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Geology, Petrology, and Chemistry of the Leadville Dolomite: host for uranium at the Pitch Mine, Saguache County, Colorado

by

J. Thomas Nash

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ABSTRACT

Newly documented uranium ore in the Pitch Mine occurs chiefly in brecciated Mississippian Leadville Dolomite along the Chester reverse fault zone, and to a lesser extent in sandstone, siltstone, and carbonaceous shale of the Pennsylvanian Belden Formation and in Precambrian granitic rocks and schist. Uranium-mineralized zones are generally thicker, more consistent, and of higher grade in dolomite than in other hosts, and roughly 50 percent of the new reserves are in dolomite. Strong physical control by dolomite is evident, as this is the only lithology that is pervasively brecciated within the fault slices that make up the footwall of the reverse fault zone. Other lithologies tend to either remain unbroken or undergo ductile deformation. Chemical controls are subtle and appear to involve chiefly formation of FeS_2 as pyrite and marcasite, which accompany uranium.

Leadville Dolomite in the area is about 130 m thick and is predominantly nonfossiliferous dolomicrite. In the Pitch Mine, Leadville Dolomite is bound by faults and maximum known thickness is about 17 m. Mud texture, paucity of fossils and other allochems, thin laminations, and probable algal mat structures suggest sedimentation in a tidal-flat (possibly supratidal) environment. Preservation of mud texture and lack of replacement features indicate that dolomitization was an early, prelithification process, as in modern tidal flats, and produced a chemically and texturally uniform rock over tens of meters with relatively few limestone beds surviving. The sedimentary and diagenetic environment of the tidal-flat dolomite, apparently most favorable for uranium deposits, probably obtained over a large area and should consistute an exploration target over a broad area of central Colorado.

Carbonate rocks of the Belden Formation, in contrast to those of the Leadville, contain calcite in great excess of dolomite, more than 5 percent silt-size quartz and clay, and abundant fossils and oolites. Belden limestones (sandy micrite and sandy wackestone) probably were deposited in an intertidal or subtidal environment. Very little uranium ore occurs in these rocks. Chemical aspects, such as the iron, sulfur, and organic carbon contents, are very similar to those of Leadville dolomites, and hence seem favorable, but Belden limestones generally are only mildly fractured.

The minor-element content of ore-bearing dolomites is generally normal judging from the relatively scarce data yet published for comparable rocks. Elements enriched in ore include iron, sulfur, molybdenum, and lead. One surface expression of ore in dolomite is ocher-colored, leached, porous gossan that is characterized by residual silica and limonite and by high radioactivity but low chemical uranium content.

INTRODUCTION

The Pitch Mine is located in the Sawatch Range in Saguache County, Colorado, about 60 km east of Gunnison (fig. 1). The Pitch Mine (formerly known as the Pinnacle Mine or Erie No. 28 claim) and several other uranium prospects were located in 1955. Development of the Pitch Mine began in 1959 with the opening of two underground adits. The mine closed in 1962 when its contract with U.S. Atomic Energy Commission expired. About 100,000 tons of ore averaging 0.50 percent U_3O_8 (1,000,000 lbs U_3O_8) was mined, and another 100,000 lbs U_3O_8 was recovered by solution mining (Ward, 1978). In 1972, Homestake Mining Company acquired the property and began to reevaluate the mine area for additional reserves amenable to open-pit mining, because the previous nistory had demonstrated that fault offsets of ore and unstable wallrocks made underground mining costly.

In the period 1972 to 1977, Homestake Mining Company documented a reserve minable by open-pit methods of 2.1 million tons of ore at an average grade of 0.17 percent U_3O_8 (7,140,000 lbs U_3O_8) (Ward, 1978). Rather than seek high-grade "vein-type" ore, Homestake explored for more dispersed ore using vertical rotary drilling supplemented by approximately 10 percent angle and vertical core drilling. Success came in 1973 when the company recognized a "new type" of ore in brecciated dolomite of the Mississippian Leadville Dolomite. The dolomite was found to be complexly faulted between slices of sandstone, siltstone, and shale of the Pennsylvanian Belden Formation. Much of the ore mined in 1959-61 also probably was in Leadville Dolomite, but was not recognized as such (J. M. Ward, Homestake Mining Co., oral commun., 1979). Homestake is mining the deposit at a rate of about 600 tons per day from an open pit that will be about 1,500 m long and have an average depth of 120 m.

The "new" geologic development at Pitch Mine is the observation that approximately half of the reserves occur in dolomite. Although most knowledge comes from drill logs, cuttings, and core, it is clear that uranium mineralization strongly favors Leadville Dolomite. I know of no other significant uranium deposit with this type of lithologic influence. It is clear that physical properties of the dolomite are a very important factor in creating breccia zones. Chemical controls on uranium deposition are not clear. To help answer the question of what chemical factors are involved, this report describes ore-bearing host rocks and barren equivalents, with emphasis on petrology, major- and minor-element chemistry, and a discussion of possible

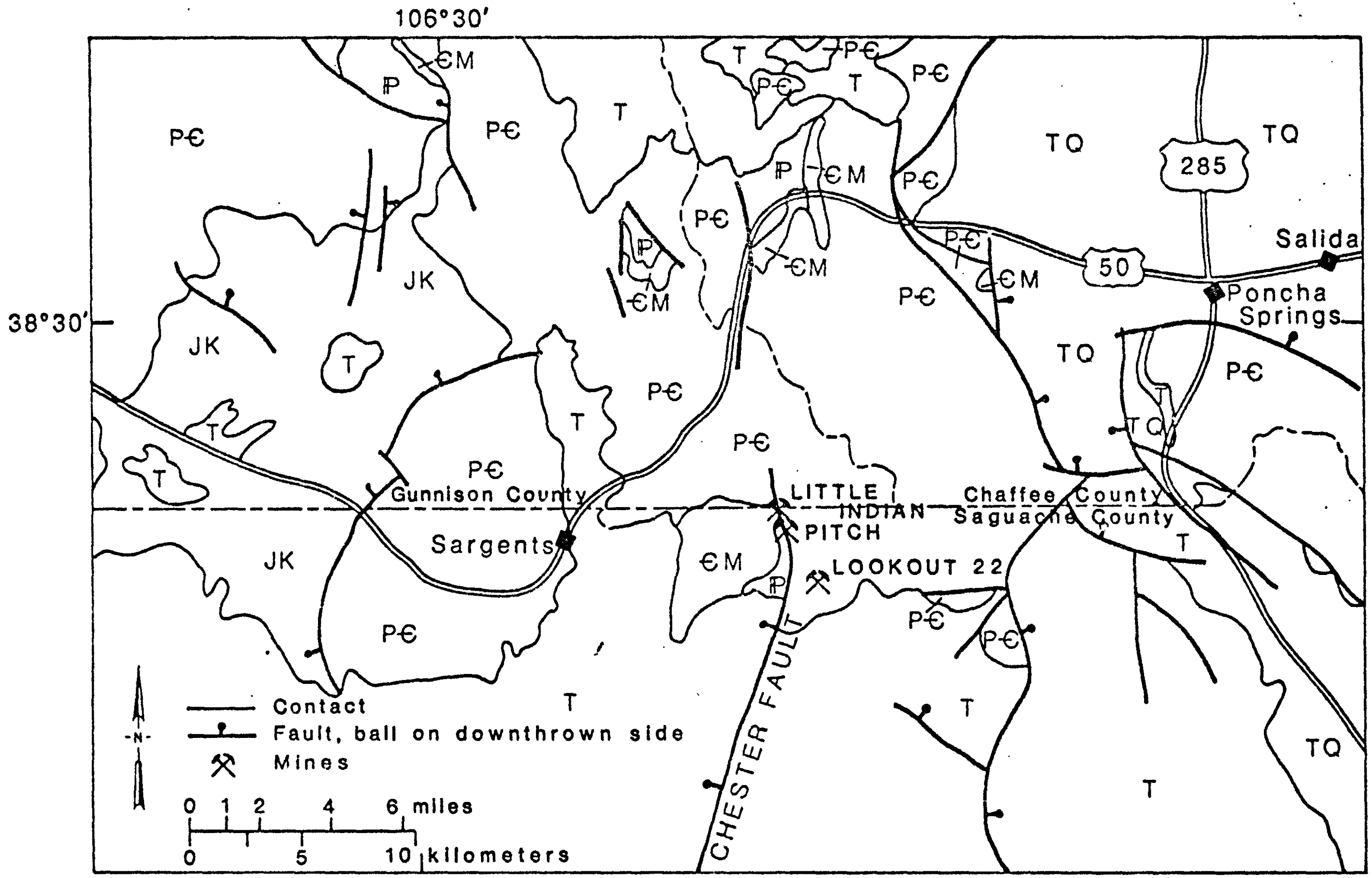

Figure 1.--Generalized geologic map and location of Pitch Mine, Colorado (after Tweto and others, 1976). Note that more detailed mapping (Olson, 1977) does not show the Chester fault cutting Tertiary volcanics. Abbreviations: TQ, Tertiary and Quaternary sediments, largely post-volcanic; T, Tertiary intrusive and volcanic rocks; ℙ, Pennsylvanian sedimentary rocks; JK, Jurassic-Cretaceous rocks; ЄM, Cambrian to Mississippian sedimentary rocks; PЄ, Precambrian rocks.

mode of origin for the Leadville Dolomite. Additional analyses are underway, and better understanding of many critical geologic relations must wait for mapping of mine exposures.

Acknowledgments.--It is a pleasure to acknowledge the cooperation of Homestake Mining Company. This project obviously would not have been possible without their permission to examine surface and mine exposures, and to log and sample drill core and cuttings. Homestake also provided important base maps and geologic information. J. Mersch Ward, District Geologist, was a gracious host and offered stimulating discussion. Jerry C. Olson, USGS, introduced me to regional geology and offered helpful information on structure and stratigraphy. John A. Campbell, USGS, patiently guided this "hardrock" geologist in the new relm of carbonate petrology and sedimentation, and reviewed the manuscript. Statistical computations and X-ray determinations were made by Karen Parsons.

GEOLOGIC SETTING

Rocks ranging in age from Precambrian to Oligocene(?) are known in the Pitch Mine area (table 1). Precambrian rocks are chiefly pegmatitic granite, hornblende-biotite schist, hornblende gneiss, and pegmatite. A hematitic regolith was developed on the Precambrian rocks prior to the Mississippian. Above the Precambrian was deposited about 600 m of Paleozoic rocks. The lower half is predominantly dolomite, with three beds of quartzite that are useful stratigraphic markers between the similar-appearing dolomites. The Leadville Dolomite is the darkest dolomite in the area, and generally is very massive with very faint laminations. The top of the Leadville often is limonitic, the result of a karst that was developed prior to deposition of the Belden Formation. The Belden Formation comprises diverse lithologies, including coarse kaolinitic sandstone; green, clay-rich, fine sandstone; black and red shale; and gray and black limestone and minor dolomite. Rapid facies changes are common over lateral distances of 300 m. A few erosional remnants of sandy Oligocene(?) quartz latite flows are preserved topographically above and a kilometer north of the Pitch Mine. About 6 km south of the mine, more than 300 m of Tertiary andesitic volcanics of the San Juan volcanic field cover Paleozoic rocks.

The major structural feature in the mine is the Chester Fault zone, which dips east at about 70°, strikes nearly due north, and places Precambrian rocks above and west of Paleozoic rocks (figs. 2 and 3). Net reverse movement along

Table 1.--Simplified stratigraphic column in the Pitch Mine area (After Olson, 1977)

Oligocene(?) QUARTZ LATITE FLOWS: light colored felsic flows, 0-20 m thick

--unconformity--

Pennsylvanian BELDEN FORMATION: contains three units: lower white sandstone and black shale (40-90 m thick); middle blue-gray limestone with red shale and fine sandstone (30-60 m thick); and upper green and brown sandstone and gray shale; 200 m or more thick

--unconformity--

Mississippian LEADVILLE DOLOMITE: dark blue-gray to brownish-gray dolomite and minor limestone; contains calcite and chalcedony veinlets and local black chert zones; about 130 m thick.

Devonian DYER DOLOMITE: tan to light-gray dolomite; about 50 m thick.

Devonian PARTING QUARTZITE: varicolored shale and quartzite; about 5 m thick

--unconformity--

Ordovician FREMONT DOLOMITE: blue-gray limestone and dolomite; about 55 m thick.

Ordovician HARDING QUARTZITE: white quartzite, often with limonitic stain, and some black shale; about 10 m thick

--unconformity--

Ordovician MANITOU DOLOMITE: light-pinkish-gray dolomite, 75-90 m thick.

Cambrian SAWATCH QUARTZITE: vitreous quartzite less than 1 m thick

--unconformity--

numerous fault strands is approximately 600 m. The fault zone is about 100 m wide in the mine area (fig. 2). Paleozoic rocks immediately west of the Chester fault are folded into a south-plunging syncline whose east limb is probably overturned under the fault zone (fig. 3). West of the mine Paleozoic rocks have a low dip and are gently warped in broad folds. East-trending faults cut the Chester Fault zone and form rotated blocks. The faulting in the Chester Fault zone is of Laramide age; Cretaceous rocks about 20 km to the west are displaced by similar reverse faults (fig. 1); and Oligocene(?) volcanic rocks are not displaced by the Chester Fault (Olson, 1977). Younger north-trending faults displace volcanic rocks southeast of the mine (Olson, 1977).

URANIUM DEPOSITS

Uranium anomalies, occurrences, and deposits are known in five geologic settings in the Marshall Pass district. The following are arranged by decreasing age of host, but the ages of mineralization are not known.

(1) Precambrian biotite schist--several prospects and small mines occur in the Harry Creek area (Lookout 22, Marshall Pass No. 5 prospects) about 2 km east of the Pitch Mine. Mineralization is probably pitchblende and some hexavalent uranium minerals. Near these vein-like deposits are high grade concentrations of uranium in alluvium (type 5 below). The deposits are probably related, and the high concentrations mined probably reflect supergene processes (Malan, 1959; Gross, 1965), but the source and age of the original uranium is moot.

(2) Precambrian pegmatite--shears in pegmatite in the Pitch Mine area contain pitchblende, including the discovery outcrop for the Pitch Mine (Ward, 1978).

(3) Ordovician Harding Quartzite--uranophane and other U^{+6} minerals fill fractures in the quartzite and generally are accompanied by limonite (Malan, 1959). A carbonaceous bed containing fish scales at the top of the Harding is radioactive. This bed guided prospectors to the Little Indian 36 deposit, where the Harding is fractured in the Chester Fault Zone 2 km north of the Pitch Mine. Production from the Little Indian 36 mine from 1957 to 1959 was about 6,800 tons of 0.48 percent U_3O_8 (65,000 lbs U_3O_8) (Ward, 1978).

