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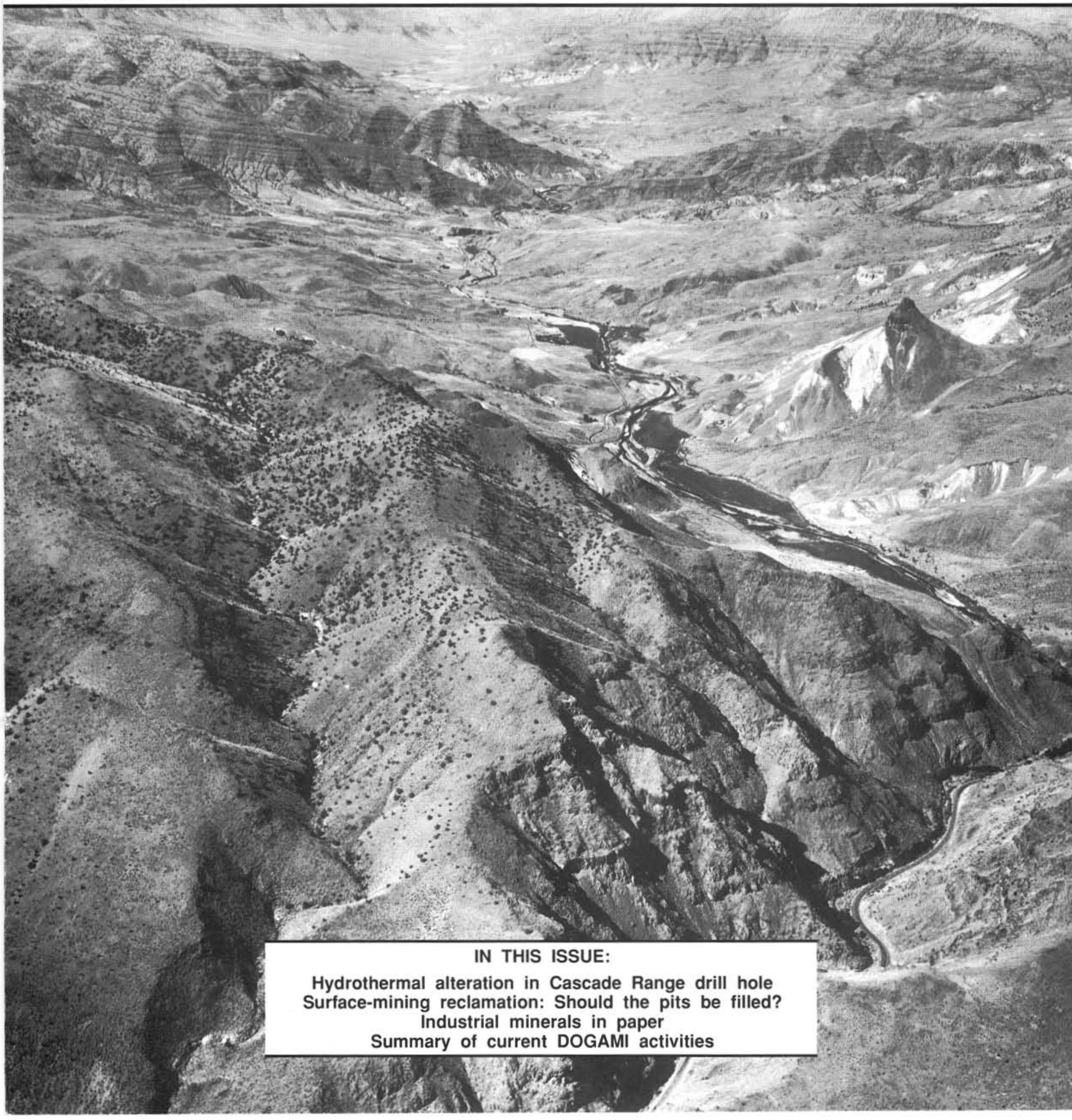

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Oregon Geology is designed to reach a wide spectrum of readers interested in the geology and mineral industry of Oregon. Manuscript contributions are invited on both technical and general-interest subjects relating to Oregon geology. Two copies of the manuscript should be submitted, typed double-spaced throughout (including references) and on one side of the paper only. If manuscript was prepared on common word-processing equipment, a file copy on 5-in. diskette may be submitted in addition to the paper copies. Graphic illustrations should be camera-ready; photographs should be black-and-white glossies. All figures should be clearly marked, and all figure captions should be typed together on a separate sheet of paper.

The style to be followed is generally that of U.S. Geological Survey publications. (See the USGS manual *Suggestions to Authors*, 6th ed., 1978.) The bibliography should be limited to references cited. Authors are responsible for the accuracy of the bibliographic references. Names of reviewers should be included in the acknowledgments.

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of the Oregon Department of Geology and Mineral Industries.

