway is large inactive travertine mound with 20-m-diameter circular depression at crest, about 30 m above level of present spring discharge. Water used for swimming pool.
CA 5	Travertine Hot Springs at Bridgeport	W S	Springs issue in large area on hillside. Sampled at main spring at highest level of spring area, where water rises in 0.5-m-diameter cement cylinder. Extensive aprons and ridges of inactive travertine cover the area. Fresh travertine is forming at current orifices. Travertine has been mined for stone.
CA 6	Spring on Big Alkali Flat in Bodie Hills	W	Spring rises in shallow pond about 10 m diameter. Sampled at edge of pond.
CA 7	Warm spring in Bodie Hills	W	Spring rises near base of low hill and forms marshy pond. Sampled near point of issue at north edge of pond.
CA 8	Sulphur artesian well at Mono Lake	W W	Water rises through metal pipe about 10 cm diameter and flows out at ground level. Sampled at point of issue. H_2S smell.
CA 9	Hot spring at Mono Lake	W S	Spring rises underground and flows about 100 m north through 15-cm-diameter metal pipe to 1-m-long cement-walled rectangular pool. Vertical vent pipe near source allows escape of steam. Sampled where water flows into pool from pipe. Fresh travertine is forming at water level around edge of pool.
CA10	Warm springs at Mono Lake	W	Spring rises in sandy 0.3-m-diameter pool east of Mono Lake. Sampled at point of issue.

Site No.	Site name	Sample type	Remarks
			Colorado
CO 1	Sulphur Springs near Kremmling	W S	Springs issue in numerous places on west-facing slope. Sampled at main spring by road in gulley to north of other springs. H_2S smell.
CO 2	Hot Sulphur Springs	W S	Springs issue in several places on hillside behind motel. Main spring is piped underground to motel. Sampled at spring of smaller flow. Some precipitates are forming in drainage. H_2S smell.
CO 3	Glenwood Springs	W S	Springs issue at several places along river. Main spring that feeds swimming pool rises in circular 10-m-diameter cement-walled pool with vigorous bubbling of large-volume flow. Sampled at outlet from main spring. Precipitates have formed at pool edges.
CO 4	Sulphur Springs at Sulphur Mountain	W S	Springs seep from ground on south side of hill. Sampled at one place where bubbles rise with water. Water used for stock. Sample PAR 1 of Mallory and Barnett (1973).
CO 5	Hartsel Hot Springs	W S	Springs issue in several places at base of hill south of Hartsel. Sampled inside small wooden bathhouse near large building, where water rises in pool about 0.5 m diameter. Water used for bathing. Sample PAR 5 of Mallory and Barnett (1973).
CO 6	Salt Spring near Antero	W	Springs issue from base of low slope east of road and flow east. Sampled near point of issue. Sample PAR 2 of Mallory and Barnett (1973).
CO 7	Salt Works spring near Antero	W S	Spring issues from pipe next to old salt works building. Sampled at point of issue. Water used for stock. Sample PAR 3 of Mallory and Barnett (1973).
CO 8	Colonel Chinn artesian well	W	Water flows from valved wellhead on terrace south of river. Sampled at wellhead. H_2S smell.
CO 9	Sulphur Gulch spring	W S	Springs issue in three 2- to 3-m-diameter pools in rock outcrops in lower end of gulley. Sampled at edge of middle pool. H_2S smell.
CO10	Austin springs	W S	Several springs issue near base of hill or in gulleys on hillside. Sampled northermost spring which rises at base of outcrop in pool 0.5 m diameter. Travertine shelf and apron are present farther south toward river. H_2S smell.
CO11	Fish hatchery adit spring	W S	Spring issues in dugout "adit" about 2 m high and 3 m deep in hillside on north side of road. Sampled at entrance to "adit" at edge of pool. Soil bank at edge of road contains travertine-cemented talus. H_2S smell.
CO12	Doughty springs (A, Bathtub spring; B, Alum spring)	W S	Springs issue at base of rock outcrops on north side of river. Travertine forms shelf 300 m long by 30 m wide between outcrops and river. Sampled one spring at east end of shelf which rises in small 0.5-m-diameter pool and flows into largest blue pool on shelf; also sampled spring at west end of shelf which flows from rock crevice and into black pool. Travertine is forming along drainages and at shelf edge. H_2S smell.
CO13	Alum Gulch	S	Water seeps from outcrops on west side of gulley. Alum deposits have formed on underside of overhanging ledges. Alum has been mined.
CO14	Yellow Soda Spring near Guffey	W S	Springs issue in pools on travertine mound on hillside. Sampled at point of issue of main 2-m-diameter pool at crest of mound. Precipitate is forming at present orifice. Sample PAR 4 of Mallory and Barnett (1973).
CO15	Taylor Soda Spring	W S	Springs issue in large area about 100 by 500 m at base of hill. Sampled at spring at southwest edge of area. Travertine mounds up to 0.5 m high surrounded some of the orifices. Precipitate is forming in some springs. Sample FRE 1 of Mallory and Barnett (1973).
CO16	Waunita Hot Springs	W	Springs issue at base of hill near resort and also along south side of creek several hundred meters to northwest. Tested where water issues from underneath small building in highest part of spring area along creek.
CO17	Poncha Hot Springs	W S	Springs issue at several places on steep slope. Sampled at No. 13 where water rises in 0.5-m-square cement-walled orifice. Inactive travertine forms numerous mounds on slope. Sample CHA 6 of Mallory and Barnett (1973). Water from springs flows underground through pipes to reservoir and then to town of Poncha Springs.
CO18	Spring near Powderhorn	S	Springs issue at several places on southwest side of valley. Inactive travertine forms two aprons about 200 by 400 m on northeast side of road west of Cebolla Hot Springs.
CO19	Mineral Hot Springs	W S	Springs issue in several places on or near broad mounds on valley floor. Tested at flowing well in northeast part of spring area. Mounds are inactive travertine. Sample similar to SAG 4 of Mallory and Barnett (1973).
CO20	Lower Red Creek soda springs	S	No water. Two 3-m-high mounds having 1-m-dimeter depressions in crests are present in 50-square-m area of inactive travertine.
CO21	Orvis Hot Spring	W	Spring issues at bottom of circular depression on top of inactive travertine shelf. Sampled at edge of pool.
CO22	Ouray hot springs	W S	Springs issue on hillside behind motel about 15 m up slope and also in cave on river bank about 5 m above river level several hundred meters west of motel. Sampled at point of issue behind motel, where water rises in covered pool about 1 m square. Inactive travertine forms large apron below point of issue. Water used for hot tubs and for municipal swimming pool.
CO23	Ophir Iron Spring	S	Spring issues from dugout adit. Tested at point of issue. Iron-rich travertine forms deposits near spring and at base of hill. Travertine has been mined.