(4) Mississippian Leadville Dolomite and Pennsylvanian Belden Formation--at the Pitch Mine oxidized and reduced uranium minerals occur in dark-gray dolomite, sandstone, black shale, and coaley shale. Oxidation occurs to

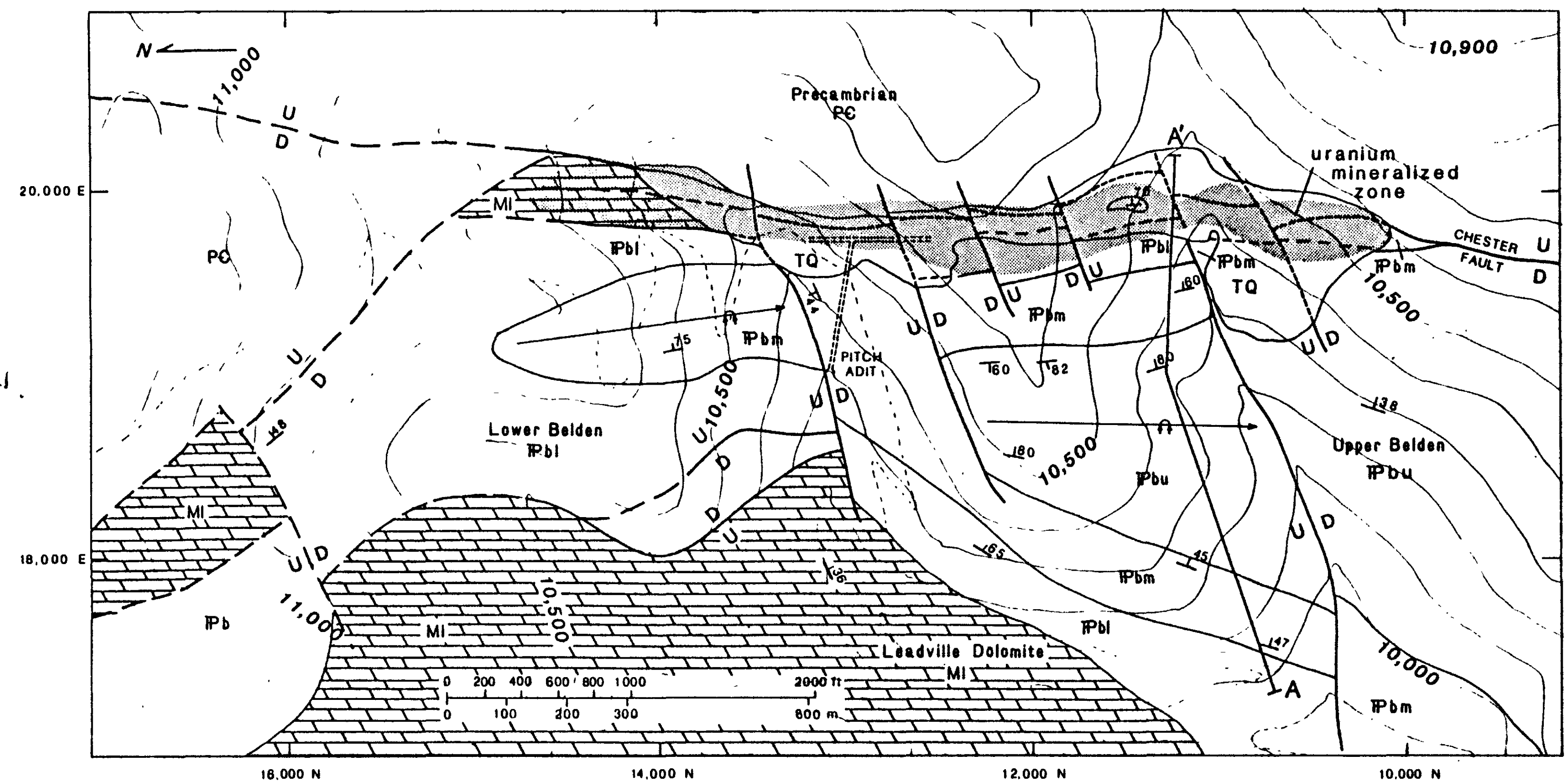

Figure 2.--Preliminary geologic map of the Pitch Mine area. Cross section A-A' is shown in figure 3. Geology in places adapted from mapping by Olson (1977) and J. M. Ward, Homestake Mining Co. (unpub. data, 1972-1977). Base generalized from 1:2,400 map of Homestake Mining Co. Grid is mine coordinate system used by Homestake Mining Co.

EXPLANATION FOR FIGURE 2

TQ: Tertiary to Quaternary talus and alluvium

IPbu: Pennsylvanian Belden Formation, upper unit

IPbm: Pennsylvanian Belden Formation, middle unit

IPbl: Pennsylvanian Belden Formation, lower unit

Ml: Mississippian Leadville Dolomite

P€: Precambrian rocks, undivided

36 Strike and dip of beds

Fault, dashed where approximately located, dotted where covered

Contact, approximately located

Overturned syncline, inferred

Uranium mineralized zone (>0.01 percent U_3O_8), projected to surface

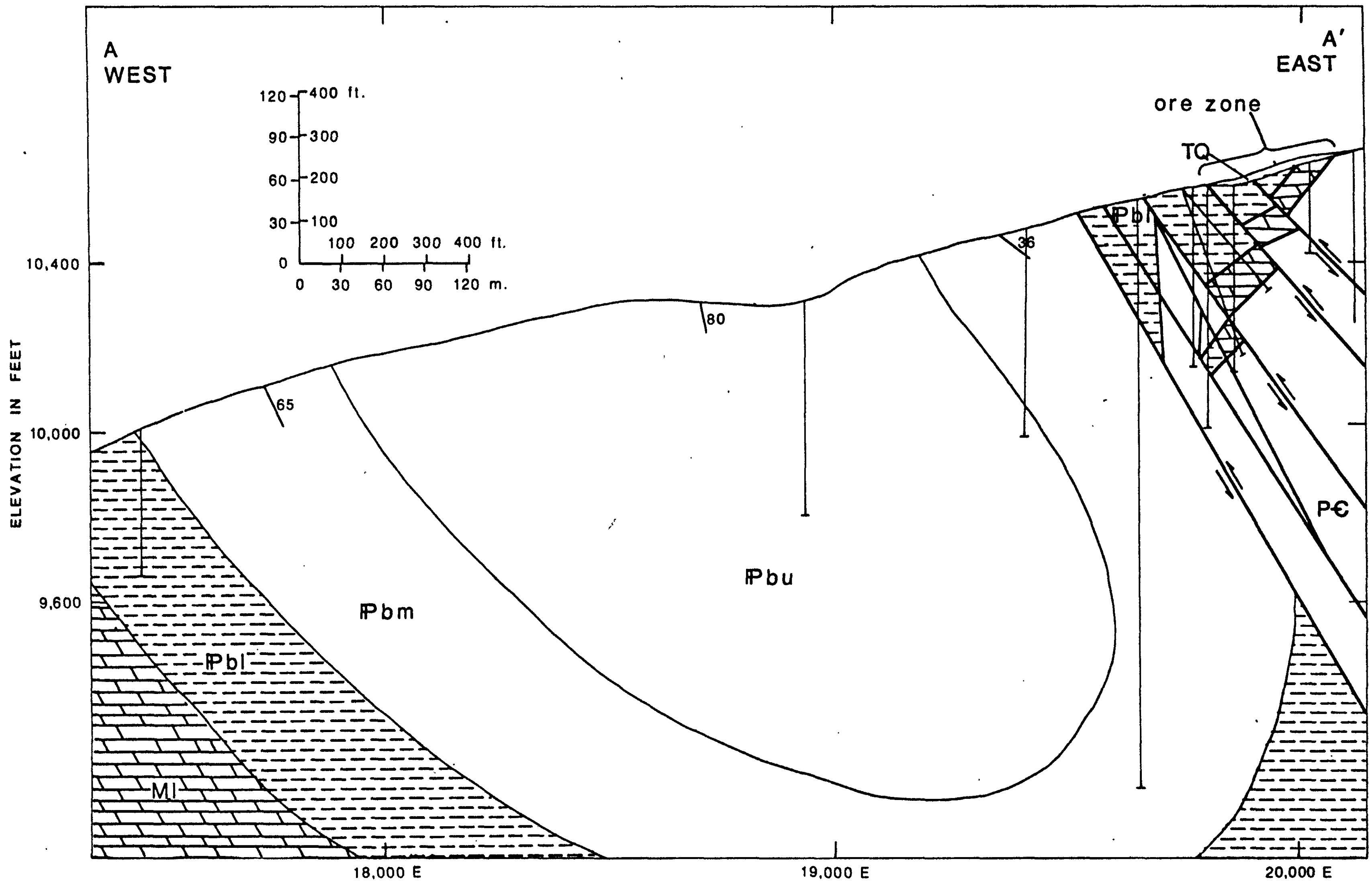

Figure 3.--Schematic cross section A-A' of the Pitch Mine area. Line of section is shown on the geologic map (fig. 2). Structure in the Chester fault zone is known from drilling to be much more complex than shown. The overturned synclinal structure is inferred from sparse surface outcrops showing bedding attitudes. Symbols are same as on figure 2.

depths of about 100 m. In oxidized zones, disequilibrium is great and radioactivity is much in excess of chemical uranium content (Malan, 1959). Pyrite occurs in most unoxidized rocks, but many pyritic rocks have very low uranium content. Fractures, shears, and breccia zones carry the uranium ores. Past production from the Pitch (Pinnacle) Mine was about 1,100,000 lbs U_3O_8 (Ward, 1978).

Carbonaceous shales of the Belden are radioactive in many places, as at the mouth of Indian Creek, 6 km southwest of the Pitch Mine.

(5) Eocene(?) carbonaceous regolith--several unusual small but high-grade concentrations of uranium have been mined from "alluvium" (Gross, 1965) and carbonaceous regolith developed in Precambrian gneiss and schist and in places overlain by Tertiary volcanic flows (Malan, 1959). Mined localities were at the Lookout No. 22 claim, previously mentioned, and the Bonita claims east of the Continental Divide (about 11 km east of the Pitch Mine). Pitchblende and a number of U^{+6} minerals have been identified from these deposits (Malan, 1959; Gross, 1965). Most of the several hundred tons of high-grade ore (about 3,900 lbs U_3O_8) produced from these deposits was from the pockets in alluvium, and a lesser amount from vein-like deposits within Precambrian host rocks (type 1, above) (Malan, 1959; Ward, 1978).

Unresolved problems are the ages and genetic relations of these various types of uranium deposits. Most observers suspect the deposits have a fundamental geologic relation, such as a common source.

PETROCHEMISTRY OF CARBONATE ROCKS

Introduction.--The descriptive data base for this study comes from mapping surface exposures, logging about 29,000 ft (8.8 km) of drill core in 73 holes, and laboratory study of about 300 samples by petrographic, X-ray, and chemical methods. Samples were routinely X-rayed to yield quick semiquantitative estimates of major minerals precise to about 1±1 part per ten. Approximately 150 thin sections of carbonate rocks have been examined and an estimate of mineral proportions made. All sections were stained with alizarin red S to impart a red stain to calcite, however X-ray diffraction proved most reliable in mineral determinations. Petrographic data and rock classifications are presented in table 2 along with the results of chemical and X-ray analyses of 99 samples. Sample localities are shown on figure 4. Petrologic data and classifications are given for 62 of the analyzed samples. The amount of data in table 2 is enormous, and much of it cannot be described and interpreted

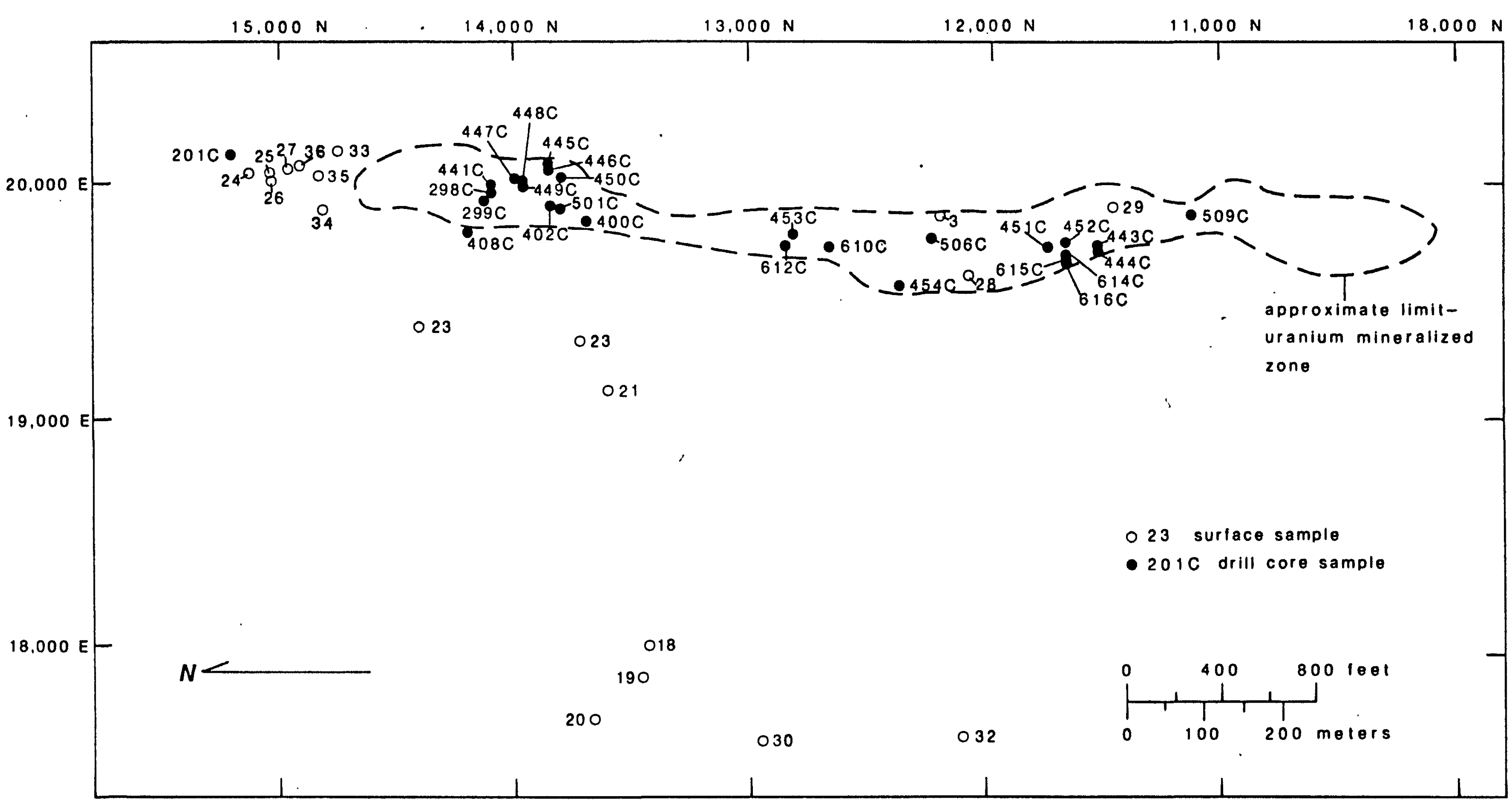

Figure 4.--Map showing location of analyzed surface samples and core hole collars. Most drill holes are inclined 15° to 45° from vertical on an E-W bearing.

here. A statistical summary for 39 of the variables measured on all samples is included in table 3.

Lithology.--Approximately 350 m of carbonate rocks in five formations, occur in the mine area. Many of the carbonates are lithologically very similar to each other, especially the pinkish-tan-weathering dolomites[1] of the Manitou, Fremont, and Dyer Dolomites. Dolomites and limestones of the Belden and Leadville Formations generally are darker than the underlying carbonates and seem to be reliably mapped even where present in thin faulted slivers (Olson, 1977). Attention in this study has been focused on carbonate rocks of the Leadville and the Belden because they host ore in the Pitch deposits.