Cover photo

Where/what is this?—How well do you know Oregon's geology?—Send a note with your answer to Klaus Neuendorf at our Portland office (address above) before the next issue is released. If your answer is correct, your name will be entered in a drawing for a one-year free subscription to *Oregon Geology*, applicable to your current subscription or to a new or gift subscription. For a hint, we'll tell you that you ought to be able to identify one geologic landmark in the picture. The photo is one of the many masterful aerial photographs made by the late Leonard Delano of Portland. Copyright photo courtesy Delano Horizons, Inc.

OIL AND GAS NEWS

DY Oil performs workover on gas well

DY Oil has completed workover operations on its well Neverstill 33-30 at Mist Gas Field, Columbia County. Since gas production from the well had declined significantly, the well was reperforated within the Clark and Wilson sandstone reservoir in an attempt to restore commercial production. The well was put back into production during May. This is the only well at the field that is not operated by ARCO Oil and Gas Company.

Rules to be presented for adoption

In June, administrative rules for implementation of Oregon House Bill 2089 were adopted by the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI). These rules provide for ground-water protection and surface reclamation when shallow exploratory holes, such as seismic shot holes, are drilled by the oil and gas industry in Oregon. Copies of these rules will be available in August. For details, contact Dan Wermiel at the DOGAMI office, phone (503) 229-5580. □

DOGAMI Governing Board adds new member

John W. Stephens of Portland has been appointed by Governor Neil Goldschmidt and confirmed by the Oregon Senate for a four-year term as member of the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI). He succeeds Portland lawyer Donald A. Haagensen.

A native of Portland, Stephens is a Stanford graduate and received his law degree from the University of California at Los Angeles. He is a partner in the Portland law firm of Esler, Stephens, and Buckley. During the last six years, he also served on the board of directors of the Northwest Pilot Project, a volunteer social-service agency. Stephens has had a lifelong, even if nonacademic, interest in the geology of Oregon and attended the central Oregon summer camps of the Oregon Museum of Science and Industry at Camp Hancock for several years when he was growing up.

Serving with Stephens on the three-member board are Sidney R. Johnson, current chair, president of Johnson Homes in Baker City, and Ronald K. Culbertson of Myrtle Creek, president of the South Umpqua State Bank in Roseburg. □

Contents

Hydrothermal alteration in geothermal drill hole CTGH-1, High Cascade Range, Oregon

by Keith E. Bargar, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

ABSTRACT

Geothermal drill hole CTGH-1, located about 14 km northeast of Breitenbush Hot Springs in the High Cascade Range of northwestern Oregon, was drilled to a depth of 1,463 m. The maximum reported temperature at the bottom of the drill hole was 96.4 °C. Continuous drill core from the CTGH-1 drill hole consists of andesitic to basaltic lava flows, tuffs, and volcanic breccia. Red to orange iron-oxide-stained tuffaceous rocks are at least partly altered to smectite. Vesicles, fractures, and open spaces between breccia fragments are partly to completely filled by secondary minerals. Initial alteration mineral deposits consist of iron- and magnesium-rich minerals (hematite, smectite, and celadonite), which were followed by precipitation of potassium-rich minerals (celadonite, wellsite, and phillipsite). Later formed deposits include sodium-rich analcime, clinoptilolite, calcium-rich zeolite minerals (chabazite, erionite, heulandite, scolecite, and thomsonite), silica minerals (β-cristobalite, α-cristobalite, chalcedony, and quartz), and mordenite. Minor native copper, calcite, apatite(?), and adularia(?) are present in the drill core. The above secondary minerals are compatible with the present low-temperature hydrothermal conditions.

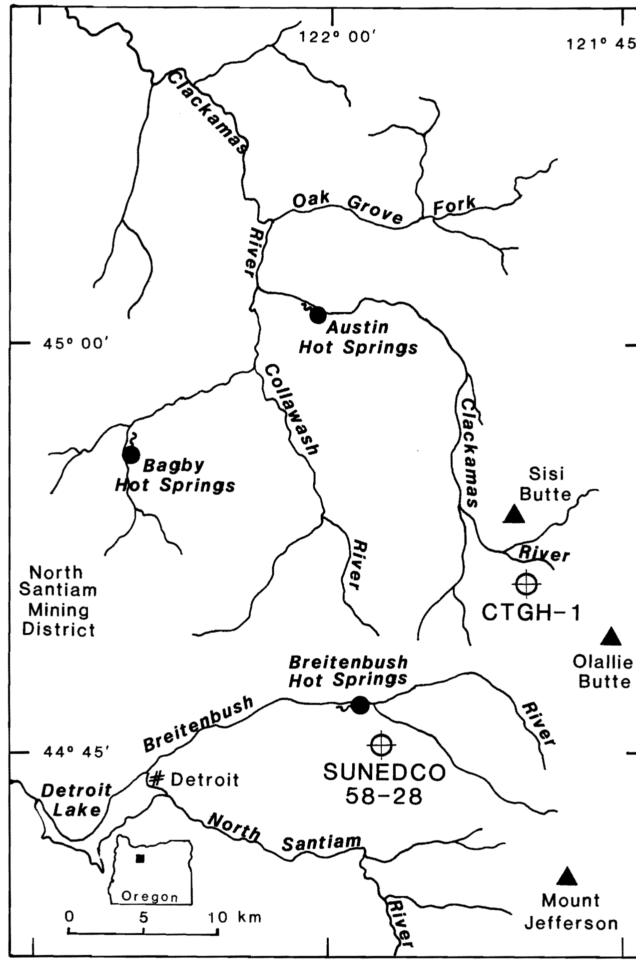

Figure 1. Map showing the location of geothermal drill hole CTGH-1 in northwestern Oregon.