Table 1.--Sample site descriptions--Continued

Site No.	Site name	Sample type	Remarks
			Colorado--Continued
C024	Dunton Hot Springs	W S	Spring issues near base of hill. Tested at point of issue. Travertine forms thin depoit near spring, below bathouse.
C025	Wagon Wheel Gap hot springs	W	Springs issue in two places, one near old spa building and one upstream, or south, from building. Tested at northern spring. Sample MIN 2 of Mallory and Barnett (1973). Water used for bathing.
C026	Sulphur Springs near La Veta	W	Springs issue in two places at base of outcrop, one 15 m upstream, or west, from other. Tested at eastern spring. Sample HUE 5 of Mallory and Barnett (1973). H_2S smell.
C027	Bakers Bridge hot springs near Durango	W S	Springs issue on east side of highway in large pond and on west side of highway about 50 m up hillside. Sampled at edge of large pond. Travertine froms large apron below springs on hillside west of highway.
C028	Pagosa Springs	S	Springs issue near motel and along south bank of river. Precipitates are forming around orifices and along drainages. H_2S smell.
			Idaho
ID 1	Heise Hot Springs	W S	Spring issues on hillside about 10 m above river on north side of river and south of road. Point of issue is enclosed in cement structure. Sampled at leak in pipe 7 m from source. Travertine is forming where water leaks from pipe. Water used for swimming pool. H_2S smell.
ID 2	Fall Creek Mineral Springs	W S	Springs issue on south bank of Fall Creek. Sampled at point of issue of main spring, where travertine apron is actively forming. Inactive travertine mounds occur downstream.
ID 3	Soda Springs artesian well(?)	W S	Water gushes horizontally out of pipe extending about 7 m from cement building presumably over source. Sampled at end of pipe. Building is on flank of large travertine mound about 15 m high. Fresh travertine is forming where water falls on mound.
ID 4	Lava Hot Springs	W	Springs issue at base of cliff. Sampled at point of issue. Inactive travertine coats cliff and forms grotto-like deposits nearby. Water used for swimming pool.
ID 5	Pleasantview Warm Springs	W	Spring issues in broad area, seeping out of gravel at pond edges. Sampled at one point of issue.
ID 6	Spring	W S	Confidential.
			Montana
MT 1	Broadwater hot well	W S	Water issues in seeps and has been tapped by wells. Sampled at 10-cm-diameter wellhead 1 m above ground. Water had to be pumped out from about 1 m depth because it was not flowing. Being developed for geothermal energy. H_2S smell at one steam vent.
MT 2	White Sulphur Springs	W	Water issues from 0.3-m-diameter pipe in soil bank. Sampled at pipe. Pinkish white precipitates form thin coatings on pebbles where water flows to west. H_2S smell.
MT 3	Alhambra Hot Springs	W S	Springs issue in cement-walled covered orifices. Sampled at upper end of main orifice near gazebo. Edge of travertine shelf crops out about 5 m north of springs. Some spring water issues from pipe and is now forming travertine on the shelf slope.
MT 4	Alhambra warm well	W	Water issues from pipe about 1 m above ground. Sampled at pipe.
MT 5	Boulder Hot Springs	W S	Main spring issues in 3-m-diameter cement tank on hillside behind hotel. Sampled at end of 5-m-long pipe extending from side of tank. Some encrustations have formed on pipe. Other smaller springs issue farther up hillside. Water used for swimming pool.
MT 6	Warm Springs at State Hospital	W S	Spring issues at top of large travertine mound which stands about 15 m above valley floor. Sampled at outlet pipe at base of gazebo on top of mound, where water is now forming travertine as it flows down the slope of the mound.
MT 7	Gregson Hot Springs	W	Springs issue in tanks covered by wooden pyramidal roofs. Sampled in cement-walled and covered cylindrical 2-m-diameter collecting tank a few meters east of springs. Water was taken from the north one of the two pipes on the west side of the tank as it emptied into the tank. H_2S smell. Water used for swimming pool.
MT 8	Pipestone Hot Springs	W	Water issues from 1-m-high 5-cm-diameter vertical pipe at south side of creek, several meters southwest of gazebo. Sampled at pipe.
MT 9	Silver Star hot springs	W	Springs issue in walled and grated orifices on gentle hillside. Sampled at main spring issuing in 1-m-square cement-walled pool. Water used for swimming pool.
MT10	Norris Hot Springs	W	Spring issues from 3-m-high vertical pipe at edge of swimming pool on north side of valley. Sampled at pool edge. Other springs issue on the south side of the valley in a reedy area.
MT11	Biltmore Hot Springs	W S	Water is tapped by 8-m-deep well. Sampled at spigot attached to well casing. Travertine encrustations coat drainage area near well. Water used for swimming pool.
MT12	Elkhorn Hot Springs	W	Springs issue in fenced grassy area in valley. Sampled at uppermost spring where it issues into a small natural catchment basin in outcrop. Water used for swimming pool.
MT13	Jardine Hot Spring near Jackson	W	Spring issues in 4-m-square cement-walled pool with vigorous bubbling of large-volume flow on slight rise in valley floor. Sampled at pool edge.

Table 1.--Sample site descriptions--Continued

Site No.	Site name	Sample type	Remarks
			Montana--Continued
MT14	La Duke Hot Spring	W S	Spring issues in long cement-walled covered orifice along east side of highway at base of hill. Sampled at outlet pipe on west side of highway, where water gushes out and is forming a travertine apron. Radon sample was taken at small-flow spring issuing from gravel slope south of main cement-walled orifice on east side of highway.
			Nevada
NV 1	Baltazor Hot Spring	W	Springs issue on valley floor. Largest one forms 4-m-diameter pool in grassy area. Sampled at spring 30 m east of house, where it rises in 0.5-m-diameter metal cylinder set in ground.
NV 2	Virgin Valley Warm Spring	W	Spring issues in pool near base of hill. Sampled at pool outlet.
NV 3	Howard Hot Spring	W	Springs issue in several places on gentle slope. Sampled at main spring on southwest side of area, where water forms pools several meters diameter.
NV 4	Hot springs near Wells	S	Springs issue in large area on hillside. Travertine forms extensive apron.
NV 5	Threemile Sulphur Spring	W S	Spring issues from crevice in rock outcrop and forms pool. Sampled at point of issue. H_2S smell.
NV 6	Golconda Hot Spring (A, main spring; B, smaller spring)	W S	Springs issue in large area. Sampled where water pours from ground at outlet from highest level pool in northeast part of area. Three pools here are 5 to 6 m diameter and are rimmed with travertine. Also sampled in 1977 was small pool in west part of area near radioactive spot. Travertine has been mined for Mn.
NV 7	Plank Spring	W	Spring issues in 1-m-square cement-walled pool. Sampled in pool in 1977. Spring dry in 1980.
NV 8	Brooks Hot Spring	W	Spring issues in depression on valley floor about 5 m diameter. Sampled at point of issue at south edge of spring pool.
NV 9	Great Boiling Spring at Gerlach	W	Springs issue in numerous places in broad area. Sampled at edge of main spring near parking area where it rises in pool about 10 m diameter with vigorous bubbling of large-volume flow.
NV10	Sulphur Hot Springs in Ruby Valley	W S	Springs issue in numerous places on valley floor. Sampled at hottest spring tested, which rises in 2-m-diameter pool. H_2S smell.
NV11	The Geysers at Beowawe	W S	Springs issue on terrace several hundred meters long on north slope of hill. At least two wells tap water. Main stream of water roars vertically about 15 m into air. Sampled at pipe about 30 m east of main spout, where water comes out with less force. Terrace is formed by travertine. New deposits are forming around pipes.
NV12	Kyle Hot Springs	W S	Springs issue in several places on low mound about 50 m across. Sampled at hottest spring at point of issue in depression 1.5 m below surface. Low mound has about 5 m relief and is composed of inactive travertine. H_2S smell. Water used for bathing.
NV13	Hot Spring Point hot spring	W	Spring issues about 100 m northwest of rock quarry on hillside. Sampled where spring rises into 1-m-diameter pool.
NV14	Buffalo Valley Hot Springs	W S	Springs issue at many points over broad area of valley floor. Sampled at one spring with enough flow to use. Small travertine cones up to 0.7 m high surround many springs. Water used for stock.
NV15	Sou Hot Springs	W S	Springs issue at several places near base of hill. Sampled at outlet of spring of largest flow most accessible between two travertine mounds. Two broad inactive travertine mounds are about 5 m high.
NV16	Collar and Elbow spring	W	Spring issues at base of grass-covered low mound on valley floor. Water forms shallow pool with no obvious point source. Sampled at edge of pool.
NV17	Borchert John spring	W	Spring issues from bank of alluvium and flows northeast about 50 m into cement-walled pool which feeds into 10-cm-diameter pipe leading toward valley floor. Sampled at cement-walled pool.
NV18	Monte Neva Hot Springs	W S	Spring issues from cut in large travertine mound several hundred meters diameter. Sampled at point of issue in cut 2 m below crest of mound. Fresh travertine is forming along edge of drainage where water flows out to west and north. Faint H_2S smell.
NV19	Bartine Hot Springs	W S	Springs issue in two places. Sampled larger spring, which rises through 10-cm-diameter pipe into 1-m-square cement-walled pool. Inactive travertine forms mounds about 1 m high in area.
NV20	Steptoe warm springs	W	Springs issue in several places along gentle slope and feed a collecting pond. Sampled at spring that issues at southwest side of pond and flows 20 m to the pond. Water used for irrigation.
NV21	McGill Spring	W	Spring issues from 0.5-m-diameter pipe in ground into large pond used for swimming. Sampled at pipe.
NV22	Spencer Hot Springs	W S	Springs issue on top of large broad apron. Sampled at one point of issue where water rises near metal pipe in pool about 1 m diameter. Apron is inactive travertine.
NV23	Lackawanna Springs	W	Spring issues at base of hill where water forms 1-m-diameter pool. Sampled near pipe below water surface, where water seems to be entering pool.
NV24	Rawhide hot spring	W	Spring issues from valley floor. Sampled near point of issue of main spring near house.