In the mine area dolomite is the predominant lithology of the Leadville. Limestone occurs in a few places, one being 1 km west of the mine. The limestone is generally thick bedded (about 30 cm), in places is cross-bedded, and is light to medium blue-gray on weathered surfaces and medium gray on freshly broken surfaces. Fossils (ostracods, gastropods, forams, and brachiopods) and oolites are abundant. Dolomites are medium gray to black, often with brownish or reddish-brown tones, and tend to be a bit lighter and bluish on weathered surfaces. Bedding ranges from medium to massive. Dolomites are often faintly laminated (mm scale). Carbonaceous shale and sand layers are very rare and are thin where present. Measurement of strike and dip of beds in outcrop or drill core often is difficult or impossible. Most Leadville Dolomites are fetid when broken. Brecciation of several types is common in the Leadville Dolomite. In a few places the brecciation is associated with curved surfaces and bounded by undeformed beds, suggesting intraformational slumping. Some breccia at the top of the Leadville contains iron oxides and seems to reflect karst development. Sample 39 is an example (table 2). A large area of breccia 2 km south of the Pitch Mine contains angular and subangular fragments but very little sparry carbonate cement. This breccia, which probably formed in pre-Belden time, contains small amounts of iron oxides and does not seem to be related to karst.

Leadville Dolomite in the Chester Fault zone at the mine is interpreted to be bound by faults (fig. 2). In some drill core the dolomite is observed

[1]The term dolomite, with lower case "d", will be used for rocks with dolomite as the major constituent, and limestone for rocks having calcite as the major constituent. The term carbonate is collective for both limestone and dolomite. "Dolomite" in formation names has a capital "D".

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on a hematitic regolith of Precambrian rocks, which suggests a possible depositional contact. However, there is no terrigenous debris in the dolomite above the regolith, and on a regional scale a large paleoslope would be required to permit both Leadville Dolomite and Sawatch Quartzite to have been deposited on the Precambrian. The Sawatch depositional contact is 2 km north of the Pitch Mine and about 250 m lower in the section. The localities showing Leadville on regolith are interpreted to be fault contacts, even though the faults are not obvious in core. Maximum thickness of Leadville Dolomite in the mine is about 17 m, only a small fraction of the total Leadville section known in the area (about 130 m). It is not possible to establish the stratigraphic position of the Leadville in the mine because it is highly deformed, and the outlying Leadville displays no obvious internal units useful for correlation.

Chert is common in the Leadville as veinlets, bed-like stringers, and concretionary nodules. The chert is generally black, presumably from organic matter. In some well exposed localities the bed-like chert is faulted off and cut by a breccia of recrystallized dolomite. Much of the chert is probably early diagenetic (Banks, 1970) although the occurrence of several cherty zones that crop out over an area of more than a thousand square meters adjacent to (under) the Chester Fault zone suggests some chert may be structurally controlled and of Tertiary age.

Carbonate rocks in the Belden Formation generally are limestone, with rare dolomite, and have thick to massive bedding. Color is light gray or bluish gray in outcrop, and medium gray to black or brownish black on fresh surfaces or core. Terrigenous material is generally abundant in Belden carbonates; black or red shale laminae or enclosing beds are much more common than in the Leadville. White or pink calcite veinlets are common in the Belden carbonates, but chert and intraformational breccia have not been observed.

Petrography.--Petrographic study of Leadville and Belden carbonate rocks reveals the following major features:

(1) Leadville carbonates are consistently rich in dolomite, whereas in most Belden carbonates calcite greatly exceeds dolomite.

(2) Clastic quartz sand and silt is consistently absent or less than 5 percent in Leadville samples, but is commonly present in Belden samples.

(3) Fossils are essentially absent in the Leadville (only a few brachiopods were seen at two localities), whereas fossils (chiefly brachiopods, forams, and ostracods) and oolites are present in most Belden carbonates.

(4) Most carbonate rocks in the ore zone are extremely fine grained and are no more recrystallized than are those away from ore.

Leadville Dolomites (58 studied) consistently contain more than 95 percent dolomite and rarely contain more than traces of terrigenous quartz and clay.[2] Pyrite is, or was, present in essentially all dolomites in amounts ranging from about 0.2 to 16 percent. Twenty percent of the dolomites display faint lamination, 7 percent contain intraclasts, 8 percent contain burrows or evidence of bioturbation, 3 percent contain sparse fossils, and 2 percent contain pellets. Sand grains are generally round and are probably windblown. Possible mudcracks are present in 5 percent of the dolomites, and possible "birdseye" textures (openings filled by sparry carbonate) are present in 3 percent. No gypsum, anhydrite, or halite have been observed in thin sections or X-ray diffraction patterns, nor were any casts or pseudomorphs after these evaporite minerals detected.

Based on composition and texture, all of the Leadville Dolomites are classified as dolomicrites (Folk, 1959, 1962) or dolomite mudstone (Dunham, 1962) (table 2). In other words, the dolomites formed from dolomite mud or dolomitized lime mud. The general absence of terrigenous grains or carbonate clasts testifies to a probable lack of strong currents or wave action, meaning that the environments were probably protected from the source by a barrier or by distance. (See Dunham, 1962; Folk, 1962; and others.)

Two samples (numbers 37 and 38, table 2) from the Leadville collected about 1 km west of the mine are notably different from the typical carbonates described above. These samples show good bedding and crossbedding, are composed entirely of calcite, and contain 30 to 40 percent fossils supported in very fine calcite mud. They are classified as fossiliferous biomicrite (Folk, 1962) or packstone (Dunham, 1962). The locality 1 km west of the mine appears to be in the middle to upper part of the Leadville. The significance of these textures is that they testify to moderate current or wave energy that was sufficient to move particles but not so great as to winnow out the fine car-

[2]This is clearly an oversimplification, as chemical analyses consistently indicate more quartz and clay, based on normative calculations, than are visible in thin section. This discrepancy is discussed later.

bonate mud. This facies of the Leadville, unusual in the mine area, probably formed during a marine transgression.

Carbonate rocks in the Belden Formation are compositionally and texturally more diverse than in the Leadville. It is clear that in the Belden a continuum exists between essentially pure carbonate rocks and terrigenous rocks. Here we will consider only those samples containing more than 50 percent carbonate minerals. Of the 29 samples that meet this criterion, 60 percent contain 10 to 50 percent sand and silt grains, 28 percent are fossiliferous, 18 percent are bioturbated, and 12 percent contain intraclasts. Most of the Belden carbonates contain calcite and very little or no dolomite; 15 percent had dolomite in excess of calcite. Based on these compositional and textural data (table 2), most Belden carbonates are classified as sandy micrite (Folk, 1962) or sandy wackestone (Dunham, 1962). In a few samples, sparry calcite cements clasts. These rocks contained very little mud and are classified as grainstone (Dunham, 1962).

Chert nodules and stringers in the Leadville are replacements of carbonate rock and are very finely crystalline chalcedonic quartz. Grain size typically is less than 15 microns. Specks of opaque iron oxides and carbonaceous matter occur between chalcedony crystallites. Irregular veinlets or swaths of more coarsely crystalline quartz (50 microns to 1 mm size) cut or grade from the aphanitic chert. Textures of chalcedony and quartz in the broad, silicified "jasper" zones are similar to that in chert nodules.

Petrography of ore-bearing carbonate rocks.--Most of the foregoing petrographic descriptions pertain to carbonate rocks in the ore zone. For emphasis some additional comments are warranted here. Specific topics of interest are the textures of dolomites hosting ore, the nature of breccias hosting ore, the occurrence of pyrite and uranium minerals, and the nature of oxidation in ocher dolomites.

The most important host for ore in the Pitch deposit is dark-gray dolomite of the Leadville. In the ore zone this dolomite has a very consistent composition. Calcite is a minor constituent, except in the oxidized ocher dolomites discussed below. Quartz content is the major variable and is chiefly cherty silica, which quite probably is older than the ore. Fragments of chert are seen in breccia; hence that chert is pre-fault. Terrigenous quartz, feldspar, and clay are very rare to nonexistent, even though the dolomite frequently rests on the Precambrian and some have proposed that the

Leadville was deposited on the Precambrian. Some Leadville samples contain 1 to 3 percent quartz silt, but dolomites with silt content greater than this are probably from the Belden but this is not possible to recognize while logging core. All ore-bearing dolomites are fractured or brecciated. The narrow, millimeter-size fractures generally carry sparry dolomite or calcite, with some fine pyrite. Texturally, the Leadville Dolomites in the ore zone are extremely simple, as no fossils and only a few dolomite intraclasts have been observed. The rocks must have been dolomicrite, some of which have been neomorphosed to x-microdolospar and x-pseudodolospar. There is no evidence for the Leadville Dolomites being secondary after limestone, as they have all the features of modern primary or penecontemporaneous dolomites, as will be discussed.

Some dolomites in the ore zone contain more than 10 percent clastic quartz and are fossiliferous. These rocks have the petrographic features of Belden carbonates. Because very little of the Belden carbonate is dolomite, some of these samples may reflect secondary dolomitization, although there is no evidence for secondary replacement textures, or paragenetic relation to ore. These samples also represent a special structural and stratigraphic problem and will not be discussed further--except to point out that some (10 percent?) of the dolomite in the ore zone is probably Belden. An alternative possibility is that the silty dolomite is an upfaulted block to Dyer Dolomite.

Carbonate breccias are very extensive in the Chester Fault crush zone. It is common to observe in drill core 5 to 10 m of quite uniformly and thoroughly brecciated dolomite. Such zones are generally consistently mineralized, indicating that dark dolomite breccia is a favorable host, presumably for both physical and chemical reasons. The breccias generally are not well cemented, and fragments and matrix are not notably recrystallized. Extensive cementation of breccia by silica or sparry carbonate has not been recognized. Many breccias are a mixture of lithologies that must have originated in different formations. The mixing of breccia fragments is consistent with the extremely complex interfaulting of slivers of Precambrian, Leadville, and Belden rocks.

Carbonate rocks in the Pitch Mine area have been recrystallized to varying extents, but there is no evidence that the recrystallization depends on proximity to the ore zone or the Chester Fault zone. Most dolomites have been recrystallized to equigranular subhedral crystals with average size 15 to 50 microns. According to the classification of Folk (1965), most neomorphic dolomite is x-pseudospar (>31 microns) and x-microspar (4 to 31 microns). At some localities dolomite is so coarsely recrystallized that individual grains sparkle in hand specimen and are seen to be 100 to 200 microns across in thin section. These crystalline dolomites are in zones that are cherty and show evidence for intraformational slumping and brecciation, hence the coarsest recrystallization appears to be an early diagenetic phenomenon.

Dolomites in the ore zone, and in general in breccias along the Chester Fault zone, show remarkably little recrystallization. Many are essentially unrecrystallized (grain size less than 4 microns), and dolomite matrix between the breccia fragments typically is very finely crystalline (less than 16 microns) and generally is finer than the dolomite in the breccia fragments. Crustified and syntaxial overgrowths (Folk, 1965) have not been observed, even in fault breccia. Sparry calcite and dolomite fill fractures and possible desiccation cracks as relatively coarse-grained (50-200 micron) crystals, but the fill is not neomorphic carbonate.

Recrystallization of these carbonate rocks seems to be normal coalescive neomorphism, as commonly happens during diagenesis (Folk, 1965). Hence, most recrystallization probably occurred in the Paleozoic, long before the area was deformed and probably long before uranium was emplaced.

Pyrite occurs in all Paleozoic lithologies in the ore zone. It is most conspicuous as coarse crystals in white Belden sandstones, but pyrite is also present as small crystals in siltstone, carbonaceous shale, and coal, and in dolomite and limestone of the Belden and Leadville. Pyrite in carbonate rocks occurs in three habits: (1) along silty bedding planes; (2) dispersed as tiny crystals, generally less than 50 microns in size, throughout the rock; and (3) along fractures and in breccia matrix. The contribution of fine dispersed pyrite is significant and probably explains as much as about 0.5 weight percent of the sulfur content (or about 1 percent pyrite).

The distribution of uranium minerals in carbonate rocks is a very complex topic that cannot be covered adequately here. Veinlets of pitchblende and coffinite a few millimeters wide are rarely seen. Much of the uranium is not visible in recognizable minerals in drill core or under the microscope in incident light. Even in core samples containing 2 to 5 weight percent U_3O_8 no uranium minerals are visible. Presumably most of the uranium is carried in the matrix of breccia and along numerous tiny cracks as very fine grained films of pitchblende or coffinite.

Carbonate rocks in the Chester Fault zone are oxidized to depths of more than 100 m along faults and can be pervasively oxidized in the upper 60 m of some breccia zones. In the most severe instances, near-surface carbonate rocks are oxidized and leached to a porous, friable, ocher-colored rock composed of quartz, iron oxide, with only traces of calcite (sample 3, table 2). More common is an intermediate product--ocher colored dolomite (e.g., samples 612-15 and 445-28, table 2), which may have some voids and has more quartz and calcite than normal. Petrographically, the ocher dolomites seem to be only slightly modified, with the exception that original disseminated pyrite is oxidized to iron oxides and cracks are covered with a thin film of iron oxide (transported iron). Hence, there seem to be two end-member situations: (1) leached and oxidized gossan formed from dolomite, and (2) oxidized but otherwise barely altered dolomite in which the only major change is oxidization of pyrite and transport of some iron to produce a strong color effect. Uranium, which was probably present in much of the ocher dolomite of both types, is present at concentrations of only about 50 to 200 ppm (0.005 to 0.02 percent) (table 2). Most of this oxidation and uranium leaching must be relatively recent, because the oxidized rocks are badly out of radioactive equilibrium. Some reduced zones are reported to have chemical uranium in excess of radiometric (Malan, 1959), suggesting redeposition of recently leached uranium. Presumably the cause of the leaching is sulfuric acid generated by oxidizing pyrite. Radium is precipitated by sulfate, a factor contributing to the disequilibrium problem (Phair and Levine, 1954).

Preliminary comments on carbonate geochemistry.--Analytical data for 99 samples of carbonate rocks from the Leadville Dolomite and Belden Formation are in table 2 along with mineralogical and other descriptive data. The surface samples generally were collected as being representative of larger volumes of similar lithology. The drill-core samples (those having five- or six-digit numbers, in the conventional hole number-depth numbering style) generally were selected for special attributes such as color, oxidation, or uranium content, and as such may be representative of several feet of core, or of less than a foot. Drill-core samples generally were less than 200 grams total weight, and part of each sample was reserved for X-ray studies and a thin section; hence the material analyzed is not representative of a large volume of rock. No sampling was done according to a uniform plan, as is commonly advocated for statistical rigor, and some lithologies, such as chert, were probably sampled in excess of their geologic occurrence.

Statistical summaries of 39 variables in two sample groups, Leadville and Belden, are given in table 3. Multivariate statistical tests are being made and will be interpreted and reported in a separate publication.