INTRODUCTION

Geothermal drill hole CTGH-1 is located about 14 km northeast of Breitenbush Hot Springs and 6 km northwest of Olallie Butte, at an elevation of 1,170 m, near the Western Cascade-High Cascade boundary in northwestern Oregon (Figure 1). Drilling of the 1,463-m-deep core hole by Thermal Power Company and Chevron Geothermal on a cost-sharing basis with the U.S. Department of Energy began on June 7, 1986, and was completed September 7, 1986 (Conrey and Sherrod, 1988). The hole was rotary-drilled to 161-m depth and then cored to the hole bottom with essentially 100-percent core recovery. The maximum reported temperature at the bottom of the drill hole was 96.4 °C (Blackwell and Steele, 1987) (Figure 2), and the temperature gradient below the ~ 500-m depth was about 80 °C/km (Priest and others, 1987; Blackwell and Baker, 1988).

Drill core from the CTGH-1 drill hole is stored in the University of Utah Research Institute core library in Salt Lake City, Utah. A total of 307 core samples, between depths of 163 m and 1,463 m, consisting of fracture fillings, vug fillings, or representative samples of stratigraphic intervals, was obtained to identify the alteration minerals and to determine the physical and chemical conditions responsible for secondary mineralization of the drill core. Petrographic and binocular microscope, X-ray diffraction, and scanning electron microscope (SEM) (equipped with an X-ray energy dispersive spectrometer—EDS) methods were used in studying the drill core samples.

Lithologic and petrographic descriptions as well as K-Ar ages and chemical analyses of late Tertiary (Pliocene) to Quaternary rocks recovered from the drill hole are given in Sherrod and Conrey (1988) and Conrey and Sherrod (1988). Except for one dacitic interval, drill core from the CTGH-1 drill hole consists predominantly of andesitic to basaltic lava flows, tuffs, and breccias. The more silicic rocks contain some vapor-phase tridymite in addition to primary minerals (quartz, plagioclase, magnetite, and pyroxene). Primary minerals of the mafic rocks are mostly plagioclase, pyroxene, magnetite, olivine, and hornblende (identified in only one sample); α-cristobalite from devitrification occurs in several samples.

Textures of the lava flows vary from massive to vesicular; fracturing ranges from moderate to very intense. Most fractures and vesicles contain at least traces of mineralization, and the majority of open spaces are partly to completely filled by secondary minerals.

SECONDARY MINERALIZATION

Introduction

From 163- to 622-m depth, the secondary mineralogy consists of smectite, hematite, and scarce zeolites (chabazite, wellsite, and heulandite) (Figure 2). Between depths of 622 m and 885 m, smectite and chabazite are the predominant alteration minerals, although significant analcime and other zeolite minerals (clinoptilolite, heulandite, phillipsite, scolecite, and thomsonite) are present along with minor hematite, calcite, and apatite(?). Below 885-m depth, smectite remains the dominant secondary mineral and is found along with celadonite, zeolite minerals (clinoptilolite, erionite, heulandite, and mordenite), and silica minerals (β-cristobalite, α-cristobalite, chalcedony, and quartz); less abundant hematite and rare goethite, native copper, and adularia(?) also were identified.