Table 1.--Sample site descriptions--Continued

Site No.	Site name	Sample type	Remarks
			Nevada--Continued
NV25	Nevada Hot Springs (A, to north; B, to south)	W	Springs issue from talus bank about 5 m above road level and flow along ditch in talus before descending to valley floor. Sampled where water flows from talus in middle of spring area and also where water flowed from pipe set in ground at north end of spring area in 1977 (pipe dry in 1979).
NV26	Darrough Hot Springs	W S	Water gushes horizontally from valved pipe at wellhead in spring area on valley floor. Sampled where water emerges from pipe. Encrustations have formed on wellhead apparatus.
NV27	Spring in Gillis Range	W	Spring issues on slope and flows about 3 m through 3-cm-diameter pipe. Sampled where water flows from pipe. Water used for stock.
NV28	Spring in Nye Canyon	W	Spring issues at base of outcrop in ditch on north side of road. Sampled at point of issue, where water forms 1-m-diameter pool. Water used for stock.
NV29	Grant View hot springs	W S	Springs issue at base of outcrop on southeast side of river. Sampled at main spring, which rises in 0.5-m-diameter pool.
NV30	Soda Springs at Sodaville	W S	Springs issue in several places on valley floor on west side of highway. Sampled at edge of spring in north end of area at highest altitude of slope, where water rises in 3-m-diameter pool.
NV31	Spring near Aurora	W	Spring rises in 1-m-diameter metal barrel at base of hill. Sampled in barrel.
NV32	Spring at Teels Marsh	W S	Spring issues in irregular-shaped pond few meters diameter. Sampled at edge of pond.
NV33	Gap Spring	W S	Spring issues on side of mound near base of hill. Sampled at point of issue, where water rises in 1-m-diameter pool. Mound of inactive travertine is about 500 m long, 100 m across, and 15 m high.
NV34	Alkali Hot Spring	W S	Spring issues from dugout, partly collapsed adit and also flows from about 15-cm-diameter pipe 30 m from adit. Sampled where water pours from end of pipe. Large inactive travertine shelf is present nearby.
NV35	Silverpeak artesian well(?)	W	Water gushes from pipe leading from building over spring source at base of east side of small hill and empties into pool. Sampled at end of pipe. Could not locate spring shown on 7-1/2 min. topographic map.
NV36	Spring	W	Confidential.
			New Mexico
NM 1	Soda Dam Hot Springs	W S	Springs issue at several places in and near "dam," which is a large ridge of travertine extending most of the way across river. Sampled at one point of issue about 40 m downstream from "dam" on northwest bank of river about 1 m above river level, where radioactivity was relatively high.
NM 2	San Francisco Hot Springs	W	Spring issues at river level on east bank of river. Tested at spring pool.
NM 3	Gila Hot Springs	W	Springs issue at numerous places along east bank of creek. Tested at one point of issue.
NM 4	Mimbres Hot Springs	W	Springs issue on hillside behind house and form small creek. Tested at at one point of issue.
NM 5	Faywood Hot Springs	W S	Spring issues near top of inactive travertine mound about 20 m high. Sampled at point of issue, where water rises in pool about 2 m diameter.
			Utah
UT 1	Udy Hot Springs	W S	Springs issue in numerous places in river and on west bank of river. Sampled at one spring in central part of area. Water possibly treated with $CuSO_4$ to prevent algae growth. Travertine deposits have formed in area. Water used for swimming and bathing.
UT 2	Garland Springs	W	Spring issues into large pond. Small building located over spring source. Sampled at pipe at head of pond.
UT 3	Locomotive Springs	W	Springs issue in several places on mudflats. Sampled Baker Spring at edge of large pond about 15 m diameter where water seems to rise.
UT 4	Salt Spring near Tremonton	W	Springs issue at base of hill. Sampled at one of numerous points of issue near west side of area.
UT 5	Crystal Springs (A, cold spring; B, hot spring)	W S	Hot spring issues from underneath stone wall near swimming pool. Sampled at point of issue where water pours out. Encrustations of travertine form along drainage. Cold spring issues in pool a few meters north of hot spring. Water used for swimming pool.
UT 6	Poison Spring	W S	Spring issues in 20-m-diameter irregular-shaped shallow pond. Point of issue is not obvious. Sampled at edge of pond.
UT 7	Painted Rock spring	W S	Spring issues at base of rock outcrop. Sampled at point of issue.
UT 8	Little Mountain hot spring	W	Spring issues at southwest end of Little Mountain on south side of highway. Sampled where water pours from horizontal pipe conduit.
UT 9	Stinking Hot Springs (A, near cliff; B, near bathhouse)	W S	Springs issue at base of outcrop at southeast end of Little Mountain on north side of highway. Sampled at spring closest to outcrop near east end of spring area a few meters west of southeast point of outcrop. Also sampled on south side of highway at intake to bathhouse, where water source is not obvious. Travertine forms deposits at and below ground level (no mounds), and precipitates coat drainages. H_2S smell. Water used for bathing. Travertine has been mined for barite.