Two methods can be used to evaluate the chemical data: comparison within the sampled population, and comparison with rocks elsewhere. Within-population variation will be tested by multivariate methods. Regrettably, there is remarkably little chemical information in the literature for many key elements, such as organic carbon, iron, and sulfur, and most analyzed carbonates are not described lithologically. Weber (1964) reports data for several types of dolomites, but his element suite is limited; nonetheless it probably is the best data for comparison because specific varieties of dolomite are grouped. Graf (1960) has assembled a great mass of chemical data, and his compilation probably the most complete available, but most reports that Graf cites do not include petrographic description. Consequently, it is difficult to know if much of the chemistry is unusual, because comparable information is lacking.

Aluminum.--Mean aluminum content of Leadville and Belden carbonates is 1.78 and 2.17 percent Al_2O_3, respectively, which is equivalent to 4.4 and 5 percent normative clay (table 3). The clay in the Leadville samples generally is not evident in thin sections, possibly because of the contrasting optics of dolomite and very fine clay. The aluminum content of these carbonates is much higher than reported by Weber (1964) for primary dolomites or Till (1970) for lagoonal carbonate sediment. However, the amount of normative clay, calculated from aluminum, is less than Roehl (1967) reports for supratidal dolomite. Till (1970) demonstrated that aluminum content correlates strongly with carbonate mud content in Holocene sediments and suggested that an environmental factor, probably quietness of water, controls the concentration of clay minerals and carbonate mud. Till's remarks seem relevant to the present problem, but the amount of clay or aluminum typical of various carbonate environments has not been established.

Iron.--Iron is most easily discussed as total iron or as total iron expressed as Fe_2O_3, because many analyses in the literature report only total iron. Also, it is possible that the relative amounts of ferrous and ferric iron in the present analyses are in error, because there generally is more ferric iron than indicators such as organic carbon and pyrite would suggest. Total iron content of the Leadville Dolomites (2.84 percent Fe_2O_3; 1.99 percent Fe)

Table 3.--Statistical summary of petrochemical data for Leadville Dolomite and Belden Formation

Variable	Leadville Dolomite				Belden Formation				Mean Reference value[1]
	Average	Standard deviation	Minimum value	Maximum value	Average	Standard deviation	Minimum value	Maximum value	
SiO_2 (%)	22.67	26.93	0.20	97.70	21.37	20.57	2.90	92.20	--
Al_2O_3 (%)	1.79	2.65	0.03	13.70	2.17	2.21	0.33	11.60	0.34 (W)
Fe_2O_3 (%)	2.54	7.28	0.02	46.40	1.37	1.30	0.05	4.70	0.40 (W)
FeO (%)	0.27	0.30	0.00	1.40	0.33	0.48	0.00	2.50	--
MgO (%)	13.28	7.06	0.07	20.80	7.43	6.98	0.35	18.70	--
CaO (%)	23.92	11.64	0.15	53.10	31.98	12.82	2.00	53.00	--
Na_2O (%)	0.030	0.03	0.00	0.10	0.04	0.05	0.00	0.28	0.053 (W)
K_2O (%)	0.38	0.42	0.00	1.60	0.55	0.61	0.04	3.40	0.79 (W)
H_2O^+ (%)	0.98	1.56	0.16	9.10	0.80	0.61	0.24	2.60	--
H_2O^- (%)	0.39	0.84	0.01	5.50	0.28	0.22	0.03	0.89	--
TiO_2 (%)	0.088	0.11	0.00	0.53	0.13	0.13	0.00	0.69	0.034 (W)
P_2O_5 (%)	0.038	0.03	0.00	0.20	0.093	0.11	0.01	0.63	--
MnO (%)	0.074	0.06	0.00	0.31	0.078	0.05	0.01	0.19	0.032 (W)
CO_2 (%)	33.15	15.26	0.00	48.20	33.02	10.76	1.20	45.50	--
F (%)	0.032	0.02	0.00	0.08	0.038	0.03	0.01	0.21	0.032 (G)
S (%)	0.36	0.99	0.01	6.30	0.34	0.73	0.02	3.10	--
C total (%)	9.37	4.13	0.20	13.16	9.42	2.98	0.44	12.85	--
C organic (%)	0.25	0.22	0.00	0.88	0.34	0.66	0.00	4.20	0.24 (Ge)
Carbonate (%)	9.11	4.17	0.00	13.07	9.07	2.96	0.42	12.35	--
Cl (ppm)	143.6	125.7	25.0	550	82.5	53.8	25.0	230	207. (W)
Ba (ppm)	116.8	131.7	20.0	920	182.8	317.9	55.0	2100	86. (W)
Sr (ppm)	91.9	75.4	10.0	310	240.5	147.9	49.0	620	174. (W)
Pb (ppm)	20.9	34.9	0.8	220	22.7	39.9	1.0	200	68. (W)
Zn (ppm)	112.6	341.0	5.0	2600	127.7	236.4	5.0	1000	1100. (W)
Mo (ppm)	6.94	15.5	0.05	88.0	2.28	4.0	0.05	19.0	1.1 (G)
Hg (ppm)	0.187	0.49	0.005	2.6	0.050	0.099	0.005	0.56	0.07 (G)
U (ppm)	1506.8	5874.4	0.18	33500	116.4	217.9	1.56	1190	2.1 (G)
Dolomite XR	5.8	3.1	0.0	10	4.3	2.8	0.00	9.0	
Calcite XR	1.18	2.32	0.0	10	2.3	2.8	0.00	8.0	
Quartz XR	3.0	2.8	0.0	10	3.1	1.6	1.0	10.0	
Clay XR	0.2	0.46	0.0	2	0.3	0.6	0.00	0.0	
Hematite XR	0.08	0.5	0.0	4	0.0	0.0	0.0	0.0	
Dolomite NM	63.8	33.0	0.5	99.0	37.6	33.3	2.0	92.0	
Calcite NM	9.8	19.7	0.0	95.0	38.9	34.5	0.5	95.0	
Quartz NM	19.5	26.3	0.5	98.0	16.9	19.2	2.0	91.0	
Clay NM	4.4	7.6	0.0	39.0	5.02	5.5	1.0	31.0	
Hematite NM	1.8	6.8	0.0	44.0	0.58	0.8	0.0	3.2	
Pyrite NM	0.8	2.40	0.0	16.0	0.8	1.9	0.0	8.0	

[1]Reference values from Graf (1960), (G); Gehman (1962), (Ge); and Weber (1964), (W).

appears to be abnormally high, approximately seven times the 0.40 percent Fe_2O_3 reported by Weber (1964). Belden carbonates contain about four times the amount of iron Weber reports. Statistical tests on ore zone samples indicate that iron correlates very strongly with uranium and is important in forming iron sulfides, which also correlate very strongly with uranium. At this point I do not know any residence of iron other than FeS_2, or the time of introduction of iron (sedimentation, diagenesis, or epigenesis). Iron appears to be a key chemical component.

Sodium and chlorine.--These elements have been proposed as indicators of sedimentary environment (Land and Hoops, 1973). Sodium and chlorine content of these carbonates is not as high as reported by Weber (1964) for primary dolomites. Possibly the criteria of Land and Hoops (1973) are not reliable for ancient dolomites that are highly fractured and hence, susceptable to loss of soluble salts.

Organic carbon.--Organic carbon content of Leadville Dolomites (mean 0.24 percent) is not as high as anticipated for these dark-gray rocks. This value matches that reported by Gehman (1962) for his survey of carbonate rocks. Apparently the Leadville and Belden carbonates do not contain abnormal amounts of organic carbon, although the literature data base does not appear broad enough to be a reliable comparison. Preliminary correlation and R-mode factor analyses indicate that uranium is essentially independent of organic carbon content.

Sulfur and normative pyrite.--Sulfur content of these rocks, about 0.35 percent for both Leadville and Belden samples, may be abnormal. However, I have been unable to locate any chemical data on sulfur content of carbonate rocks elsewhere. For reduced rocks containing organic carbon and visible pyrite, calculations of normative pyrite indicate that iron is present in excess of the amount that could combine with the available sulfur to form FeS_2. Normative pyrite and total S correlate extremely highly with uranium. Sulfur and iron history of these rocks seems to be important in formation of the uranium deposits.

Pyrite and marcasite occur as very fine disseminations and veinlets in dolomite. The age(s) of the FeS_2 is not understood at present, nor are the reasons for enrichment in FeS_2. The organic matter in the Leadville-Belden section would probably have fostered sulfate-reducing bacteria, and carbonaceous matter in shales or in carbonate rocks may have served as a substrate for bacteria. The viability of this mechanism to make sulfide, and its pertinence to reduction of uranium, should be testable by stable isotope studies.

Minor elements.--Minor elements Ba, Sr, Pb, Zn, Mo, Hg, and Ag were investigated for use as possible pathfinder elements for uranium. Minor element concentrations in the Leadville and the Beldon appear to be at or below normal levels, compared to those in normal rocks elsewhere (Weber, 1964; Graf, 1960). Mo is the only minor element enriched in either formation: it has a mean concentration of about 6.7 ppm in Leadville samples, and it ranges as high as 88 ppm in a high-grade ore sample. Mo correlates very strongly with U in statistical tests on ore sample subsets and appears to be a useful pathfinder for uranium.

Summary data for Cr, Cu, Ni, V, and Zr are in table 4. It is evident that normal amounts of these elements occur in Leadville and Belden carbonates and that ore samples are not enriched relative to unmineralized rocks. In this environment, Cr, Cu, Ni, V, and Zr do not appear to be of use in exploration for uranium.

INTERPRETATION

Sedimentation and diagenesis of the Leadville Dolomite.--The selectivity of uranium for Leadville Dolomite necessitates inquiry into the origin of the rock in order to better understand possible causal relationships. Are there mineralogic, petrologic, or chemical features that explain uranium deposition? Are there features of the host dolomites that should be anticipated in selecting favorable targets elsewhere in the Leadville or in other formations?

Several features of Leadville Dolomites bear attention in considering the origin of the rock: (1) the dolomite is consistent vertically (tens of meters) and laterally (thousands of meters); (2) intraclasts such as fossils and carbonate clasts are extremely rare; (3) terrigenous clastics are volumetrically insignificant within dolomite beds or as interbeds; (4) samples suspected to have undergone very little recrystallization are very fine grained (micrite) and hence were deposited as muds; and (5) recrystallization appears to have taken the form of coalescive neomorphism, which produced larger grains of relatively uniform grain size with rare evidence for replacement of former grains or filling of pores.

The texture and the mineralogy of the dolomicrites and of their neomorphosed equivalents are consistent with numerous reports of ancient or Holocene dolomite termed "primary" or "early" dolomite (Folk, 1973). These rocks are

Table 4.--Statistical Data for Cr, Cu, Ni, V, and Zr

[Semiquantitative emission spectrographic determinations by J. C. Hamilton and E. S. Silk.]

Element	Leadville		Belden		Ore samples 0.01-0.05% U		Ore samples >0.05% U		Mean reference value	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.		
Cr ppm	11	8.0	20	15	13	8	13	12	21	(W)
Cu ppm	3.8	3.5	3.5	3.2	5.0	4.4	3.5	2.5	5.7	(W)
Ni ppm	9.7	10	11	9.1	13	14	10	6.6	126	(W)
V ppm	11	7.9	14	5.3	14	14.5	12	11	15	(G)
Zr ppm	46	71	50	52	36	56	24	26	17	(G)
Number samples	30		20		12		6			

[1]Reference values: (W), Weber (1964); (G), Graf (1960).

generally believed to form from carbonate mud that accumulated in relatively quiet water, such as lagoons, or in beach areas beyond the reach of normal wave action (supratidal zone[3]). The genesis of the mud is moot: debated origins include chemical precipitation, decay of algae, and disintegration of shells.

It is generally agreed that diagenesis of the carbonate mud starts as soon as the mud grains settle because they are chemically reactive in pore fluids. The origin of dolomite has been extensively debated over the past 20 years, and no universal mechanism is agreed upon. The common association of dolomite with evaporites, especially gypsum and anhydrite, is pertinent to this debate because crystallization of the calcium sulfate mineral raises the Mg:Ca ratio of seawater (e.g. Deffeyes and others, 1965; Folk, 1973). The supratidal environment seems a more logical setting for development of evaporites, but such an environment is not clearly established for the Leadville in the Pitch Mine area.

Features of carbonate rocks associated with supratidal, intertidal, and subtidal environments (Kahle and Floyd, 1971) are listed in table 5 along with observations for the Leadville and Belden carbonates in this study. Many features associated with supratidal environments are observed in the Leadville Dolomites, particularly the thin laminae and the lack of fossils. Other features need comment. Algal stromatolites are either poorly developed or absent in the Leadville of this area. Nothing resembling stromatolite heads has been observed, but possibly the relatively common thin laminae are flat-laminated stromatolites or algal mats such as are present in some supratidal zones (Campbell, 1970; Gebelein and Hoffman, 1973; J. A. Campbell, oral commun., 1979). Although neomorphism could have obscured stromatolite structures, the apparent absence of stromatolites seems to be a problem if the Leadville was supratidal. Desiccation cracks and "birdseye" textures are rare if present at all, and no evaporite minerals have been confirmed or inferred.

[3]Supratidal, intertidal, and subtidal, are used in the sense of Shinn and others (1965), Laporte (1967), and Roehl (1967). Quoting Roehl (1967, p 1991): "The supratidal zone * * * is above mean high tide and is only subject to spring- and storm-tide floods. The intertidal zone * * * is between mean low and high tides. The infratidal zone [here called subtidal] * * * is below mean low tides, including most of the shallow offshore marine." The term "tidal flat" will be used for the slightly less specific zone that includes both supratidal and intertidal, that is, both the zone that is frequently flooded and the zone that is usually unflooded.

Table 5.--Sedimentary features associated with carbonate depositional environments (after Kahle and Floyd, 1971)

[C, common; R, rare or less common; No, not observed; Y, observed with no estimate of frequency; P?, possibly present; --, not reported]

Feature	Environment			This study	
	Supratidal	Intertidal	Subtidal	Leadville Dolomite	Belden Carbonates
Finely laminated dolomite mud	C	R	--	C	R
Intraclasts	C	R	--	R	R
Algal stromatolites	C	R	--	P?	No
Desiccation cracks	C	C	--	R	No
Bituminous films	C	--	--	C	R
Lack of fossils	C	R	N	C	R
Evaporite minerals	C	R	No	No	No
Birdseye texture	C	C	No	P?	No
Crossbedding	--	C	--	R	No
Burrows	R	C	C	R	R
Highly fossiliferous	--	R	C	No	C
Ooolites	No	R	C	No	C
Red color	Y	--	--	No	Y
Gray color	C	C	C	C	C

Some thin beds of white minerals have been observed by geologists of Homestake Mining Company when logging fresh core, but I have not recognized any in core or outcrop. The paucity of evaporite minerals might be explained by recent leaching of these soluble minerals, although no voids with rectangular morphology have been observed. Likewise no edgewise conglomerate, prominent intraclasts, or other evidence for high-energy activity from storms or high tides are known in the Leadville, although such features would be expected in carbonates deposited in a supratidal succession.

Although not firmly established, there are several lines of evidence that the Leadville in the Pitch Mine area accumulated in a supratidal zone, and this interpretation has been accepted as a working hypothesis. The most likely alternative environment is that of a lagoon; however, a lagoonal environment probably should have left a record of abundant shells, forams, and oolites (e.g. Laporte, 1967; Till, 1970), which are rare in the Leadville.