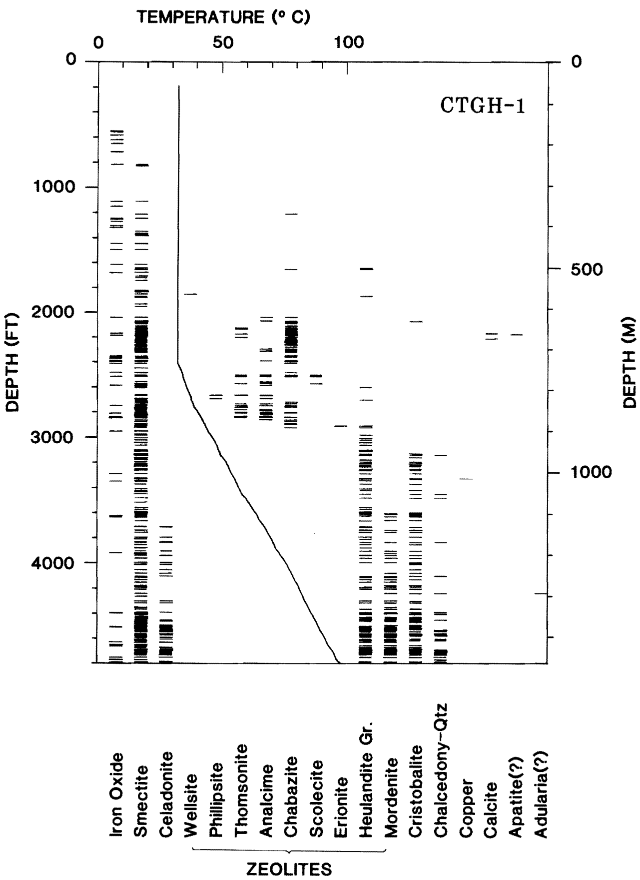

Figure 2. Distribution of secondary minerals with depth in drill hole CTGH-1. Temperature data from Blackwell and Steele (1987).

Hematite

Red-orange-brown iron-oxide stains are scattered throughout the CTGH-1 drill core (Figure 2) in abundances that range from a pervasive brick-red coloring of an entire specimen to microscopic orange-staining. The iron oxide was usually identified as hematite by X-ray diffraction; however, a few samples appear to contain X-ray amorphous iron oxide. Much of the hematite occurs in association with volcanic breccias, highly vesicular basalts, or tuffaceous deposits, where it probably formed by oxidation of primary magnetite during cooling of the volcanic rocks. A few thin red hematite stains on fracture surfaces or vesicle walls in the lower part of the drill hole appear to be closely associated with later secondary mineral fillings. Similarly, soft orange-red goethite coats a fracture surface at 1,456-m depth. The only other secondary iron-oxide mineral identified in the drill core is ilmenite, which occurs as black, metallic, hexagonal crystals that are closely associated with vapor-phase tridymite at 440-m depth.

Smectite

Above 480-m depth, very few samples contain smectite; however, below that depth, smectite occurs in virtually every sampled interval as coating on fracture surfaces, lining of vesicle walls, or complete filling of vesicles; between breccia fragments; and as groundmass alteration (particularly in tuffaceous rocks). In some vesicles, several generations of smectite were deposited earlier than other secondary minerals. Semiquantitative chemical analyses of selected smectite samples, using an EDS on the SEM, are given in Table 1. X-ray diffraction analyses together with the EDS chemical data suggest that smectite in the CTGH-1 drill core consists of randomly distributed deposits of montmorillonite (commonly a Ca- or Na-rich smectite), nontronite (Fe-rich smectite), or saponite (Mg-rich smectite).

Celadonite

Micaceous celadonite (Figure 3) occurs intermittently below 1,130-m depth normally as a soft, blue-green claylike material deposited as horizontal layers (later than green smectite) in cavities and fractures. In a few vesicles, the blue-green clayey layers are sandwiched between horizontal beds of medium- and dark-green smectite. At 1,138-m depth, celadonite formed earlier than a heulandite-group mineral (probably clinoptilolite) and β-cristobalite (Figure 4). Later formed, emerald-green, micaceous celadonite, like that shown in Figure 3, is sprinkled on top of the β-cristobalite. Semiquantitative chemical data for celadonite are given in Table 1.

Zeolite minerals

In the interval from 163 to 622 m, the only secondary minerals other than hematite and smectite are, in rare occurrences, chabazite, heulandite, and wellsite. Wellsite, an intermediate zeolite mineral in the phillipsite-harmotome group, was identified only in vesicles of basaltic rock from 564-m depth, where the mineral formed as randomly oriented, elongate, prismatic crystals, clusters of radiating crystals (Figure 5), or closely spaced elongate crystals deposited

Table 1. *Relative abundance of elements in hydrothermal minerals from the CTGH-1 drill core**