Table 1.--Sample site descriptions--Continued

Site No.	Site name	Sample type	Remarks
			Utah--Continued
UT10	Utah Hot Springs	W S	Springs issue near base of cliff. Largest flow rises in concrete tank and flows out through pipes and then under RR track to west. Sampled in 1976 at pipe outlet; sampled in 1980 in newly exposed concrete tank. Iron-rich travertine forms low-lying shelf on west side of RR tracks.
UT11	Ogden hot spring	W S	Springs issue in two places on hillside on south side of river. Sampled at eastern spring. Travertine forms deposits around spring.
UT12	Hooper Hot Springs	W S	Springs issue in marshy area on top of low mound on mudflats. Sampled at one point of issue at west edge of mound.
UT13	Grantsville Warm Springs	W S	Springs issue in numerous places on mudflats. Sampled at one spring near end of road having relatively low specific conductance and temperature. Water rises in circular travertine pools whose rims are about 1 m high. Travertine is present over area several hundred meters square.
UT14	Midway Hot Springs	W S	Springs issue in numerous places on valley floor. Sampled one spring near road (hot pot C-2 of Baker, 1968). Inactive travertine forms extensive deposits in area. Water used for swimming pool.
UT15	Morgan Ranch Warm Spring	W	Spring rises in oblong pond about 30 m long. Point of issue not obvious. Sampled at southwest edge of pond.
UT16	Coyote Springs in Simpson Mountains	W	Spring issues from steep hillside. Sampled 1 m from point of issue.
UT17	Rock Springs	W	Spring issues in grassy area on slope. Sampled at point of issue. Water used for stock.
UT18	Wilson Health Springs	W S	Springs issue at tops of several large low mounds on mudflats. Sampled at edge of 20-m-diameter pool at crest of third mound northeast from southwest end of spring group. Travertine forms the mounds and is forming at the edges of the pools.
UT19	Wildhorse Spring	W S	Spring issues from ground through 5-cm-diameter pipe into 1-m-square cement-walled covered tank. Sampled where water flows from pipe. Travertine-cemented colluvium forms eroded shelf behind spring. Metal tank 8 m diameter apparently collects water flowing underground from sampled spring. Water flows from metal tank and is forming travertine encrustations in trough. Water used for stock.
UT20	Cane Springs	W S	Spring issues into peaty area and forms pool about 10 m diameter. Sampled at pool edge. Water used for stock.
UT21	Trough Spring	W	Spring issues from colluvium on hillside. Pipe funnels flow into cement-lined trough. Sampled where water flows from pipe into trough. Tested at point of issue. Water used for stock.
UT22	Lime Spring	W S	Spring seeps into 10-m-diameter collecting pond from colluvium on gentle slope. Sampled at seep on west edge of pond. Water used for stock.
UT23	Baker Hot Springs	W S	Springs issue over large area of valley floor. Sampled at edge of 10-m-long irregular-shaped pool at west-central edge of spring area. Travertine forms extensive low mounds and hummocky terrain. Travertine has been mined for Mn.
UT24	Schoenburger Spring	W	Spring issues into 1-m-square cement-walled covered pool at base of slope. Sampled in pool.
UT25	Gandy Warm Springs	W	Springs issue along base of cliff and flow down into natural pool. Sampled at one spring west of the pool. Travertine forms large shelf between cliff and pool, but no fresh travertine is forming. Water used for swimming.
UT26	Mourning Dove Spring	W	Spring issues at base of cliff and flows through 3-cm-diameter pipe into cylindrical cement pool. Sampled at end of pipe, where water flows into pool. Water used for stock.
UT27	Coyote Spring in Tule Valley	W	Spring issues into 1-m-diameter metal cylindrical tank on valley floor. Sampled in tank.
UT28	Swasey Spring	W	Spring issues into cylindrical metal container and drains out through pipe emerging from ground 3 m below container. Sampled at end of pipe.
UT29	Bishop Springs	W	Main springs issue at Twin Springs, two ponds about 10 m diameter on valley floor. Sampled at edge of south pond.
UT30	Stove Spring	W	Spring issues from bank into 3-m-long 3-cm-diameter pipe. Sampled at end of pipe, where water flows into trough. Water used for stock.
UT31	Tule Spring	W	Spring issues in reedy area on valley floor. Sampled at 1-m-diameter pool at south end of marshy area.
UT32	First Spring	W	Spring issues through plastic hose into trough. Sampled at end of hose. Water used for stock.
UT33	Whisky Spring	W	Spring issues from colluvial bank in valley. Sampled at point of issue.
UT34	Knoll Springs	W	Springs issue as seeps at sides or bases of several 6- to 10-m-high silt- and grass-covered mounds. Sampled at 1-m-diameter pool in hummocky ground in northeast part of spring area.
UT35	Mud Spring	W	Spring issues in marshy area on gentle slope. Sampled at 0.8-m-diameter metal tank in marshy area. Water used for stock.
UT36	Stinking Springs near Manti (A, in reeds; B, near	W S	Springs and seeps issue in several places on hillside. Sampled at northeasternmost spring, which has largest flow, and at spring near corral Travertine apron extends corral) outward from spring near corral to southwest. Precipitates are forming in drainages.
UT37	Fayette Springs	W	Spring issues in grassy area on hillside. Sampled at point of issue. Water used for town water supply.
UT38	Ninemile spring	W	Spring issues near base of hill. Sampled at point of issue.

Table 1.--Sample site descriptions--Continued

Site No.	Site name	Sample type	Remarks
			Utah--Continued
UT39	Oak Spring	W	Spring issues in marshy area on gentle slope. Two 5-cm-diameter pipes channel water into 0.8-m-square cement-walled tank. Sampled where pipes feed into tank.
UT40	Flowing well near Holden	W	Water pours out of wellhead beneath wooden cap few meters west of road. One of numerous flowing wells on valley floor in this area. Sampled at wellhead. Water used for irrigation.
UT41	Monroe Hot Springs	W S	Springs issue near base of hill. Spring several hundred meters north of swimming pool issues at top of extensive travertine apron about 10 m high. Sampled at point of issue at top of apron. Fresh travertine is forming along drainage.
UT42	Joseph Hot Springs	S	Springs issue over large area on east bank of river. Tested at one point of issue. Travertine shelf has formed around springs.
UT43	Thermo Hot Springs	W S	Springs issue along tops and sides of two low ridges on desert valley floor. Tested spring south of road on southeast flank of southern ridge. Travertine forms ridges.
UT44	Dixie Hot Springs	W S	Springs issue on north and south banks and in bed of river. Sampled at easternmost large spring in cave on south side of river. Travertine forms deposits around springs, and white precipitates are visible in river bed. Water used for swimming pool.
			Wyoming
WY 1	Taylor artesian well at Thermopolis	W S	Water flows from wellhead about 1 m above ground. Sampled at wellhead. Travertine forms irregular mound around well. H_2S smell.
WY 2	Ulcer spring at Thermopolis	W S	Spring issues at west base of RR cut on west bank of river 15 m south of foot bridge which crosses river from Thermopolis State Park on east bank. Sampled at point of issue. Some precipitate lines drainage.
WY 3	Big Spring at Thermopolis	W	Spring rises in 8-m-diameter pool with vigorous bubbling of large-volume flow at base of cliff. Sampled at edge of pool. Extensive travertine shelf has formed on east bank of river between hills and river. Travertine is still forming along drainages and at river edge. State Park.
WY 4	Wedding of the Waters spring	W S	Spring issues in irregular-shaped shallow pond east of road on east side of river at base of cliff. Point of issue not obvious. Sampled at edge of pond.
WY 5	Granite Creek Hot Spring	W S	Spring issues from crevices in rock. Sampled at point of issue before water flows into cement-lined pool. Water used for swimming. State Park.
WY 6	Astoria Mineral Hot Springs	W S	Springs issue on terrace at bend of river on south bank. Sampled at point of issue of one spring northeast of the northeast corner of swimming pool about 3 m above river level. Travertine is forming along drainage. Water used for swimming pool.
WY 7	Stinking Springs at Hoback Canyon	W	Springs issue on north and south sides of river at mouth of canyon. Sampled easternmost of three springs on south side of river. White precipitate coats drainages. H_2S smell.
WY 8	Washakie Mineral Hot Springs	W S	Spring issues in large pool about 50 m diameter. Point of issue not obvious. Sampled at outlet from pool. Travertine deposits are present around edges of pool. Water used for swimming.
WY 9	Auburn sulphur springs	W S	Springs issue in area about 10 by 30 m on north side of pond about 50 by 20 m across. Sampled at hottest point of issue at east side of spring area, apparently a well flowing at ground level. Numerous mounds of travertine and sulfurous precipitates up to 1.5 m high are forming around points of issue. Older travertine is visible around edges of pond. H_2S smell. Deposits have been mined for S.
WY10	Sulphur Springs at Doty Mountain (A, to north; B, to south)	W S	Springs issue in two 2- to 3-m-diameter pools, one on east side of road and one on west side of road about 100 m to south. Sampled at points of issue.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number