The Leadville Dolomite exhibits finely laminated dolomicrite in the Leadville-Aspen-Glenwood Springs areas, about 75 to 150 km north and northwest of the Pitch Mine. Leadville dolomicrite in the Pitch Mine area seems very similar to the Redcliff Member of the Leadville defined by Nadeau (1972), but the dolomicrite is thicker (about 130 m) in the mine area than the 29 to 53 m reported for the Redcliff Member. Nadeau (1972) interpreted the micrites and dolomicrites of the Redcliff Member to have formed "as a result of biogenic action in a sheltered environment such as a shallow lagoon" (p. 99). Conley (1972) reported on the Leadville about 40 to 80 km northwest of the area studied by Nadeau, and observed similar features. He observed 3 to 15 m of laminated dolomicrite in the lower part of the Leadville with common desiccation polygons and some casts of salt crystals. He concluded that the laminations are similar to features interpreted to be algal stromatolites in other areas. Conley interpreted that the laminated dolomicrite formed in what he termed the "upper intertidal zone," which is "flooded infrequently by spring or storm tides" (p. 113)--termed supratidal here. The Dyer Formation, similar in most aspects to the overlying Leadville, displays most of the sedimentary features of the Leadville (Campbell, 1970). The Coffee Pot Member of the Dyer, a dolomicrite is essentially the mirror image of the Redcliffe Member in a regressive-transgressive sequence, is interpreted by Campbell (1970, p. 95) to have formed in an "intertidal mud-flat environment that was periodically * * * flooded with shallow warm water that transported carbonate mud."

Campbell notes that algal stromatolites probably produced the thin laminations in the dolomicrite and that burrowing organisms probably destroyed much of the laminations, explaining the rarity of stromatolitic heads and other associated features observed in better preserved examples elsewhere.

Sedimentation of the finely laminated carbonate muds of the Leadville thus appears to have occurred in a tidal flat or supratidal environment, based on comparisons with modern (e.g., Shinn and others, 1969) and ancient (LaPorte, 1967; Roehl, 1967) examples and with other carbonate rocks nearby. The key concept is that there was very low water energy. Dolomitization probably started soon after the mud was deposited. The observed uniformity of the dolomite is a major constraint on the mechanism of dolomitization. If evaporation of pore waters (Shinn and others, 1965) produces interbedded limestone and dolomite, as suggested by Thompson (1970), then that mechanism cannot be advocated for this area. Reflux dolomitization (Deffeyes and others, 1965) is thought to affect thicker sections of tidal flat sediments by through-going movement of dense hypersaline brines, which would seem to fit the geometry of the dolomite in this study area. There is no evidence for "rock-selective" dolomitization along permeable beds, however, as Murray (1969) suggested should occur with a refluxing brine.

An interesting alternative environment for dolomicrite formation is in alkaline lakes as documented by von der Borch (1976) for the Coorong area, South Australia. Important aspects of Coorong-type dolomicrite are the absence of associated evaporites and replacement textures. This variety of dolomite forms from continental ground water near the interface with marine ground water, immediately inland from the coast in a lagoonal setting. Dolomite formed from continental ground water would probably have diagnostic geochemical characteristics, such as higher silica, iron, and uranium content than marine dolomite, but these chemical differences have not been documented in the Coorong area.

Diagenesis of the Leadville Dolomite, including formation of dolomite and chert, and recrystallization, probably was essentially complete prior to sedimentation of the Belden. This conclusion is based on the general observation that diagenetic effects appear to be intraformational and on the observation (e.g., Land, 1973) that diagenesis (cementation, dolomitization) can be very rapid (less than about 100,000 years) and can occur at near-surface temperature and pressure. The dolomite does not display replacement textures, which is consistent with a prelithification origin. Recrystallization clearly occurred prior to deformation along the Chester Fault because breccia fragments contain intermixed coarse and fine-grained dolomite in a matrix of fine dolomite. The dolomite shows no evidence of diagenesis by meteoric water (Folk, 1973) during the time of the sub-Belden unconformity, except for the development of karst containing ferrugenous cement, similar to the terra rosa that Roehl (1967) notes associated with karst, and some chertification.

Extent of favorable facies.--If the previous interpretation that sedimentation occurred in a tidal flat or supratidal environment is correct, then one can predict that the dolomicrite facies, apparently favorable for uranium, should have great lateral persistence. Studies of Holocene tidal flats (e.g., Deffeyes and others, 1965; Shinn and others, 1969), of ancient carbonates interpreted to have formed in the tidal-flat environment (e.g., LaPorte, 1967; Roehl, 1967; Griffith and others, 1969), and of similar facies of the Leadville in Colorado (Nadeau, 1972) indicate that the environment is persistent for at least 1 km downdip and for tens of kilometers along strike. The observation that ancient rocks deposited on tidal flats are much more extensive than recent tidal flats merely shows the effect of gradual transgression and regression through time (Shinn and others, 1969). The unusual thickness and uniformity of the Leadville dolomicrite suggests that the Leadville sea and the adjoining landmasses were unusually stable, hence the dolomicrite may be expected to have once extended over a very large area, approximately thousands of square kilometers. Thickness of the dolomicrite probably was very uniform over this area also. However, if the Leadville formed in a Coorong-type lacustrine setting, dolomicrite facies would be more localized and would be interbedded with marine-type wackestone and packstone (von der Borch, 1976).

Influence of sedimentary environment on rock geochemistry.--Sedimentation obviously was the prime influence on the present contents of major constituents, such as SiO_2 and CaO. Content of Al_2O_3, reflected chiefly as clay, is possibly unusually low for the tidal-flat environment, as supratidal carbonates often contain more than 5 percent clay (e.g., Roehl, 1967, p 2026). The sedimentary setting probably was a major influence on dolomitization (MgO), as previously discussed. Three elements of particular interest to the problem of formation of uranium deposits are organic carbon, iron, and sulfur.

It was suspected a priori that the contents of organic carbon, iron, or sulfur in the Leadville Dolomite might influence uranium deposition as they are believed to do in other types of uranium deposits. At this point iron, sulfide, and uranium correlate strongly, and uranium appears to be independent of organic carbon. Unfortunately there is a scarcity of published data on organic carbon in carbonate rocks, especially for specific carbonate environments.

According to the literature, there is no clear pattern of organic carbon variation with carbonate environments. The limited data of Gehman (1962) show that the mean organic carbon content of lime mud is 0.18 percent, as compared to 0.23 percent for skeletal grains and 0.24 percent for all limestones. Till (1970) found no correlation of organic carbon with lime mud or with other constituents across three facies of a modern lagoon; no algal tidal-flat environments were sampled. However, carbonaceous films are described in supratidal micrites (e.g., Kahle and Floyd, 1971), and organic layers in laminated rocks are said to form from decayed algal mats (Hamilton and Greenfield, 1965; Shearman and Skipwith, 1965; Alberstadt, 1973; Gebelein and Hoffman, 1973). Another source of organic matter could be marsh grass, roots, and leaves of plants growing in tidal marsh. At this point I have insufficient information to demonstrate that an ancient tidal-flat environment should contain abnormal amounts of organic carbon. I find this hypothesis attractive, but clearly more testing is required.

Iron and sulfur are of obvious interest as possible reductants for uranium. Because the two elements commonly combine to form FeS_2 (pyrite or marcasite), they will be considered together. In a survey of minor elements in dolomites, Weber (1964) found an average of 2,790 ppm iron (0.40 percent Fe_2O_3). Friedman (1969) pointed out that river water contains much more iron than sea water and that this difference is reflected in the composition of calcareous sediments and shells. Lagoonal carbonates contain about 1,000 to 4,000 ppm iron, compared to about 2 to 100 ppm iron in marine carbonates. I have found no information on iron content of supratidal sediments. There is even less data on sulfur in carbonate rocks. Turekian and Wedepohl (1961) report a value of 1,200 ppm (0.12 percent) sulfur in carbonate rocks broadly defined, and that value may not be relevant for dolomites of the type described here. Bluck (1965) records frequency of pyrite crystals in carbonates, and concludes that pyrite is most abundant as detrital grains in quartz-rich graded beds. He found no overall difference in pyrite abundance across seven microfacies (supratidal to subtidal). Schmidt (1965) gives a good description of pyrite and marcasite occurrence in limestone and dolomite and reports that allochems and iron silicates are favored sites. The amount of replacement iron disulfide increases as the content of mud-size silicate increases (Schmidt, 1965, p 154). Useful information also comes from Shinn and others (1969, p. 1215), who describe sediment color and presence or absence of H_2S odor in a modern tidal flat: "All fine-grained shallow water sediments deposited below normal low tide are gray in color, whereas those above normal low-tide level are light tan or cream colored. The strong odor of H_2S and the gray color of subtidal sediments indicate that iron compounds have been reduced to dark colored iron sulfides." The observation by Shinn and others that oxidation and reduction are controlled by the level of tides is important, although it seems to conflict with observations of many dark-gray rocks that contain mudcracks and hence are interpreted to have formed subaerially in the supratidal environment. Presumably the amount of sulfur that can be held as sulfide in reduced rocks is related to iron content in the atomic ratio 1 Fe:2 S. If the average dolomite contains about 2,790 ppm Fe, then the maximum sulfide that can combine with it to form FeS_2 is about 3,200 ppm S (0.32 percent). The content of iron in the Leadville Dolomites greatly exceeds this value, and sulfur is slightly higher. There is no precedent in the literature that can be used to explain anomalous iron and sulfur content by sedimentary processes or as a diagenetic consequence of a particular sedimentary environment.

Possible role of karst.--Karst is well known in the Leadville Formation in central Colorado. Iron-stained karst in the Pitch Mine area have been prospected for mineralization (many have been excavated or blasted) and are shown as prospect pits on the topographic map. Recently Dupree and Maslyn (1979, p. 826) have proposed that uranium at the Pitch Mine "largely occurs in the black organic-rich matrix material of carbonate breccias. These breccias have previously been described as Pennsylvanian Belden Formation falut breccias". My observations, particularly in the ore zone, do not agree with those interpretations. The carbonate breccias are classic tectonic breccias very clearly related to the complex zone of faulting called the Chester Fault. The breccia, and uranium grade, die out below and to the west of the faults. By inspection of numerous cores, new open pit exposures, and thin sections I find no evidence for "organic-rich matrix" or washed in clayey sinkhole fill. Chemical analyses do not indicate presence of unusual amounts of organic carbon or aluminum in uranium-bearing breccias. On close inspection and microscopic examination, black portions of some core are fragments of black Belden shale; their presence is consistent with tectonic mixing of breccia in a complex fault zone. Karst features that I have observed outside of the mine are characterized by iron oxide fillings, not black clays, and are only slightly radioactive.

SUMMARY

Important newly documented uranium reserves at the Pitch Mine occur in brecciated Leadville Dolomite along the Chester reverse fault zone. Uranium mineralized zones are is generally thicker, more consistent, and of higher grade in dolomite than in other hosts, and roughly 50 percent of new reserves are in dolomite. Strong physical control by dolomite is evident as this is the only lithology that is pervasively brecciated within the fault slices that make up the footwall of the reverse fault zone. Physical controls on uranium distribution are probably more important than chemical, but favorable chemistry is also an obvious requirement for uranium deposition.

The Leadville is predominantly dolomicrite across tens of meters vertically and thousands of meters laterally. Mud texture, general lack of fossils and other allochems, thin laminations, and probable algal-mat structures suggest sedimentation in a tidal-flat environment. Dolomitization was pervasive and pre-lithification. An alternate environment of sedimentation, that of marginal marine lakes, is a possibility that cannot be evaluated at present but is attractive, as continent derived ground-water in that environment would be a good source of the anomalous iron and microcrystalline silica in the Leadville.

Fracture- and breccia-controlled pitchblende and coffinite are associated with epigenetic pyrite and marcasite. Magnesium, iron, sulfur, molybdenum, and lead are enriched in the ore, but uranium shows no correlation with organic carbon content. The mechanism of uranium deposition is not clear; sulfide ion seems to be involved, but organic carbon does not appear to be directly involved.

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Table 2.--Petrochemical data for carbonate rocks, Pitch Mine area

EXPLANATION

Abbreviations: --, not determined.

Chemical analyses.--Major elements, including F and S, were determined by single solution technique (Shapiro, 1975) in the U.S. Geological Survey's rapid rock analysis laboratories, Reston, Va., by H. Smith. Minor elements determined by E. Campbell using atomic absorption spectrometry for Ba, Sr, Ag, Pb, Zn, and Hg; specific-ion electrode for Cl; and spectrophotometry for Mo. Total carbon determined by combustion thermal conductivity, V. E. Shaw, analyst; carbonate carbon determined gasometrically, P. H. Briggs, analyst; and organic carbon determined by difference. U determined by delayed neutron analysis, H. T. Millard, C. McFee, and C. Bliss, analysts. Other minor elements determined by six-step emission spectrography, J. C. Hamilton, and E. Silk, analysts.

Mineralogy.--Semiquantitative estimates of dolomite, calcite, quartz, clay, and iron oxide content made by X-ray diffraction, J. T. Nash, analyst. Clays observed were kaolinite and sericite (10Å mica). Iron oxides observed were hematite and goethite. Precision and accuracy about ± 1 part in 10.

Normative minerals.--Normative content of dolomite, calcite, quartz, clay, hematite, and pyrite calculated from chemical analyses using the following rules: (1) clay--calculated from Al, Si, and K in the approximate atomic ratio 6 Al + 6 Si + 2 K for an ideal muscovite; (2) quartz--from Si remaining after step 1: (3) hematite or pyrite selected according to oxidation state of rock, and iron calculated as either Fe^{+3} or Fe^{+2} atoms, and any excess of iron not assignable to pyrite was assigned to dolomite; (4) dolomite calculated as ideal composition (1 Mg + 1 Ca + 2 C), including any Fe^{+2} remaining from step 3; (5) calcite calculated from Ca and C remaining after step 4.

Petrographic classification.--Texture (pet tex) in thin section using system of Folk (1962): 1, micrite (or inferred to have been initially); 2, fossiliferous micrite; 3, biomicrite; 4, biosparite; 5, dismicrite; 6, siltstone and very fine sandstone; 7, chert; 8, very severly altered. Composition (pet comp): major constituent--1, calcite; 2, dolomite; 3, clastic quartz sand or silt; 4, chert. Allochems (pet aloch): allochemical constituents: 0, none; 1, intraclasts; 2, oolites; 3, fossils; 4, pellets; 5, clastic quartz sand or silt. Neomorphism (pet Ncom) after Folk (1965): 0, none; 1, equant microspar grains 4 to 31 microns; 2, equant pseudospar grains greater than 31 microns; 3, veined or bladed spar, fracture controlled; 6, encrusted. Structure (pet struc): 1, fractured or veined; 2, sheared; and 3, brecciated.

Ore zone: first digit stands for grade: 1, barren outside of ore zone; 2, barren within ore zone; 3, 0.01 to 0.05 percent U; 4, 0.06 to 0.19 percent U; 5, 0.20 to 0.49 percent U; 6, greater than 0.50 percent U. Second digit stands for oxidation state: 1, reduced; 2, oxidized.

Stratigraphy; 1, Manitou Dolomite; 2, Harding Quartzite; 3, Fremont Dolomite; 4, Parting Quartzite; 5, Dyer Dolomite; 6, Leadville Dolomite; 7, Belden Formation.