Mineral	Si	Al	Ti	Fe	Mg	Ca	Ba	K	Na
Smectite	1	3	—	2	5	4	—	6	—
Smectite	1	3	—	4	5	2	—	—	—
Smectite	1	4	—	2	5	3	—	6	7
Smectite	1	4	7	2	5	3	—	6	8
Smectite	1	5	—	2	4	3	—	—	—
Smectite	1	2	—	5	—	4	3	—	—
Celadonite	1	4	6	2	5	7	—	3	8
Celadonite	1	5	—	3	4	—	—	2	—
Celadonite	1	4	—	3	5	—	—	2	—
Zeolite minerals									
Wellsite	1	3	—	—	—	5	2	4	—
Wellsite	1	2	—	—	—	5	4	3	—
Wellsite	1	2	—	—	—	5	3	4	—
Wellsite	1	2	—	—	—	5	3	4	—
Phillipsite	1	2	—	—	—	4	—	3	—
Phillipsite	1	2	—	—	—	4	—	3	—
Phillipsite	1	2	—	—	—	4	—	3	—
Phillipsite	1	3	—	—	—	4	—	2	—
Phillipsite	1	2	—	—	—	4	—	3	—
Thomsonite	1	3	—	—	—	2	—	—	—
Analcime	1	2	—	—	—	4	—	—	3
Analcime	1	2	—	—	—	—	—	—	3
Analcime	1	2	—	—	—	5	—	4	3
Chabazite	1	2	—	—	—	3	—	4	—
Scolecite	1	2	—	—	—	3	—	—	4
Scolecite	1	3	—	—	—	2	—	—	—
Scolecite	1	3	—	—	—	2	—	—	—
Scolecite	1	3	—	—	—	2	—	—	—
Erionite	1	2	—	—	—	3	—	4	5
Heulandite	1	2	—	—	—	3	5	4	—
Heulandite	1	2	—	—	—	3	—	4	—
Heulandite	1	2	—	—	—	3	—	4	—
Heulandite	1	3	—	—	—	2	—	4	—
Heulandite	1	2	—	—	—	3	—	4	—
Heulandite	1	3	—	—	—	2	—	4	—
Heulandite	1	3	—	—	—	2	—	4	5
Heulandite	1	2	—	—	—	3	—	4	5
Heulandite	1	2	—	—	—	3	—	4	5
Clinoptilolite	1	3	—	—	—	4	—	2	—
Clinoptilolite	1	2	—	—	—	3	6	4	5
Clinoptilolite	1	2	—	—	—	3	5	4	6
Clinoptilolite	1	2	—	—	—	3	—	4	5
Clinoptilolite	1	2	—	—	—	4	—	3	5
Mordenite	1	2	—	—	—	3	—	—	—

*Based on semiquantitative chemical data obtained from an X-ray energy dispersive spectrometer on the scanning electron microscope (1 = most abundant; — = not detected).

Figure 3. Scanning electron micrograph showing books of euhedral celadonite crystals from 1,133-m depth.

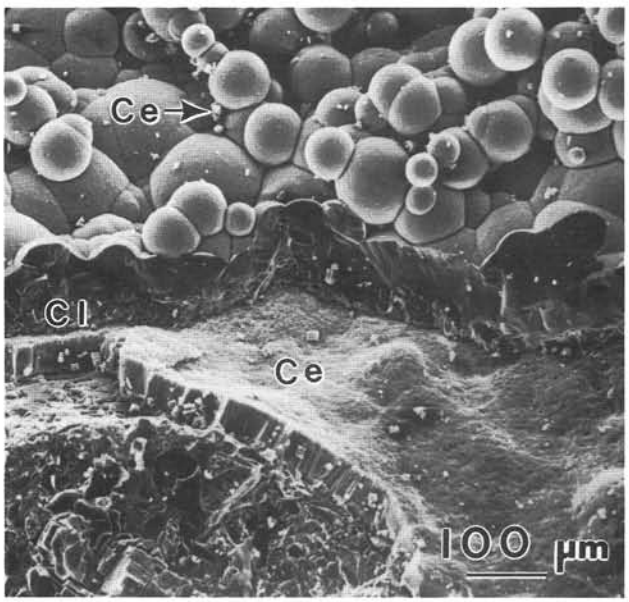

Figure 4. Scanning electron micrograph showing a fracture coating of clayey celadonite (Ce), blocky clinoptilolite (Cl), botryoidal β-cristobalite, and later micaceous celadonite (arrow) at 1,138-m depth.

as overlapping, radiating, hemispherical crystal clusters to produce a botryoidal-appearing vesicle coating. In Figure 5, the wellsite crystals appear to be partly coated by later smectite; however, the majority of the light- to dark-green horizontal smectite layers fill the bottoms of the vesicles and are earlier deposits. Semiquantitative analyses of wellsite (Table 1) show significant Ba and K and a little Ca in addition to Si and Al. X-ray diffraction analyses of the wellsite are similar to phillipsite and harmotome, but the approximately equal proportions of Ba and K suggest that the mineral is wellsite rather than Ba-poor phillipsite or K-poor harmotome (Gottardi and Galli, 1985).

In the interval from 622- to 885-m depth, zeolites occur with orange to green smectite and local iron-oxide staining (mostly hematite, but amorphous iron oxide may be present). These minerals