[eU, radioactivity in percent equivalent uranium, as determined by beta-gamma scaler. All elements except S were determined by semi-quantitative emission spectrographic analysis; S was determined by wet-chemical methods. n.d., not determined. Element and eU data are generalized from Cadigan and Felmlee (1981); see that report for further analytical data. Question mark denotes tentative identification (see notes on "results of X-ray diffraction study")]

Location	Sample			Elements present in amounts ≥ 5%							
number	number	Minerals identified	≥0.01% eU	Ca	Fe	Mn	Ba	As	Si	Na	S
		ARIZONA									
AZ 2	CF-2	Calcite, quartz, dolomite, feldspar	---	X	--	--	--	--	--	--	n.d.
AZ 4	CF-4	Gypsum, quartz(?)	---	X	--	--	--	--	--	--	n.d.
AZ 5	CF-6	Gypsum, anhydrite	---	X	--	--	--	--	--	--	n.d.
AZ 6	CF-7	Calcite	---	X	--	--	--	--	--	--	n.d.
AZ 7	CF-8	Calcite	---	X	--	--	--	--	--	--	n.d.
AZ 8	CF-9	Calcite, quartz, dolomite, feldspar	---	X	--	--	--	--	--	--	n.d.
AZ 9	CF-10	Calcite, quartz, dolomite(?), gypsum(?)	---	X	--	--	--	--	X	--	n.d.
AZ 10	CF-11	Gypsum, quartz(?)	---	X	--	--	--	--	X	--	n.d.
AZ 11	CF-12	Gypsum, quartz(?)	---	X	--	--	--	--	--	--	n.d.
AZ 12	CF-13	Calcite	---	X	--	--	--	--	--	--	n.d.
AZ 13	CF-14	Gypsum, quartz(?)	--	X	--	--	--	--	--	--	n.d.
AZ 14	CF-15	Calcite, quartz, feldspar(?), dolomite(?)	---	X	--	--	--	--	X	--	n.d.
AZ 15	CF-16	Quartz, calcite, feldspar	---	X	--	--	--	--	X	--	n.d.
AZ 16	CD-76-2	Quartz, calcite	---	--	--	X	--	--	X	--	n.d.
	CD-76-3	Quartz, feldspar, calcite, dolomite	---	X	--	--	--	--	X	--	n.d.
	CD-76-4	Quartz, calcite, feldspar	---	X	--	--	--	--	X	--	n.d.
	CD-76-5B	Quartz, feldspar	X	--	X	--	--	X	X	--	n.d.
	CD-76-6B	Calcite, quartz	X	X	X	--	--	X	X	--	n.d.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		ARIZONA--continued									
AZ 16	CD-76-7	Calcite, dolomite ?)	X	X	X	--	--	X	--	--	n.d.
	CD-76-8	Calcite, feldspar, quartz, dolomite(?)	---	X	--	--	--	--	--	--	n.d.
	CD-76-9B	Calcite	X	X	X	--	--	X	--	--	n.d.
	CD-76-10	Calcite, aragonite	X	X	--	--	--	--	--	--	n.d.
		CALIFORNIA									
CA 1	79KF-46	Calcite	---	X	--	--	--	--	--	--	n.d.
	79KF-47	Calcite	---	X	--	--	--	--	--	--	n.d.
	79KF-48	Calcite	---	X	--	--	--	--	--	--	n.d.
	79KF-50	Calcite	---	X	--	--	--	--	--	--	n.d.
CA 4	CD-77-18	Calcite, quartz, feldspar	X	X	--	--	--	--	X	--	--
	CD-77-19	Calcite, quartz, goethite, feldspar	X	X	X	--	--	--	--	--	--
	CD-77-20	Calcite, aragonite	X	X	--	--	--	--	--	--	--
	CD-77-21	Quartz, feldspar, calcite	X	X	--	--	--	--	--	--	--
	79KF-53	Calcite	---	X	--	--	--	--	--	--	n.d.
CA 5	CD-77-26	Calcite, aragonite	---	X	--	--	--	--	--	--	--
	CD-77-27	Calcite	---	X	--	--	--	--	--	--	--
	CD-77-28	Quartz, feldspar, calcite, dolomite, mica	---	X	--	--	--	--	X	--	--
CA 9	79KF-28	Calcite	---	X	--	--	--	--	--	--	n.d.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5%: Ca	Fe	Mn	Ba	As	Si	Na	S
		COLORADO									
CO 1	CD-76-24	Sulfur, gypsum, feldspar(?)	---	--	--	--	--	--	X	--	X
CO 2	CD-76-25A	Calcite, dolomite	X	X	--	--	--	--	--	--	--
	CD-76-25B	Sulfur, quartz, feldspar	---	--	--	--	--	--	X	--	X
CO 3	CD-76-T1	Calcite	---	X	--	--	--	--	--	--	--
CO 4	CD-76-T6	Quartz, feldspar, mica, kaolinite(?)	---	--	--	--	--	--	X	--	X
	CD-76-T7	Quartz, feldspar, mica, kaolinite(?)	---	--	X	--	--	--	X	--	--
	CD-76-T8	Calcite, feldspar, quartz, dolomite(?) kaolinite(?)	---	X	--	--	--	--	X	--	--
CO 5	CD-76-T5	Calcite, quartz, feldspar, mica(?)	---	X	--	--	--	--	X	--	--
CO 7	CD-76-T3	Gypsum	---	X	--	--	--	--	--	--	X
	CD-76-T4	Gypsum, quartz, feldspar, calcite dolomite	---	X	--	--	--	--	X	--	--
CO 9	CD-5902	Thenardite	---	--	--	--	--	--	--	X	X
	CD-5903	Aragonite, quartz, feldspar, gypsum	---	X	--	--	--	--	X	--	--
	CD-5994	Calcite, aragonite, quartz	---	X	--	--	--	--	X	--	--
	CD-6172	Calcite, quartz	---	X	--	--	--	--	--	--	--
CO 10	CD-5888	Thenardite, halite, quartz(?), mica(?), unidentified mineral	---	--	--	--	--	--	--	X	--
	CD-6177	Calcite, quartz, geothite	---	X	X	--	--	--	X	--	--
	CD-6189	Calcite, aragonite, quartz	---	X	--	--	--	--	--	--	--
CO 11	80KF-6	Barite, quartz, clay(?)	X	--	--	--	X	--	X	--	X