Location: Coordinates are those used by Homestake Mining Co. for drill core samples, calculated from collar coordinates, depth in hole, and inclination of hole; drift of hole not included. For samples outside of mine area, estimated by extrapolating mine grid.

sample	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	FeO %	MgO %	CaO %	Na_2O %	K_2O %	H_2O+ %	H_2O- %	TiO_2 %
18	21.90	1.80	.36	.12	16.00	23.90	.04	.68	.43	.27	.19
19	6.60	.82	.23	.08	17.80	31.30	.03	.36	.41	.25	.04
20	17.30	1.50	.26	.08	16.10	26.70	.01	.47	.61	.14	.14
24	8.60	.03	.20	.16	18.70	29.50	.04	.01	.30	.06	.02
25	96.90	.33	.18	.01	.18	.24	.06	.03	.47	.09	.0
26	97.70	.53	.21	.20	.07	.15	.02	.05	.60	.10	.02
27	61.00	.03	.06	.12	8.30	11.90	.01	.02	.24	.11	.0
298-313	.63	.34	.48	.36	20.60	29.60	0	.04	.28	.06	.01
298-327	.43	.13	4.50	1.30	18.60	27.20	.01	.02	.51	.27	.02
298-334	2.40	.14	2.60	.48	19.50	27.50	0	0	.33	.10	.01
296-341	48.00	.90	6.30	1.40	7.20	11.40	0	.09	.59	.51	.01
299-323	3.60	.60	.61	.24	19.80	29.40	.08	.10	.64	.12	.03
299-334	9.40	1.60	1.10	.52	16.10	27.60	.02	.29	.73	.36	.07
299-351	3.90	.74	1.20	.28	18.70	29.30	0	.13	.68	.26	.03
299-377	27.80	4.40	.99	.36	13.50	19.90	.07	1.20	1.10	.29	.29
3	63.00	13.70	9.10	.04	.44	.46	.07	1.50	5.10	5.50	.27
30	.20	.03	.18	.40	19.40	32.40	.02	.01	.21	.07	.0
31	.20	.03	.11	.44	20.80	30.50	.01	.03	.28	.09	.0
32	22.80	2.50	.94	.12	10.20	28.60	.06	.70	1.00	.27	.11
33	13.70	.13	.21	.40	17.80	26.70	.04	.06	.35	.05	.0
34	97.00	.13	.14	.12	.29	.31	0	.02	.32	.04	.0
35	27.50	.23	.21	.24	14.70	22.20	.08	.05	.30	.11	.0
36	9.80	.23	.08	.16	18.80	28.00	.06	.01	.30	.07	.0
37	2.50	.13	.16	.08	.60	53.10	.01	.09	.30	.06	.0
38	17.00	.63	.20	.08	.47	44.70	.05	.21	.33	.13	.03
39	32.60	7.80	46.40	.08	.27	.61	0	.61	9.10	2.20	.17
40	4.50	1.00	.87	.08	17.60	30.60	.09	.25	.52	.10	.04
402-128	40.90	3.70	1.10	.60	10.30	17.20	.04	.88	.78	.36	.27
408-368	21.50	2.90	1.50	.28	14.80	23.40	.07	.81	.85	.27	.15
41	.90	.03	.28	.04	20.60	31.00	.01	.04	.22	.20	.01
43	1.40	.13	.05	.04	.97	52.40	.05	.05	.24	.16	.02
44	97.00	.23	.80	.08	.10	.43	0	.05	.53	.05	.01
443-301	10.40	1.30	.58	.24	18.10	27.50	.02	.42	1.00	.21	.06
445-28	4.30	.74	4.90	0	13.20	34.60	.01	.18	.81	.54	.02
446-40	18.90	2.30	1.30	.08	15.70	24.20	.02	.50	.16	.32	.14
446-65	4.80	.53	2.90	.12	18.00	30.00	.01	.20	.48	.48	.03
447-131	8.70	.73	2.50	0	17.10	27.70	.03	.19	.51	.34	.05
447-98	9.20	1.50	6.40	0	16.50	25.20	.02	.34	1.60	.67	.05
448-121	7.20	.43	.44	.16	18.40	29.90	.06	.18	.36	.20	.05
448-65	23.80	3.30	2.60	.04	14.50	20.20	.03	.96	1.20	.55	.18
449-33	75.60	7.40	1.60	.08	2.20	4.30	.03	1.60	1.90	.62	.53
449-51	31.60	2.60	1.10	.16	12.40	21.60	.03	.73	.92	.23	.20
449-87	7.30	1.00	.90	.08	19.20	28.20	.01	.33	1.10	.13	.05
45	6.40	.13	.02	.12	19.00	29.70	0	.01	.30	.16	.0
450-166	10.90	1.20	2.30	.04	16.80	28.00	0	.23	.82	.38	.06

Leadville carbonates

sample	P2O5 %	MnO %	CO2 %	F %	S %	Ctotal %	Corgan %	Carbnt %	Cl ppm	Ba ppm	Sr ppm
18	.05	.06	34.40	.07	.06	10.24	.11	10.13	140	20	66
19	.02	.03	43.10	.06	.07	11.63	0	11.63	250	80	130
20	.04	.05	37.80	.07	.06	12.15	.19	11.96	75	20	130
24	.02	.11	43.50	.02	.02	11.79	.09	11.70	140	80	20
25	.02	.04	0	0	.02	.29	.29	0	25	20	10
26	.03	.04	.05	0	.03	.44	.37	.07	25	20	10
27	.02	.07	18.10	0	.02	5.26	.33	4.93	120	40	10
298-313	0	.18	46.80	.01	.12	12.99	0	12.99	380	43	28
296-327	.02	.19	41.10	.01	4.30	11.26	.03	11.23	390	280	31
298-334	.01	.17	45.10	.01	1.90	12.33	0	12.33	310	61	31
298-341	.04	.09	16.00	.01	6.30	4.97	.72	4.25	160	320	21
299-323	.02	.07	44.60	.02	.31	12.62	.41	12.21	480	83	57
299-334	.04	.06	40.90	.02	1.10	10.99	.02	10.97	64	330	83
299-351	.04	.05	43.20	.02	1.00	12.18	.19	11.99	100	110	180
299-377	.07	.02	29.20	.08	.45	8.16	.11	8.05	160	140	190
3	.09	.15	.13	.06	.03	.44	.44	0	45	120	160
30	.01	.14	46.90	.02	.02	12.70	.01	12.69	25	20	20
31	.02	.06	48.20	.01	.02	12.79	.04	12.75	85	100	10
32	.04	.03	31.30	.07	.13	9.45	.79	8.66	55	100	110
33	.02	.21	40.00	.01	.03	11.04	0	11.04	25	72	20
34	.02	.03	.08	0	.02	.23	.23	0	25	20	10
35	.03	.15	33.50	.01	.02	9.33	0	9.33	180	40	20
36	.01	.08	41.70	.02	.02	11.82	.02	11.80	140	20	20
37	.02	.02	41.40	.02	.07	11.72	.17	11.55	140	260	210
38	.03	.02	34.70	.02	.04	9.81	.15	9.66	25	120	310
39	.20	.08	.24	.06	.04	.51	.46	.05	25	20	10
40	.02	.03	45.50	.05	.04	12.31	.23	12.08	160	120	56
402-128	.09	.03	23.10	.03	.49	6.73	.15	6.58	68	100	180
408-368	.04	.03	33.80	.03	.64	9.62	.43	9.19	68	33	110
41	.02	.01	46.80	.03	.02	13.16	.09	13.07	180	40	10
43	.01	.03	43.00	.01	.05	12.10	.32	11.78	70	140	130
44	.03	.04	.06	0	.02	.20	.13	.07	25	20	10
443-301	.02	.06	40.20	.05	.34	11.42	.25	11.17	90	67	50
445-28	.02	.31	41.60	.02	.03	11.66	.05	11.61	80	300	63
446-40	.04	.03	35.10	.07	.08	9.92	.01	9.91	93	61	150
446-65	.03	.08	43.20	.02	.12	12.39	.54	11.85	78	300	57
447-131	.03	.13	41.50	.04	.05	11.59	.17	11.42	93	110	61
447-98	.06	.07	37.80	.04	.06	10.81	.46	10.35	63	170	76
448-121	.01	.07	42.80	.03	.04	12.21	.34	11.87	550	60	80
448-65	.09	.03	31.50	.05	.02	9.09	.54	8.55	110	270	220
449-33	.11	.03	3.60	.06	.03	1.21	.16	1.05	25	160	270
449-51	.07	.02	29.30	.07	.10	8.44	.40	8.04	130	110	130
449-87	.02	.01	42.90	.03	.05	12.01	.06	11.95	110	110	75
45	.01	.02	45.20	.01	.02	12.37	.07	12.30	200	60	10
450-166	.04	.06	40.40	.03	.06	11.28	0	11.28	130	140	90

Leadville carbonates

sample	Pb ppm	Zn ppm	Mo ppm	Hg ppm	U ppm	Cr(s)ppm	Cu(s)ppm	Ni(s)ppm	Sr(s)ppm	V(s)ppm	Zr(s)ppm
18	1.9	5	1.10	.005	1.86	14.0	.8	4.5	140.0	12.0	130.0
19	.8	5	.70	.005	.41	--	--	--	--	--	--
20	2.1	5	3.10	.005	.72	13.0	.8	5.6	220.0	10.0	37.0
24	2.0	32	.20	.015	3.92	3.7	.8	3.3	20.0	5.2	6.2
25	4.9	22	2.20	.065	1.05	--	--	--	--	--	--
26	15.0	22	14.00	1.150	14.20	18.0	3.4	1.9	5.6	2.8	9.9
27	5.9	22	2.50	.230	4.31	--	--	--	--	--	--
298-313	5.0	5	1.60	.005	1,160.00	--	--	--	--	--	--
298-327	25.0	5	4.50	.020	31,300.00	3.0	1.5	3.0	7.0	4.0	15.0
298-334	33.0	26	20.00	.100	4,160.00	5.0	1.0	15.0	7.0	5.0	10.0
298-341	120.0	140	68.00	.150	33,500.00	--	--	--	--	--	--
299-323	25.0	2,600	18.00	.039	1,960.00	--	--	--	--	--	--
299-334	65.0	17	73.00	.005	7,720.00	30.0	5.0	15.0	70.0	15.0	70.0
299-351	73.0	5	48.00	.005	4,300.00	--	--	--	--	--	--
299-377	5.0	35	3.40	.005	56.10	20.0	7.0	10.0	150.0	15.0	50.0
3	5.0	140	3.30	2.600	778.00	--	--	--	--	--	--
30	2.3	30	.50	.010	.89	.5	.8	3.4	25.0	8.0	6.8
31	2.6	5	.20	.012	1.74	--	--	--	--	--	--
32	11.0	5	1.50	.005	1.47	16.0	4.8	14.0	240.0	32.0	32.0
33	2.4	22	8.40	.076	3.99	--	--	--	--	--	--
34	19.0	5	4.10	.510	5.11	4.4	3.0	.8	1.1	.5	2.3
35	5.7	40	1.40	.180	2.32	--	--	--	--	--	--
36	3.6	34	3.00	.180	6.79	3.8	.8	4.3	21.0	3.8	5.9
37	1.9	5	.10	.005	2.65	--	--	--	--	--	--
38	1.5	5	.10	.005	2.42	15.0	.8	2.1	690.0	11.0	180.0
39	7.3	350	.80	.005	11.10	--	--	--	--	--	--
40	3.6	14	1.40	.005	2.16	13.0	2.1	4.9	130.0	13.0	18.0
402-128	5.0	78	15.00	.023	149.00	20.0	7.0	10.0	150.0	20.0	200.0
408-368	5.0	29	11.00	.005	151.00	--	--	--	--	--	--
41	3.8	34	.10	.005	.18	--	--	--	--	--	--
43	1.4	12	.10	.005	4.13	1.2	.8	.8	340.0	4.2	6.0
44	63.0	135	.50	.005	13.30	--	--	--	--	--	--
443-301	25.0	79	7.80	.090	109.00	7.0	7.0	10.0	20.0	10.0	10.0
445-28	5.0	300	9.40	.005	107.00	7.0	15.0	50.0	70.0	20.0	20.0
446-40	5.0	68	1.00	.005	12.50	15.0	7.0	20.0	70.0	15.0	50.0
446-65	220.0	340	1.80	.016	125.00	--	--	--	--	--	--
447-131	71.0	230	1.60	.010	97.80	5.0	7.0	20.0	50.0	7.0	20.0
447-98	39.0	99	7.40	.085	50.20	--	--	--	--	--	--
448-121	14.0	40	.05	.053	49.50	--	--	--	--	--	--
448-65	69.0	74	4.90	.045	49.90	--	--	--	--	--	--
449-33	5.0	10	.80	.023	34.30	30.0	1.5	7.0	200.0	20.0	300.0
449-51	10.0	5	1.80	.005	20.80	--	--	--	--	--	--
449-87	13.0	250	1.40	.005	102.00	15.0	1.0	3.0	20.0	7.0	10.0
45	1.1	5	.10	.005	.76	3.3	.8	3.3	18.0	1.7	2.3
450-166	42.0	49	1.80	.160	109.00	10.0	3.0	20.0	50.0	15.0	30.0

Leadville carbonates

sample	Mineralogy				Normative Minerals					
	Dolom XR	CalcitXR	QuartzXR	Clay XR	Dolom NM	CalcitNM	QuartzNM	Clay NM	Hema NM	PyriteNM
18	6.0	.5	4.0	0	79.0	.5	16.0	4.0	.29	0
19	7.0	1.0	2.0	0	64.0	10.0	4.0	2.0	.19	0
20	7.0	1.0	2.0	0	78.0	6.0	12.0	3.0	.20	0
24	9.0	0	1.0	0	88.0	5.0	7.0	0	.23	0
25	.5	0	10.0	0	1.0	0	98.0	1.0	.12	0
26	0	0	10.0	0	.5	0	98.0	1.0	.30	0
27	5.0	0	5.0	0	45.0	0	55.0	0	.11	0
298-313	10.0	0	.5	0	99.0	0	.5	1.0	0	.20
298-327	9.0	0	0	1.0	92.0	0	.5	.5	0	8.10
298-334	9.0	0	1.0	0	67.0	26.0	2.0	.5	0	5.00
298-341	5.0	0	4.0	1.0	39.0	2.0	42.0	1.0	0	16.00
299-323	9.0	0	1.0	0	93.0	3.0	2.0	1.0	0	.60
299-334	8.0	1.0	1.0	0	66.0	14.0	10.0	6.0	0	4.10
299-351	9.0	0	1.0	0	69.0	5.0	2.0	2.0	0	2.70
299-377	5.0	0	4.0	1.0	70.0	.5	19.0	10.0	0	1.10
3	0	0	10.0	0	1.0	0	52.0	39.0	7.70	0
30	7.0	3.0	0	0	91.0	9.0	.5	0	.33	0
31	10.0	0	0	0	96.0	4.0	.5	0	.32	0
32	6.0	0	4.0	0	47.0	29.0	17.0	6.0	.68	0
33	7.0	0	3.0	0	86.0	2.0	11.0	0	.39	0
34	1.0	0	9.0	0	2.0	0	98.0	0	.18	0
35	1.0	0	9.0	0	74.0	3.0	23.0	0	.30	0
36	6.0	0	4.0	0	90.0	2.0	8.0	0	.14	0
37	.5	10.0	.5	0	3.0	95.0	2.0	0	.15	0
38	.5	10.0	.5	0	3.0	82.0	14.0	1.0	.21	0
39	0	.5	8.0	0	2.0	.5	30.0	24.0	44.00	0
40	7.0	2.0	1.0	0	83.0	13.0	3.0	2.0	.56	0
402-128	5.0	0	5.0	0	59.0	3.0	30.0	8.0	0	1.20
408-368	6.0	0	4.0	.5	75.0	3.0	15.0	6.0	0	1.40
41	9.0	0	1.0	0	97.0	2.0	1.0	0	.18	0
43	.5	10.0	.5	0	5.0	94.0	1.0	0	.05	0
44	0	.5	10.0	0	1.0	0	98.0	0	1.00	0
443-301	7.0	0	3.0	0	88.0	1.0	7.0	3.0	0	.80
445-28	6.0	4.0	.5	0	64.0	28.0	3.0	2.0	3.00	0
446-40	6.0	4.0	0	.5	74.0	2.0	18.0	5.0	.80	0
446-65	8.0	1.0	1.0	0	88.0	6.0	3.0	1.0	1.80	0
447-131	6.0	2.0	2.0	0	83.0	8.0	6.0	2.0	1.50	0
447-98	7.0	0	3.0	0	83.0	4.0	6.0	3.0	4.00	0
448-121	7.0	1.0	2.0	0	87.0	6.0	5.0	1.0	.38	0
448-65	6.0	0	4.0	0	74.0	0	17.0	8.0	1.70	0
449-33	2.0	1.0	6.0	1.0	11.0	3.0	66.0	19.0	1.20	0
449-51	4.0	3.0	3.0	0	63.0	6.0	24.0	6.0	.80	0
449-87	9.0	0	1.0	0	91.0	2.0	5.0	2.0	.50	0
45	6.0	3.0	1.0	0	89.0	6.0	5.0	0	.09	0
450-166	8.0	1.0	1.0	0	81.0	8.0	8.0	2.0	1.40	0