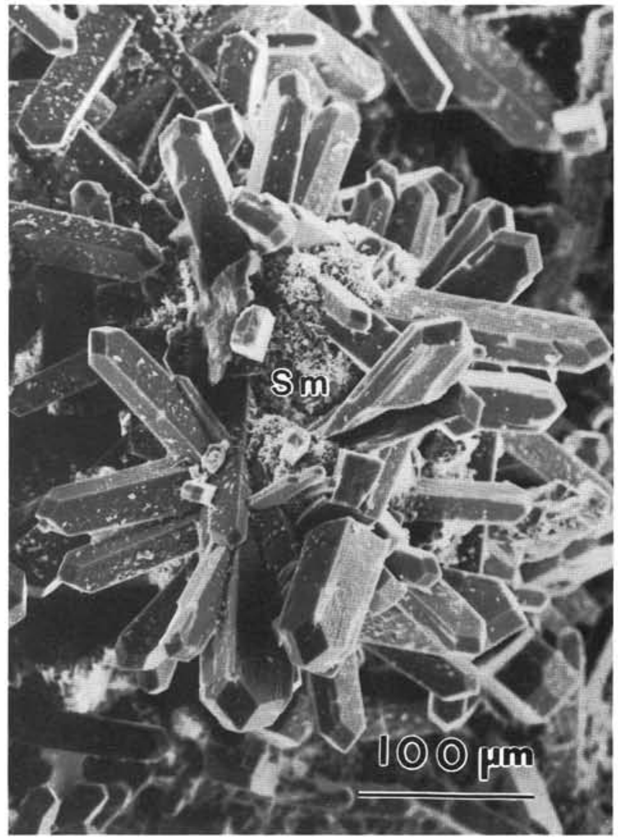

Figure 5. Scanning electron micrograph of a cluster of radiating wellsite prismatic crystals and later smectite (Sm) deposits from 564-m depth.

fill vesicles, fractures, and open spaces between volcanic breccia fragments and are dispersed in altered tuffaceous rocks. Phillipsite, an early-formed zeolite mineral in this drill core, was identified in only three samples (at 811, 812, and 821 m). At 821-m depth, colorless phillipsite crystals (Figure 6) formed in basalt vesicles, whereas, at 812-m depth, the phillipsite pervasively coats open spaces in volcanic breccia, forming clusters of closely spaced elongate crystals that appear partly dissolved. Semiquantitative EDS analyses indicate that both samples have approximately the same chemical composition: Si, Al, and K > Ca (Table 1).

At 812-m depth, phillipsite is associated with later clusters of colorless tabular or lamellar thomsonite crystals. Thomsonite crystals at 764-m depth were deposited as irregularly oriented, tabular clusters (Figure 7), whereas at a depth of 767 m, the tapered, tabular thomsonite crystals form somewhat fan-shaped clusters (Figure 8). Only Si, Al, and Ca were detected in an EDS analysis of thomsonite (Table 1). Fractures and vesicles in highly altered basalt at 663-m depth contain a soft, colorless, botryoidal coating that consists of hemispherical-shaped clusters of closely spaced thomsonite crystals.

The thomsonite crystals at 663-m depth are overlain by later deposits of colorless chabazite crystals. Pseudocubic rhombohedral chabazite (frequently twinned) (Figure 9), deposited in association with earlier smectite in many open spaces, is the predominant zeolite mineral in this interval. A semiquantitative EDS analysis of chabazite from 634-m depth (Table 1) shows the presence of Si, Al, Ca, and very minor K.

Scattered open-space deposits of colorless, trapezohedral analcime crystals are closely associated with chabazite, although the depositional sequence is undetermined; analcime also formed later

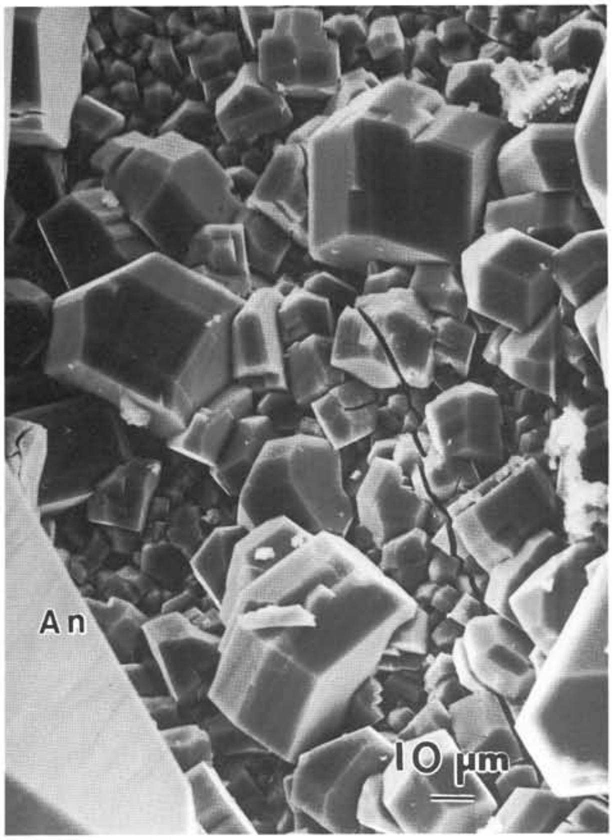

Figure 6. Scanning electron micrograph of a vesicle filling from 821-m depth containing euhedral phillipsite and later analcime (An).