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Ca	Fe	Mn	Ba	As	Si	Na	S
				Elements present in amounts ≥ 5%							
		COLORADO--continued									
CO 12	75MS-33B	Barite, quartz, gypsum, calcite	X	X	--	--	X	--	--	--	n.d.
	75MS-34	Barite, quartz, calcite, gypsum	X	X	--	--	X	--	--	--	n.d.
	80KF-5	Calcite, barite(?), quartz(?)	X	--	--	--	--	--	--	--	--
	CD-6216	Quartz, sulfur, pyrite	---	--	X	--	--	--	X	--	X
	CD-6217	Barite, sulfur, calcite(?), quartz(?)	X	X	--	--	X	--	--	--	X
CO 13	75MS-36	Soda alum, alunogen(?), halotrichite(?), unidentified mineral	---	--	--	--	--	--	--	X	n.d.
CO 14	75MS-1	Calcite, aragonite	X	X	X	--	--	X	--	--	n.d.
	75MS-2	Calcite, aragonite, feldspar(?), quartz(?)	X	X	--	--	--	--	--	--	n.d.
	75MS-3	Calcite, aragonite	---	X	--	--	--	--	--	--	n.d.
	75MS-4	Calcite, aragonite, feldspar	X	X	--	--	--	X	--	--	n.d.
	75MS-5	Calcite	---	X	--	--	--	--	--	--	n.d.
	80KF-1	Calcite, aragonite, quartz, feldspar	---	X	--	--	--	--	--	--	--
	80KF-2	Calcite, aragonite	---	X	--	--	--	--	--	--	--
CO 15	75MS-11	Calcite	X	X	X	--	--	X	--	--	n.d.
	75MS-12	Halite, quartz, feldspar, mica	---	--	--	--	--	--	--	X	n.d.
	75MS-13	Calcite, aragonite	X	X	--	--	--	--	--	--	n.d.
	75MS-14	Calcite, aragonite(?), quartz(?)	X	X	X	--	--	X	--	X	n.d.
	75MS-15	Calcite	X	X	X	--	--	--	X	--	n.d.
	75MS-16	Calcite, aragonite, quartz(?), feldspar(?)	n.d.	X	X	--	--	--	--	--	n.d.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		COLORADO--continued									
CO 15	75MS-17	Calcite, feldspar(?)	X	X	X	--	--	X	--	--	n.d.
	75MS-18	Calcite, aragonite, quartz, clay(?)	---	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
	80KF-3	Calcite, aragonite, quartz, feldspar(?)	X	X	--	--	--	--	--	--	--
	CD80-3	Calcite	X	X	X	--	--	--	--	--	--
	CD80-4	Calcite	X	X	X	--	--	X	--	--	--
CO 17	75MS-25	Goethite, romanechite, fluorite	X	X	X	X	--	--	X	--	n.d.
	75MS-26	Calcite	---	X	--	--	--	--	--	--	n.d.
	75MS-27	Fluorite, romanechite	X	X	--	X	X	--	--	--	n.d.
	80KF-4	Fluorite, romanechite, quartz(?), calcite(?)	X	X	--	X	--	--	X	--	--
	CD80-1	Fluorite, romanechite	X	--	--	X	X	--	--	--	--
CO 18	75MS-29	Calcite	---	X	--	--	--	--	--	--	n.d.
CO 19	75MS-20	Calcite	X	X	--	--	--	--	--	--	n.d.
	75MS-21	Calcite	X	X	--	--	--	--	--	--	n.d.
	75MS-22	Calcite	X	X	--	--	--	--	--	--	n.d.
CO 20	75MS-19	Calcite	---	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
CO 22	75MS-30	Goethite	X	--	X	X	--	--	--	--	n.d.
	75MS-122B	Calcite, manganite, pyrolusite	X	X	--	X	--	--	--	--	n.d.
	CD80-2	Gypsum, manganese mineral	X	--	X	X	--	--	--	--	--
CO 23	75MS-120	Goethite	---	--	X	--	--	--	--	--	n.d.
	75MS-121	Goethite	---	--	X	--	--	--	--	--	n.d.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5%: Ca	Fe	Mn	Ba	As	Si	Na	S
		COLORADO--continued									
CO 24	75MS-119	Calcite, aragonite	---	X	--	--	--	--	--	--	n.d.
CO 27	75MS-123	Calcite	---	X	--	--	--	--	--	--	n.d.
CO 28	75MS-124	Sulfur, gypsum, calcite(?)	n.d.	--	--	--	--	--	--	--	n.d.
		IDAHO									
ID 1	CD-76-41	Calcite	---	X	--	--	--	--	--	--	--
	CD-76-42	Calcite	---	X	--	--	--	--	--	--	--
	CD-76-43	Feldspar, quartz, calcite	---	X	--	--	--	--	X	--	--
ID 2	CD-76-39	Calcite	---	X	--	--	--	--	--	--	--
	CD-76-40	Calcite	--	X	--	--	--	--	--	--	--
ID 3	CD-76-44	Calcite	---	X	X	--	--	--	--	--	--
	CD-76-45	Calcite	---	X	--	--	--	--	--	--	--
ID 6	CD-76-46A	Calcite, aragonite	---	X	--	--	--	--	--	--	--
	CD-76-46B	Quartz, calcite, feldspar, goethite(?) mica(?), kaolinite(?)	X	X	X	--	--	--	X	--	--
		MONTANA									
MT 1	CD-78R-12	Quartz, calcite, feldspar, dolomite, mica	---	X	--	--	--	--	X	--	--
MT 3	CD-78R-4	Calcite	X	X	X	--	--	--	--	--	--
	CD-78R-5	Quartz, calcite, feldspar	X	X	--	--	--	--	--	X	--

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		MONTANA--continued									
MT3	CD-78R-8	Calcite	X	X	--	--	--	--	--	--	--
	CD-78R-9	Calcite, feldspar	X	X	--	--	--	--	--	--	--
	CD-78R-10	Calcite	---	X	--	--	--	--	--	--	--
MT 5	CD-78R-13	Calcite, aragonite, quartz, amorphous silica	---	X	--	--	--	--	X	--	--
MT 6	CD-78R-14	Calcite	---	X	X	--	--	--	--	--	--
	CD-78R-15	Calcite, gypsum	X	X	--	--	--	--	--	--	--
	CD-78R-16	Calcite	---	X	--	--	--	--	--	--	--
	CD-78R-17	Goethite	X	--	X	--	--	--	--	--	--
	CD-78R-18	Calcite	---	X	--	--	--	--	--	--	--
MT 11	CD-78R-19	Quartz, calcite, feldspar	---	X	--	--	--	--	X	--	--
	CD-78R-20	Gypsum, calcite, quartz	---	X	--	--	--	--	--	--	X
MT 14	CD-78R-1	Calcite, aragonite	---	X	--	--	--	--	--	--	--
	CD-78R-2	Calcite, aragonite	---	X	--	--	--	--	--	--	--
	CD-78R-3	Feldspar, quartz	X	--	X	--	--	--	X	--	--
		NEVADA									
NV 4	CD-77-55	Calcite	---	X	--	--	--	--	--	--	--
NV 5	CD-77-54	Calcite, feldspar(?)	X	X	--	--	--	--	--	--	--

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	$\geq$0.01% eU	Elements present in amounts $\geq$ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		NEVADA--continued									
NV 6	CD-77-3	Calcite	X	X	--	--	--	--	--	--	--
	CD-77-4	Calcite, feldspar	X	X	--	--	--	--	--	--	--
	CD-77-5	Quartz, calcite, feldspar, dolomite, mica(?)	X	--	--	--	--	--	X	--	--
	CD-77-6	Calcite, feldspar, romanechite(?)	X	X	--	--	--	--	--	--	--
	CD-77-7	Calcite, quartz, feldspar(?)	---	X	--	--	--	--	--	--	--
	80KF-50	Calcite	---	X	--	--	--	--	--	--	--
NV 10	CD-77-53	Quartz, amorphous silica	---	--	--	--	--	--	X	--	--
NV 11	CD-77-1	Calcite, feldspar, amorphous silica	---	--	--	--	--	--	X	--	--
	CD-77-2	Feldspar, quartz, amorphous silica	---	--	--	--	--	--	X	--	--
NV 12	CD-77-12	Calcite, quartz, feldspar	---	X	--	--	--	--	X	--	--
	CD-77-13	Calcite, quartz, feldspar, gypsum	X	X	--	--	--	--	X	--	--
	CD-77-14	Sulfur, gypsum, quartz	---	--	--	--	--	--	X	--	X
	CD-77-15	Barite, quartz, amorphous silica, cristobalite(?)	X	--	--	--	--	--	X	--	--
	CD-77-16	Halite, clay(?)	X	--	--	--	--	--	X	--	--
	CD-77-17	Gypsum, quartz, feldspar, amorphous silica, cristobalite(?)	X	--	--	--	--	--	X	--	--
NV 14	CD-77-8	Calcite	---	X	--	--	--	--	--	--	--
	CD-77-9	Calcite, quartz, feldspar	---	X	--	--	--	--	--	--	--
	CD-77-10	Calcite	---	X	--	--	--	--	--	--	--
	CD-77-11	Calcite, quartz, aragonite(?), feldspar(?), kaolinite(?)	---	X	--	--	--	--	X	--	--