Petrographic Classification

sample	Pet Tex	Pet Comp	PetAloch	Pet Neom	PetStruc	Ore Zone	Stratig	Elev Ft	North Ft	East Ft
18	1	2	1	1	0	12	6	10,360	13,410	18,020
19	1	2	0	1	0	12	6	10,340	13,450	17,900
20	1	2	0	2	0	12	6	10,320	13,650	17,720
24	1	2	0	2	1	12	6	10,820	15,140	20,050
25	7	4	0	3	1	12	6	10,800	15,050	20,040
26	7	4	0	3	3	12	6	10,800	15,040	20,040
27	1	2	0	2	1	12	6	10,780	14,960	20,070
298-313	1	2	0	2	1	41	6	10,271	14,090	19,970
298-327	1	2	0	2	1	61	6	10,257	14,090	19,970
298-334	--	--	--	--	--	51	6	10,250	14,090	19,970
298-341	1	2	0	2	3	61	6	10,242	14,090	19,970
299-323	1	2	0	0	3	41	6	10,270	14,120	19,930
299-334	--	--	--	--	--	51	6	10,259	14,120	19,930
299-351	--	--	--	--	--	51	6	10,242	14,120	19,930
299-377	1	2	1	1	0	21	6	10,216	14,120	19,930
3	--	--	--	--	--	42	6	10,650	12,360	19,820
30	1	2	0	3	3	12	6	10,175	12,950	17,630
31	1	2	0	2	0	12	6	9,975	11,620	17,130
32	2	1	3	1	0	12	6	10,160	12,120	17,650
33	1	2	0	2	0	12	6	10,725	14,750	20,140
34	7	4	0	3	1	12	6	10,760	14,820	19,890
35	7	4	0	3	1	12	6	10,760	14,830	20,030
36	1	2	0	2	1	12	6	10,775	14,920	20,090
37	3	1	3	1	0	12	6	10,880	15,000	16,000
38	3	1	3	2	0	12	6	10,780	14,600	16,200
39	8	3	5	6	3	12	6	10,800	14,600	16,200
40	1	2	0	2	3	12	6	11,130	16,600	17,000
402-128	--	--	--	--	--	31	6	10,428	13,850	19,990
408-368	1	2	5	0	--	31	6	10,355	14,200	20,050
41	1	2	0	2	0	12	6	11,120	16,700	16,800
43	1	2	0	0	1	12	6	10,950	19,000	17,800
44	7	4	0	3	1	12	6	10,900	16,500	18,300
443-301	1	2	5	3	1	31	6	10,283	11,520	19,935
445-28	--	--	--	--	--	32	6	10,524	13,870	20,080
446-40	1	2	0	3	1	22	6	10,506	13,869	20,074
446-65	--	--	--	--	--	32	6	10,483	13,869	20,082
447-131	--	--	--	--	--	22	6	10,473	14,000	20,124
447-98	1	2	0	1	1	22	6	10,497	14,000	20,100
448-121	--	--	--	--	--	21	6	10,474	13,978	20,072
448-65	--	--	--	--	--	22	6	10,514	13,978	20,033
449-33	6	3	5	0	1	22	6	10,530	13,978	20,001
449-51	--	--	--	--	--	22	6	10,514	13,978	20,009
449-87	1	2	0	0	1	32	6	10,481	13,978	20,024
45	1	2	0	2	3	12	6	10,240	8,800	15,200
450-166	1	2	0	2	1	32	6	10,416	13,800	20,047

Leadville carbonates--continued

sample	SiO2 %	Al2O3 %	Fe2O3 %	FeO %	MgO %	CaO %	Na2O %	K2O %	H2O+ %	H2O- %	TiO2 %
451-247	6.70	.94	.44	.96	18.80	28.30	0	.19	.38	.09	.03
452-249	8.90	1.20	.50	.84	18.30	27.50	0	.32	.46	.15	.05
452-265	1.10	.34	.24	.44	20.60	29.40	0	.11	.33	.01	.02
452-339	68.50	6.50	.87	.88	3.70	6.50	.04	1.20	1.80	.50	.49
454-90	13.50	1.20	1.10	.12	17.40	25.30	.01	.50	.93	.17	.08
506-168	2.00	.53	.88	.60	19.20	30.70	.04	.13	.39	.11	.03
612-15	37.30	11.30	33.90	.24	.61	1.90	.06	1.20	7.90	3.60	.25
612-160	15.60	.63	.44	.12	13.50	30.50	.01	.25	.30	.13	.03
612-36	5.90	1.10	.63	.12	17.50	30.00	.07	.26	.34	.01	.04
614-209	4.60	.53	.25	.16	18.00	30.60	0	.23	.98	.02	.04
614-219	19.40	4.20	1.40	.24	14.40	23.60	.05	1.30	1.40	.42	.22
614-225	9.20	.93	.48	.16	18.10	27.40	.04	.39	.77	.11	.06
614-263	63.50	4.40	.65	.56	2.40	12.80	.10	1.30	1.40	.24	.35
615-297	13.30	.23	.43	.16	17.30	26.70	.01	.15	.40	.06	.03
615-308	12.70	2.50	1.10	.48	16.40	24.80	.04	.84	1.20	.29	.15

sample	P2O5 %	MnO %	CO2 %	F %	S %	Ctotal %	Corgan %	Carbnt %	Cl ppm	Ba ppm	Sr ppm
451-247	.01	.15	43.80	.02	.06	12.20	.20	12.00	130	110	80
452-249	.01	.19	42.40	.03	.07	12.32	.20	11.52	190	80	75
452-265	.01	.05	47.40	.02	.06	12.55	.01	12.54	240	70	43
452-339	.10	0	7.90	.07	.37	2.50	.34	2.16	160	110	250
454-90	.04	.04	39.20	.04	.03	11.18	.49	10.69	110	70	170
506-168	.01	.25	45.60	.02	.06	12.79	.46	12.33	240	920	120
612-15	.16	.08	.01	.05	.01	.49	.28	.21	45	140	230
612-160	.03	.04	37.80	.03	.03	11.06	.52	10.54	62	45	100
612-36	.02	.03	44.10	.02	.03	12.48	.28	12.20	135	35	65
614-209	.01	.03	43.90	.02	.17	12.66	.76	11.90	450	60	50
614-219	.04	.05	33.50	.05	1.00	9.52	.29	9.23	190	120	150
614-225	.03	.04	41.20	.03	.28	11.42	0	11.42	65	60	53
614-263	.06	.02	11.60	.04	.21	3.47	.40	3.07	25	130	130
615-297	.02	.06	41.60	.02	.22	11.46	.88	10.58	530	80	55
615-308	.05	.14	39.40	.08	.72	10.51	.17	10.34	130	70	220

sample	Pb ppm	Zn ppm	Mo ppm	Hg ppm	U ppm	Cr(s)ppm	Cu(s)ppm	Ni(s)ppm	Sr(s)ppm	V(s)ppm	Zr(s)ppm
451-247	5.0	40	1.00	.070	26.50	--	--	--	--	--	--
452-249	5.0	5	.70	.560	56.20	--	--	--	--	--	--
452-265	18.0	12	5.60	.560	113.00	3.0	3.0	3.0	7.0	7.0	10.0
452-339	5.0	12	1.00	2.500	24.60	--	--	--	--	--	--
454-90	16.0	24	1.00	.093	37.90	--	--	--	--	--	--
506-168	10.0	280	1.60	.210	24.20	--	--	--	--	--	--
612-15	10.0	540	14.00	.005	241.00	--	--	--	--	--	--
612-160	5.0	5	.50	.005	26.80	--	--	--	--	--	--
612-36	5.0	10	.05	.042	11.70	--	--	--	--	--	--
614-209	5.0	5	2.10	.005	135.00	--	--	--	--	--	--
614-219	42.0	36	5.30	.110	984.00	20.0	7.0	15.0	70.0	30.0	20.0
614-225	12.0	66	2.90	.005	785.00	7.0	3.0	3.0	15.0	7.0	7.0
614-263	5.0	5	.80	.020	125.00	--	--	--	--	--	--
615-297	16.0	60	2.10	1.000	1,300.00	--	--	--	--	--	--
615-308	50.0	220	6.40	.140	330.00	15.0	10.0	20.0	100.0	15.0	20.0

	Mineralogy				Normative Minerals					
sample	Dolom XR	CalcitXR	QuartzXR	Clay XR	Dolom NM	CalcitNM	QuartzNM	Clay NM	Hema NM	PyriteNM
451-247	7.0	0	3.0	.5	89.0	4.0	4.0	2.0	.90	0
452-249	8.0	0	2.0	0	87.0	4.0	6.0	3.0	.81	0
452-265	10.0	0	.5	2.0	96.0	3.0	.5	1.0	.42	0
452-339	3.0	0	5.0	2.0	24.0	.5	59.0	16.0	0	1.00
454-90	7.0	0	3.0	0	85.0	2.0	10.0	3.0	.73	0
506-168	10.0	.5	.5	0	90.0	7.0	1.0	1.0	.89	0
612-15	0	0	5.0	1.0	5.0	.5	30.0	34.0	31.00	0
612-160	4.0	3.0	2.0	1.0	67.0	19.0	12.0	1.0	.35	0
612-36	9.0	.5	1.0	0	83.0	11.0	4.0	2.0	.43	0
614-209	7.0	2.0	1.0	0	86.0	9.0	3.0	1.0	0	.38
614-219	6.0	0	4.0	.5	72.0	4.0	12.0	9.0	0	2.30
614-225	7.0	0	3.0	0	83.0	2.0	7.0	2.0	0	.63
614-263	2.0	4.0	4.0	0	14.0	18.0	56.0	12.0	0	.63
615-297	7.0	1.0	2.0	0	83.0	5.0	10.0	.5	0	.52
615-308	8.0	0	2.0	.5	81.0	4.0	8.0	6.0	0	1.70

Leadville carbonates--continued

Petrographic Classification

sample	Pet Tex	Pet Comp	PetAloch	Pet Neom	PetStruc	Ore Zone	Stratig	Elev Ft	North Ft	East Ft
451-247	1	2	0	2	2	22	6	10,323	11,740	19,750
452-249	1	2	0	2	2	31	6	10,283	11,650	19,750
452-265	1	2	0	2	1	31	6	10,267	11,650	19,750
452-339	1	2	5	1	1	31	6	10,193	11,650	19,750
454-90	--	--	--	--	--	22	6	10,565	12,377	19,590
506-168	1	2	0	2	1	22	6	10,552	12,210	19,811
612-15	--	--	--	--	--	32	6	10,589	12,680	19,758
612-160	--	--	--	--	--	31	6	10,437	12,870	19,843
612-36	--	--	--	--	--	22	6	10,532	12,870	19,763
614-209	--	--	--	--	--	31	6	10,379	11,660	19,883
614-219	--	--	--	--	--	41	6	10,372	11,660	19,889
614-225	1	2	0	2	3	41	6	10,367	11,660	19,893
614-263	--	--	--	--	--	31	6	10,340	11,660	19,919
615-297	--	--	--	--	--	41	6	10,274	11,660	19,889
615-308	1	2	0	1	1	31	6	10,265	11,660	19,894

Beloen carbonates

sample	SiO2 %	Al2O3 %	Fe2O3 %	FeO %	MgO %	CaO %	Na2O %	K2O %	H2O+ %	H2O- %	TiO2 %
201-69	13.6	3.80	.74	1.70	2.10	39.5	.04	.72	1.20	.39	.17
21	5.9	1.00	.35	.20	.88	49.4	.08	.21	.66	.24	.08
22	2.9	.33	.05	.16	.66	53.0	.07	.04	.47	.15	.01
23	9.0	.53	.49	.16	.45	49.5	.05	.05	.56	.11	.03
28	17.6	1.80	.46	.12	.76	43.5	.05	.43	.87	.33	.11
29	2.9	.33	.07	.12	.44	53.0	0	.15	.24	.08	.0
400-174	7.7	.93	2.00	.32	18.00	27.7	.03	.22	.28	.16	.04
441-109	8.0	1.50	4.70	.04	17.00	27.6	0	.41	1.00	.78	.07
441-179	28.6	4.30	2.90	.16	12.10	20.0	.10	1.30	1.60	.65	.24
441-204	35.3	4.10	2.20	.04	10.10	19.2	.06	.95	1.60	.68	.22
441-209	39.7	3.60	1.50	.08	9.90	17.6	.05	1.10	.26	.44	.25
441-219	23.0	2.00	1.60	.08	14.80	23.1	.02	.46	1.70	.37	.08
441-223	92.2	.54	1.90	.04	.69	2.0	.01	.13	.31	.37	.02
441-229	7.2	.63	2.10	.36	18.40	28.5	.03	.14	.50	.29	.05
441-230	8.2	.84	.73	.88	18.40	27.4	.02	.21	.24	.12	.03
441-32	29.7	5.10	1.90	.08	11.00	20.0	.05	1.50	1.60	.50	.29
441-57	50.8	6.30	2.50	.20	7.10	11.4	.03	1.30	1.80	.49	.35
442-84	17.4	1.10	4.70	0	.35	41.0	0	.05	.57	.76	.07
444-215	51.5	5.70	.90	.44	1.40	20.0	.03	1.60	.44	.56	.45
449-201	76.0	1.30	1.10	.12	4.30	6.4	.01	.25	1.00	.26	.07
453-113	4.6	.83	.39	.16	7.30	43.5	.01	.23	.50	.19	.05
453-94	12.9	1.20	3.10	.08	2.90	42.4	0	.53	.90	.40	.09
453-97	12.5	1.70	.56	.12	13.40	32.1	.01	.54	.38	.21	.08
501-196	8.2	.53	.46	1.20	3.00	45.8	.07	.18	.27	.06	.03
509-200	40.7	1.90	.20	.08	.63	30.3	.04	.60	.46	.15	.24
509-206	36.0	1.90	.33	.16	.40	34.0	.03	.64	.52	.14	.14
610-152	22.3	1.10	.24	.08	.64	41.9	.02	.38	.45	.15	.08
610-181	3.4	.33	.37	.76	18.50	30.2	.04	.11	.27	.10	.04
610-228	58.6	11.60	2.60	.24	1.40	8.7	.21	3.40	2.50	.89	.69
610-229	16.5	.82	.12	.24	.53	44.5	.02	.29	.38	.14	.09
610-51	8.0	1.60	.34	2.50	2.40	44.2	.28	.35	.75	.24	.08
612-118	10.5	1.30	1.40	.16	9.70	37.4	0	.39	.35	.12	.05
612-128	15.3	1.80	1.20	.12	8.10	36.0	.07	.51	.65	.04	.09
614-159	6.1	.83	.38	.20	17.00	31.6	.01	.32	.57	.03	.06
614-186	8.1	.63	.33	.20	17.60	29.5	0	.26	.33	.07	.03
614-84	8.3	3.40	4.00	.44	.88	42.4	.03	.32	1.50	.24	.18
615-261	8.9	.73	.21	.20	18.70	27.2	.01	.32	.35	.04	.05
615-270	16.2	1.90	.56	.32	16.60	24.5	.02	.63	.68	.17	.15
616-231	9.2	4.90	3.80	.36	.81	41.5	.04	.40	2.60	.15	.21