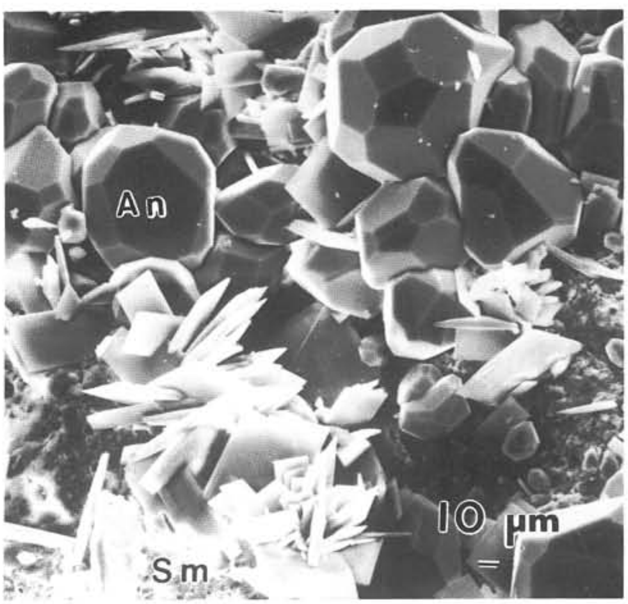

Figure 7. Scanning electron micrograph of a fracture filling from 764-m depth that is lined by smectite (Sm), later tabular thomsonite, and finally trapezohedral analcime (An) crystals.

than thomsonite (Figure 7) and phillipsite (Figure 10). Semiquantitative analyses for analcime show Si, Al, Na, K, and Ca (Table

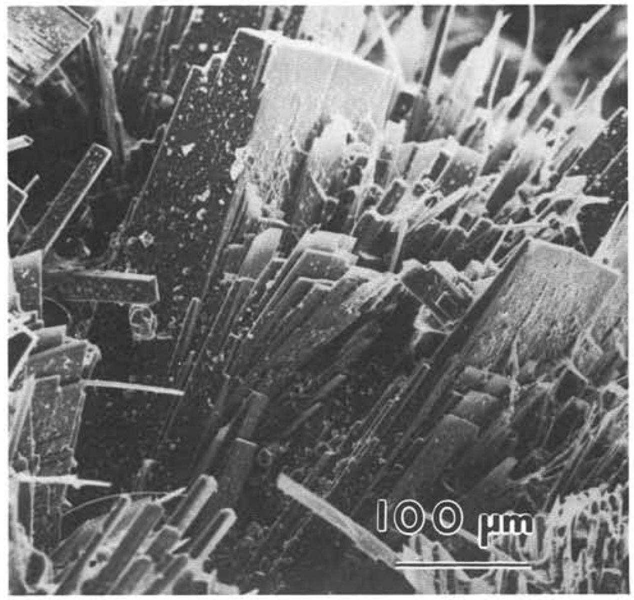

Figure 8. Scanning electron micrograph showing tabular thomsonite and acicular scolecite crystals from a fracture at 767-m depth.

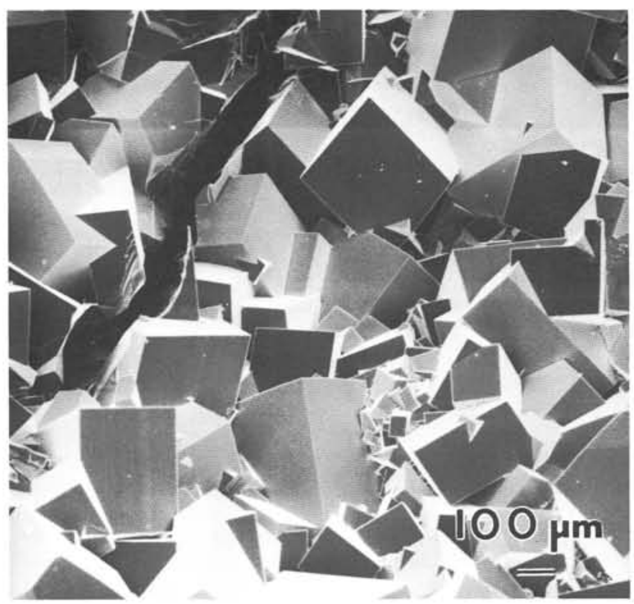

Figure 9. Scanning electron micrograph of euhedral, pseudocubic chabazite crystals lining a fracture at 634-m depth.

1). The presence of Ca indicates that the mineral is not a pure analcime end-member of the analcime-wairakite solid solution series and probably should be considered a "calcian" analcime (Gottardi and Galli, 1985).

Fracture fillings in drill core between 764- and 785-m depth contain radiating clusters of colorless, acicular scolecite crystals that were deposited later than thomsonite (Figure 11), chabazite, and analcime. Semiquantitative analyses by EDS indicate that the chemical constituents of scolecite are Si, Al, Ca, and very minor Na (Table 1).