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		NEVADA--continued									
NV 15	KF-1	Calcite	---	X	--	--	--	--	--	--	--
	KF-2	Calcite	---	X	--	--	--	--	--	--	--
NV 18	CD-77-46	Calcite, aragonite, quartz(?), dolomite(?)	X	X	--	--	--	--	--	--	--
	CD-77-47	Calcite	---	X	--	--	--	--	--	--	--
	CD-77-48	Calcite, dolomite(?)	X	X	--	--	--	--	--	--	--
	CD-77-49	Calcite, quartz, feldspar	X	X	--	--	--	--	X	--	--
	CD-77-50	Calcite, feldspar, quartz(?)	X	X	--	--	--	--	--	--	--
	CD-77-51	Quartz, calcite, feldspar, dolomite(?)	X	--	--	--	--	--	X	--	--
	CD-77-52	Calcite	---	X	--	--	--	--	--	--	--
	CD-78R-21	Calcite	X	X	--	--	--	--	--	--	--
	CD-78R-22	Calcite, aragonite	X	X	--	--	--	--	--	--	--
	CD-78R-23	Calcite	---	X	--	--	--	--	--	--	--
	CD80-69	Calcite	X	X	--	--	--	--	--	--	--
NV 19	CD-77-43	Calcite, quartz, feldspar	---	X	--	--	--	--	--	--	--
	CD-77-44	Calcite, quartz, feldspar	---	X	--	--	--	--	--	--	--
	CD-77-45	Calcite, quartz	---	X	X	--	--	--	X	--	--
NV 22	CD-77-41	Calcite, quartz	---	X	--	--	--	--	--	--	--
	CD-77-42	Calcite, quartz, feldspar	---	X	--	--	--	--	X	--	--

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	$\geq$0.01% eU	Elements present in amounts $\geq$ 5%: Ca	Fe	Mn	Ba	As	Si	Na	S
		NEVADA--continued									
NV 26	CD-77-40	Calcite, quartz, amorphous silica	---	--	--	--	--	--	X	--	--
NV 29	CD-77-24	Feldspar, quartz	X	--	--	--	--	--	X	--	--
NV 30	CD-77-32	Thenardite, calcite, quartz, gypsum	---	--	--	--	--	--	--	X	X
	CD-77-33	Thenardite, calcite, quartz, feldspar(?), gypsum(?)	---	--	--	--	--	--	X	X	X
NV 32	79KF-19	Calcite, quartz, feldspar	---	X	--	--	--	--	--	--	--
NV 33	CD-77-34	Calcite, quartz, feldspar, dolomite(?)	X	X	--	--	--	--	X	--	--
	CD-77-35	Calcite, quartz(?)	---	X	--	--	--	--	--	--	--
	CD-77-36	Calcite, feldspar(?)	---	X	--	--	--	--	--	--	--
NV 34	CD-77-37	Calcite, feldspar, mica, quartz	---	X	--	--	--	--	--	--	--
	CD-77-38	Calcite, feldspar, quartz	---	X	--	--	--	--	X	--	--
	CD-77-39	Quartz, feldspar, mica, calcite, kaolinite(?)	---	--	X	--	--	--	X	--	--
		NEW MEXICO									
NM 1	75MS-40	Calcite, quartz, feldspar	X	X	--	X	--	--	--	--	n.d.
NM 5	CD-76-1B	Calcite	X	X	--	--	--	--	--	--	n.d.
		UTAH									
UT 1	CD-76-13	Calcite, quartz, feldspar, dolomite	---	X	--	--	--	--	X	--	n.d.
	CD-76-14	Calcite, quartz	---	X	--	--	--	--	--	--	n.d.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		UTAH--continued									
UT 5	CD-76-12	Calcite, quartz, dolomite, feldspar(?)	X	X	--	--	--	--	X	--	n.d.
UT 6	CD-76-16	Calcite, quartz, feldspar, dolomite	---	X	--	--	--	--	X	X	n.d.
UT 7	CD-76-15	Calcite, quartz, feldspar	---	X	--	--	--	--	--	--	n.d.
UT 9	75MS-101B	Barite, calcite	X	X	--	--	X	--	--	--	n.d.
	75MS-102B	Calcite, barite, quartz, dolomite, feldspar	X	X	--	--	X	--	X	--	n.d.
	75MS-103B	Calcite, barite, quartz, dolomite, feldspar	X	X	--	--	--	--	X	--	n.d.
	CD-76-11B	Barite	X	--	--	--	X	--	--	--	X
	CD-76-19	Sulfur, calcite, quartz, dolomite	X	X	--	--	--	--	X	X	X
UT 10	75MS-104B	Calcite, quartz	X	--	--	--	--	--	--	--	n.d.
	75MS-105	Calcite	---	X	X	--	--	--	--	--	n.d.
	CD-76-20B	Calcite, quartz	X	X	X	--	--	--	--	--	n.d.
UT 11	75MS-106B	Calcite, quartz, mica, feldspar, kaolinite(?)	X	X	X	--	--	--	X	--	n.d.
UT 12	75MS-107	Quartz, calcite, feldspar, dolomite	X	X	--	X	--	--	X	--	n.d.
UT 13	CD-76-21	Calcite	X	X	--	--	--	--	--	--	--
	CD-76-22	Calcite	---	X	--	--	--	--	--	--	n.d.
UT 14	75MS-108	Calcite	---	X	--	--	--	--	--	--	n.d.
UT 18	CD-77-56	Gypsum	---	X	--	--	--	--	--	X	X
	CD-77-57	Calcite	X	X	--	--	--	--	--	--	--

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	$\geq$0.01% eU	Elements present in amounts $\geq$ 5%							
				Ca	Fe	Mn	Ba	As	Si	Na	S
		UTAH--continued									
UT 18	CD-77-58	Calcite, quartz, dolomite(?)	X	X	--	--	--	--	--	--	--
	CD-77-59	Gypsum	---	X	--	--	--	--	--	--	X
	CD-77-60	Calcite, gypsum, quartz, dolomite	X	X	X	--	--	--	X	--	--
	CD-77-61	Calcite, gypsum	X	X	X	--	--	--	--	--	--
	CD-77-62	Calcite, quartz, dolomite, feldspar	X	X	--	--	--	--	X	--	--
	CD-77-63	Calcite	X	X	--	--	--	--	--	--	--
	CD-79-1	Calcite, quartz, feldspar, gypsum, dolomite	---	X	--	--	--	--	--	--	--
UT 19	CD-79-12	Quartz, feldspar, mica	---	--	--	--	--	--	X	--	--
	CD-79-13	Calcite, quartz, feldspar, mica	---	X	--	--	--	--	X	--	--
	CD-79-14	Quartz, calcite, feldspar, mica	---	X	--	--	--	--	X	--	--
	CD-79-15	Calcite, quartz, dolomite(?)	---	X	--	--	--	--	--	--	--
	KF-79-2	Calcite, quartz, feldspar, dolomite(?)	---	X	--	--	--	--	--	--	--
UT 20	CD-79-8	Calcite	---	X	--	--	--	--	--	--	--
	CD-79-9	Calcite, gypsum	---	X	--	--	--	--	--	--	--
	CD-79-10	Calcite, gypsum, quartz, feldspar, manganese mineral(?)	---	X	X	--	--	--	--	--	X
UT 22	CD-79-6	Calcite, quartz, dolomite	---	X	--	--	--	--	X	--	--
UT 23	75MS-109B	Calcite, gypsum, hematite, manganite(?)	X	X	X	--	--	--	--	--	n.d.
	75MS-110	Calcite, aragonite	---	X	--	--	--	--	--	--	n.d.