Heloen carbonates

sample	P2O5 %	MnO %	CO2 %	F %	S %	Ctotal %	Corgan %	Carbnt %	Cl ppm	Ba ppm	Sr ppm
201-69	.20	.14	35.7	.03	.14	10.12	.31	9.81	55	180	360
21	.10	.07	40.9	.03	.04	11.38	.31	11.09	25	160	350
22	.10	.06	42.8	.02	.03	11.65	.17	11.48	25	180	500
23	.15	.07	39.9	.03	.02	10.95	.20	10.75	25	80	330
28	.20	.04	34.4	.07	.05	9.80	.47	9.33	25	170	325
29	.01	.04	42.0	.01	.03	11.81	.12	11.69	25	160	300
400-174	.02	.04	41.7	.02	1.50	11.63	.28	11.35	68	76	110
441-109	.12	.10	39.9	.02	.04	11.07	.01	11.06	73	170	230
441-179	.09	.12	27.8	.06	.04	7.86	.22	7.64	150	150	180
441-204	.12	.15	25.5	.03	.04	7.37	.06	7.31	53	220	300
441-209	.10	.05	25.9	.06	.06	6.80	.29	6.51	63	110	180
441-219	.04	.12	32.7	.02	.03	9.69	.31	9.38	100	160	77
441-223	.06	.02	1.2	.01	.03	.44	.02	.42	120	250	65
441-229	.02	.13	42.8	.01	.05	12.07	.09	11.98	150	120	65
441-230	.02	.12	42.1	.03	.16	11.90	.45	11.45	130	76	49
441-32	.06	.05	26.5	.06	.08	7.68	.25	7.43	75	160	130
441-57	.11	.03	15.7	.03	1.70	5.00	.73	4.27	25	97	180
442-84	.13	.16	32.8	.04	.04	9.11	.03	9.08	25	2,100	420
444-215	.09	.03	15.8	.09	.21	4.80	.30	4.50	46	140	250
449-201	.05	.14	8.7	.02	.03	2.72	.41	2.31	100	360	90
453-113	.02	.12	41.4	.02	.20	11.91	.39	11.52	85	70	390
453-94	.04	.14	35.6	.03	.02	9.70	.02	9.68	25	160	50
453-97	.03	.02	39.5	.03	.06	11.14	.01	11.13	68	110	120
501-196	.01	.08	39.6	.02	.15	11.02	0	11.02	170	70	260
509-200	.03	.05	24.7	.02	.04	6.79	.13	6.66	48	90	210
509-206	.04	.01	26.3	.02	.22	7.71	.69	7.02	38	160	260
610-152	.03	.10	32.8	.02	.03	9.51	.54	8.97	78	110	420
610-181	.01	.12	45.5	.01	.06	12.40	.05	12.35	56	60	75
610-228	.10	.04	6.4	.21	1.20	2.04	.26	1.78	25	300	350
610-229	.02	.19	35.5	.02	.07	9.93	.02	9.91	47	120	310
610-51	.20	.07	39.1	.03	.06	10.92	.06	10.86	110	90	310
612-118	.04	.05	39.1	.04	.21	10.95	0	10.95	130	90	210
612-128	.06	.08	36.2	.02	.03	9.88	.18	9.70	68	100	400
614-159	.03	.05	42.1	.03	.12	12.46	.70	11.76	230	60	120
614-186	.02	.03	43.2	.03	.10	11.75	.02	11.73	160	55	70
614-84	.63	.07	33.3	.10	3.10	10.24	.11	9.13	52	95	550
615-261	.02	.02	42.4	.03	.08	12.21	.62	11.59	210	60	55
615-270	.04	.05	39.1	.04	.36	10.37	.06	10.31	140	60	110
616-231	.46	.08	31.5	.07	3.00	12.85	4.20	8.65	120	150	620

sample	Pb ppm	Zn ppm	Mo ppm	Hg ppm	U ppm	Cr(s)ppm	Cu(s)ppm	Ni(s)ppm	Sr(s)ppm	V(s)ppm	Zr(s)ppm
201-69	5.0	38	.50	.005	19.80	50.0	1.5	3	300	15.0	50
21	5.8	58	.20	.010	3.43	--	--	--	--	--	--
22	1.0	56	.10	.005	4.10	7.5	.8	2	1,200	8.5	35
23	2.2	20	.10	.005	3.60	--	--	--	--	--	--
28	9.5	10	.40	.005	3.00	28.0	1.7	11	830	16.0	190
29	1.4	5	.10	.005	1.56	--	--	--	--	--	--
400-174	80.0	34	19.00	.560	739.00	--	--	--	--	--	--
441-109	57.0	48	.80	.120	35.70	20.0	3.0	20	300	15.0	30
441-179	5.0	44	.60	.005	36.50	--	--	--	--	--	--
441-204	25.0	140	1.00	.015	26.50	15.0	15.0	20	200	10.0	70
441-209	5.0	44	.40	.005	33.90	--	--	--	--	--	--
441-219	25.0	610	.40	.010	50.70	10.0	7.0	20	70	15.0	30
441-223	160.0	1,000	.60	.110	62.60	--	--	--	--	--	--
441-229	41.0	850	.40	.058	61.80	15.0	3.0	30	30	7.0	20
441-230	20.0	710	3.40	.010	256.00	--	--	--	--	--	--
441-32	5.0	92	.80	.030	38.80	30.0	1.5	20	200	30.0	70
441-57	5.0	48	3.70	.005	107.00	--	--	--	--	--	--
442-84	5.0	47	.05	.065	38.80	20.0	7.0	7	500	15.0	15
444-215	5.0	20	1.40	.005	141.00	--	--	--	--	--	--
449-201	22.0	120	1.50	.018	116.00	--	--	--	--	--	--
453-113	14.0	310	14.00	.005	1,190.00	--	--	--	--	--	--
453-94	12.0	160	1.60	.060	53.60	15.0	3.0	30	50	15.0	70
453-97	10.0	12	1.40	.005	19.00	15.0	3.0	7	70	10.0	30
501-196	5.0	5	.80	.005	64.40	7.0	1.5	3	200	5.0	10
509-200	10.0	5	.80	.005	63.40	70.0	5.0	2	150	15.0	200
509-206	10.0	5	.70	.005	19.40	--	--	--	--	--	--
610-152	22.0	5	.70	.005	55.20	--	--	--	--	--	--
610-181	200.0	41	1.80	.075	103.00	3.0	1.0	10	30	10.0	7
610-228	5.0	29	2.10	.039	395.00	--	--	--	--	--	--
610-229	10.0	36	.80	.005	248.00	15.0	1.5	3	200	15.0	50
610-51	5.0	37	.80	.005	111.00	30.0	1.5	7	500	15.0	20
612-118	14.0	14	1.60	.005	121.00	15.0	3.0	5	100	15.0	20
612-128	17.0	57	1.30	.039	59.20	20.0	5.0	15	500	20.0	50
614-159	10.0	89	1.60	.005	33.00	--	--	--	--	--	--
614-186	5.0	5	.80	.160	29.20	7.0	2.0	3	30	7.0	7
614-84	20.0	50	12.00	.240	9.78	20.0	3.0	15	500	15.0	20
615-261	12.0	5	1.30	.005	38.40	--	--	--	--	--	--
615-270	5.0	13	1.10	.090	106.00	15.0	3.0	3	50	15.0	50
616-231	14.0	110	8.10	.160	40.40	--	--	--	--	--	--

Belcen carbonates

sample	Dolom XR	CalcitXR	QuartzXR	Clay XR	Dolom NM	CalcitNM	QuartzNM	Clay NM	Hema NM	PyriteNM
	Mineralogy				Normative Minerals					
201-69	2.0	6.0	2	0	16	65.0	8	9	0	.30
21	8.0	0	2	0	4	89.0	4	2	.35	0
22	1.0	8.0	1	0	3	94.0	2	1	.15	0
23	.5	8.0	2	0	2	90.0	7	1	.39	0
28	0	7.0	3	0	4	78.0	13	4	.36	0
29	0	6.0	4	0	2	95.0	2	1	.10	0
400-174	8.0	0	2	0	86	3.0	5	2	0	3.30
441-109	9.0	0	1	0	83	6.0	5	3	2.90	0
441-179	7.0	.5	3	.5	62	6.0	20	10	1.30	0
441-204	6.0	0	4	0	53	9.0	27	9	1.50	0
441-209	5.0	1.0	4	.5	52	7.0	31	9	1.00	0
441-219	6.0	0	4	0	74	4.0	17	4	1.00	0
441-223	0	0	10	0	4	2.0	91	1	1.40	0
441-229	8.0	.5	2	0	87	5.0	5	1	1.40	0
441-230	7.0	1.0	2	0	92	.5	6	2	0	.40
441-32	5.0	2.0	3	0	59	7.0	20	12	0	1.40
441-57	5.0	0	4	1.0	43	2.0	41	10	0	4.50
442-84	.5	5.0	4	1.0	2	78.0	14	2	3.20	0
444-215	5.0	0	4	1.0	11	32.0	42	14	0	.50
449-201	6.0	0	4	0	24	.5	72	3	.90	0
453-113	4.0	0	5	1.0	36	58.0	3	2	0	.65
453-94	3.0	5.0	2	0	15	70.0	10	3	2.10	0
453-97	4.0	0	4	2.0	65	23.0	9	4	.44	0
501-196	.5	8.0	2	0	19	73.0	6	1	0	.41
509-200	6.0	0	4	0	3	57.0	35	5	.22	0
509-205	5.0	0	5	0	3	62.0	30	5	0	.58
610-152	.5	6.0	4	0	3	75.0	18	3	.21	0
610-181	9.0	0	1	0	88	9.0	2	1	.66	0
610-228	0	1.0	5	2.0	13	8.0	44	31	0	3.40
610-229	0	6.0	4	0	3	82.0	13	2	.26	0
610-51	3.0	6.0	1	.5	12	77.0	5	4	1.80	0
612-118	4.0	4.0	2	0	51	38.0	7	3	0	.54
612-128	4.0	3.0	3	0	41	43.0	11	4	.85	0
614-159	6.0	3.0	1	0	83	11.0	4	2	0	.28
614-186	5.0	3.0	2	0	84	8.0	6	1	0	.24
614-84	6.0	0	2	2.0	8	73.0	4	8	0	8.00
615-261	6.0	0	4	0	89	2.0	6	2	.24	0
615-270	7.0	0	3	.5	81	3.0	11	4	0	.81
616-231	6.0	0	3	1.0	6	73.0	3	11	0	7.50

Belden carbonates

Petrographic Classification

sample	Pet Tex	Pet Comp	PetAloch	Pet Neom	PetStruc	Ore Zone	Stratig	Elev Ft	North Ft	East Ft
201-69	--	--	--	--	--	21	7	10,749	15,200	20,130
21	2	2	3	1	0	12	7	10,480	13,610	19,140
22	3	1	3	1	0	12	7	10,540	13,660	19,340
23	1	1	0	3	1	12	7	10,775	14,400	19,390
28	1	1	5	1	0	12	7	10,625	12,060	19,610
29	3	1	2	2	0	12	7	10,510	11,420	19,870
400-174	1	2	0	3	3	41	7	10,374	13,690	19,960
441-109	1	2	0	3	3	22	7	10,494	14,080	20,030
441-179	8	2	5	3	1	22	7	10,436	14,080	20,070
441-204	1	2	5	3	3	22	7	10,416	14,080	20,090
441-209	1	2	5	3	1	22	7	10,412	14,080	20,090
441-219	1	2	5	2	3	22	7	10,404	14,080	20,100
441-223	--	--	--	--	--	22	7	10,400	14,080	20,100
441-229	1	2	5	1	1	22	7	10,395	14,080	20,100
441-230	1	2	5	1	1	31	7	10,394	14,080	20,100
441-32	8	2	5	0	1	22	7	10,557	14,080	19,990
441-57	6	2	0	1	3	31	7	10,536	14,080	20,000
442-84	--	--	--	--	--	21	7	10,522	11,813	19,593
444-215	1	2	5	2	1	31	7	10,317	11,520	19,838
449-201	7	4	5	0	3	32	7	10,378	13,978	20,072
453-113	--	--	--	--	--	21	7	10,486	12,802	19,810
453-94	--	--	--	--	--	22	7	10,505	12,802	19,810
453-97	--	--	--	--	--	21	7	10,502	12,802	19,810
501-196	4	2	2	2	1	21	7	10,353	13,810	19,996
509-200	4	2	3	2	1	21	7	10,279	11,120	20,021
509-206	4	2	5	2	1	21	7	10,274	11,120	20,026
610-152	--	--	--	--	--	21	7	10,470	12,680	19,826
610-181	--	--	--	--	--	31	7	10,445	12,680	19,840
610-228	--	--	--	--	--	31	7	10,405	12,680	19,864
610-229	--	--	--	--	--	21	7	10,404	12,680	19,864
610-51	--	--	--	--	--	31	7	10,558	12,680	19,775
612-118	--	--	--	--	--	31	7	10,470	12,870	19,816
612-128	--	--	--	--	--	21	7	10,462	12,870	19,822
614-159	--	--	--	--	--	21	7	10,416	11,660	19,848
614-186	--	--	--	--	--	21	7	10,396	11,660	19,867
614-84	--	--	--	--	--	21	7	10,470	11,660	19,797
615-261	--	--	--	--	--	21	7	10,306	11,660	19,870
615-270	1	2	1	2	0	31	7	10,298	11,660	19,875
616-231	--	--	--	--	--	21	7	10,312	11,660	19,811