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		UTAH--continued									
UT 23	75MS-111B	Calcite, aragonite	X	X	X	--	--	--	--	--	n.d.
	CD-79-2	Calcite, gypsum	---	X	--	X	X	--	--	--	--
	CD-79-4	Calcite, quartz, feldspar, dolomite	---	X	--	--	--	--	--	--	--
UT 36	75MS-112	Quartz, calcite, dolomite	X	--	--	--	--	--	--	--	n.d.
	CD-76-23B-1	Calcite, quartz	X	X	--	--	--	--	--	--	--
	CD-76-23B-2	Calcite, quartz, dolomite, kaolinite(?)	X	X	--	--	--	--	--	--	--
UT 41	75MS-113B	Calcite, gypsum, hematite, goethite, manganite(?)	X	X	X	X	--	X	--	--	n.d.
	75MS-114	Calcite, kaolinite(?)	X	X	--	--	--	--	--	--	n.d.
	75MS-115	Calcite, aragonite	---	X	--	--	--	--	--	--	n.d.
UT 42	75MS-116	Calcite, gypsum	X	X	--	--	--	--	--	--	n.d.
UT 43	75MS-117	Calcite, quartz, feldspar	---	X	--	--	--	--	X	--	n.d.
UT 44	75MS-118	Calcite, gypsum	---	X	--	--	--	--	--	--	n.d.
		WYOMING									
WY 1	CD-76-29	Calcite	---	X	--	--	--	--	--	--	--
	CD-76-30	Calcite	---	X	--	--	--	--	--	--	--
WY 2	CD-76-31A	Calcite, quartz, feldspar(?)	---	X	--	--	--	--	--	--	--
WY 4	CD-76-31B	Quartz, calcite, dolomite, feldspar	---	X	--	--	--	--	X	--	--
WY 5	CD-76-32	Calcite, dolomite	X	X	--	--	--	--	--	--	--
WY 6	CD-76-33	Calcite, feldspar	---	X	--	--	--	--	--	--	--

Table 2.--Summary of minerals identified by X-ray diffraction analysis, listed by locality and sample number--continued

Location number	Sample number	Minerals identified	≥0.01% eU	Elements present in amounts ≥ 5% Ca	Fe	Mn	Ba	As	Si	Na	S
		WYOMING--continued									
WY 8	CD-76-28	Calcite	X	X	--	--	--	--	--	--	--
WY 9	CD-76-34	Calcite	X	X	--	--	--	--	--	--	--
	CD-76-35	Sulfur, gypsum, anhydrite	---	X	--	--	--	--	X	--	X
	CD-76-36	Sulfur, gypsum	---	--	--	--	--	--	X	--	X
	CD-76-37	Gypsum	---	--	--	--	--	--	--	--	X
	CD-76-38	Calcite	---	--	--	--	--	--	--	--	--
WY 10	CD-76-27	Quartz, feldspar, dolomite	---	--	--	--	--	--	X	--	--

Table 3.--Summary of minerals identified by X-ray diffraction analysis, listed by mineral name
[Calcite was identified at all sites except AZ 4, AZ 5, AZ 10, AZ 11, AZ 13, CO 1, CO 11, CO 23, NV 10, NV 29, and WY 10. Quartz, feldspar, mica, clay, and other accessory minerals were identified but omitted from this table because most commonly they are detrital contaminants. Leaders (---), mineral not identified. Question mark indicates uncertain identification]

Mineral	Localities								
	Arizona	California	Colorado	Idaho	Montana	Nevada	New Mexico	Utah	Wyoming
Alunogen[$Al_2(SO_4)_3 \ 16H_2O$]	---	---	CO13(?)	---	---	---	---	---	---
Anhydrite[$CaSO_4$]	AZ 5	---	---	---	---	---	---	---	WY 9
Aragonite[$CaCO_3$]	AZ16	CA 4 CA 5	CO 9 CO10 CO14 CO15 CO24	ID 6	MT 5 MT14	NV14(?) NV18	---	UT23 UT41	---
Barite[$BaSO_4$]	---	---	CO11 CO12	---	---	NV12	---	UT 9	---
Cristobalite[SiO_2]	---	---	---	---	---	NV12(?)	---	---	---
Dolomite[$Ca(Mg,Fe,Mn)(CO_3)_2$]	AZ 2 AZ 8 AZ 9(?) AZ14(?) AZ16	CA 5	CO 2 CO4(?) CO 7 CO14 CO25	---	MT 5	NV 6 NV12(?) NV18(?) NV33(?)	---	UT 1 UT 5 UT 6 UT 9 UT12 UT18 UT19(?) UT22 UT23 UT36	WY 4 WY 5 WY 9 WY10
Fluorite[CaF_2]	---	---	CO17	---	---	---	---	---	---
Goethite[$HFeO_2$]	---	CA 4	CO10 CO17 CO22 CO23	ID 6(?)	MT 6	---	---	UT41	---
Gypsum[$CaSO_4 \ 2H_2O$]	AZ 4 AZ 5 AZ 9(?) AZ10 AZ11 AZ13	---	CO 1 CO 2(?) CO 7 CO 9 CO12 CO22 CO28	---	MT 6 MT11	NV12 NV30	---	UT18 UT20 UT23 UT41 UT42 UT44	WY 9
Halite[$NaCl$]	---	---	CO10 CO15	---	---	NV12	---	---	---
Halotrichite[$FeAl_2(SO_4)_4 \ 22H_2O$]	---	---	CO13(?)	---	---	---	---	---	---
Hematite[Fe_2O_3]	---	---	---	---	---	---	---	UT23 UT41	---
Manganite[$MnO(OH)$]	---	---	CO22	---	---	---	---	UT23(?) UT41(?)	---
Pyrite[FeS_2]	---	---	CO12	---	---	---	---	---	---
Pyrolusite[MnO_2]	---	---	CO22	---	---	---	---	---	---
Romanechite[$BaMnO_{16}(OH)_4$]	---	---	CO17	---	---	NV 6(?)	---	---	---
Siliceous material[?]	---	---	---	---	MT 5	NV10 NV11 NV12 NV26	---	---	---
Soda alum[$NaAl(SO_4)_2 \ 12H_2O$]	---	---	CO13	---	---	---	---	---	---
Sulfur[S]	---	---	CO 1 CO 2 CO12 CO28	---	---	NV12	---	UT 9	WY 9
Thenardite[Na_2SO_4]	---	---	CO 9 CO10	---	---	NV30	---	---	---

Table 4. -- Organic content of selected samples

[Analysis performed by Mark Stanton, USGS]

Sample	Total weight percent	Organic by difference weight percent	Carbonate carbon weight perecent
80 KF-5	10.29	2.02	8.27
CD-76-11B	2.51	2.14	.37
80KF-50	11.53	2.08	9.45