Below 885-m depth, except for one occurrence of chabazite at 892-m depth, the zeolite minerals discussed above are com-

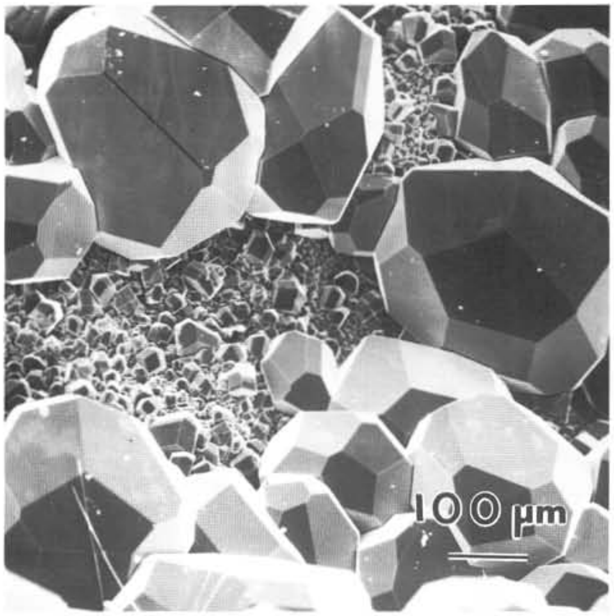

Figure 10. Scanning electron micrograph of a vesicle filling at 821-m depth lined by tiny phillipsite crystals and later large trapezohedral analcime crystals.

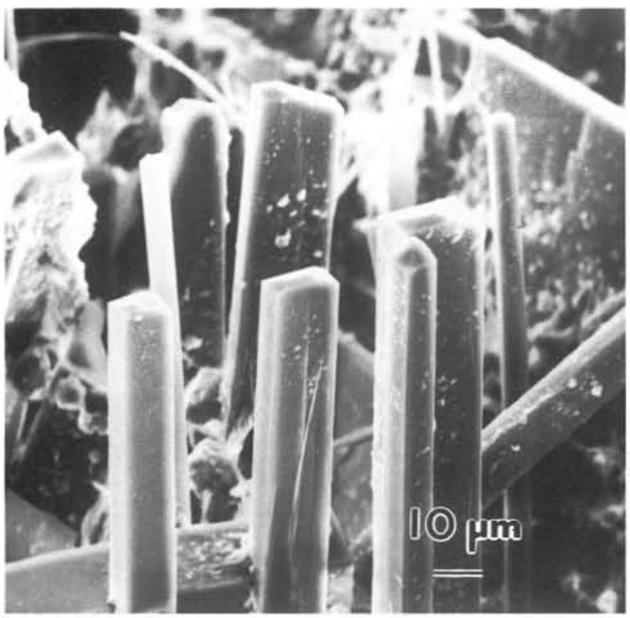

Figure 11. Scanning electron micrograph showing tabular thomsonite and later acicular scolecite crystals that coat fractures at 767-m depth.

pletely absent, and the interval contains heulandite-group zeolites (heulandite and clinoptilolite) along with abundant mordenite and minor erionite. Early-formed reddish hematite staining is sporadically distributed through the interval. Later formed smectite is the dominant open-space filling. At depths greater than 1,130 m, blue-green clayey celadonite fracture and vesicle deposits formed either later than green smectite or are sandwiched between horizontal green smectite layers.

Three samples between the depths of 886 m and 888 m contain columnar bundles of acicular erionite crystals that were deposited

Figure 12. Scanning electron micrograph showing columnar bundles of erionite crystals and later blocky heulandite crystals from 887-m depth.

later than green smectite. In the SEM, these columns occasionally show hexagonal cross sections (Figure 12) and are seen to have formed earlier than associated blocky heulandite crystals at 887-m depth. An EDS analysis of erionite shows the presence of Si, Al, Ca, K, and Na (Table 1).

Heulandite (Ca > Na+K) and clinoptilolite (Na+K > Ca), two heulandite-group zeolite minerals, are both present in the lower part of the CTGH-1 drill core. Clinoptilolite is abundant below 892-m depth but was identified in only one sample above that depth. In drill hole CTGH-1, heulandite-group zeolite minerals, deposited in vesicles and fractures and between breccia fragments, formed later than hematite, smectite, celadonite, and erionite but are earlier than α-cristobalite, β-cristobalite, or mordenite (Figures 13 and 14). Minor smectite appears to be deposited later than some open-space heulandite-group minerals (Figure 15). The crystal morphology of the heulandite-group minerals in drill core CTGH-1 varies from a tabular "tombstonelike" habit shown in Figure 15 to a more blocky morphology as seen in Figures 12, 13, and 14.

White, cottonlike mats of interwoven long, thin, fibrous crystals or small tufts of fibrous mordenite crystals (Figure 14) appear to be the latest mineral deposited in many open spaces below 1,099-m depth in the CTGH-1 drill core. An EDS analysis of mordenite from 1,260-m depth showed the presence of only Ca, Al, and Si.

Silica minerals

Silica minerals (β-cristobalite, α-cristobalite, chalcedony, and quartz) from the CTGH-1 drill hole occur as open-space deposits that formed later than most other minerals except for mordenite (Figure 14) and minor smectite (Figure 16). Between depths of

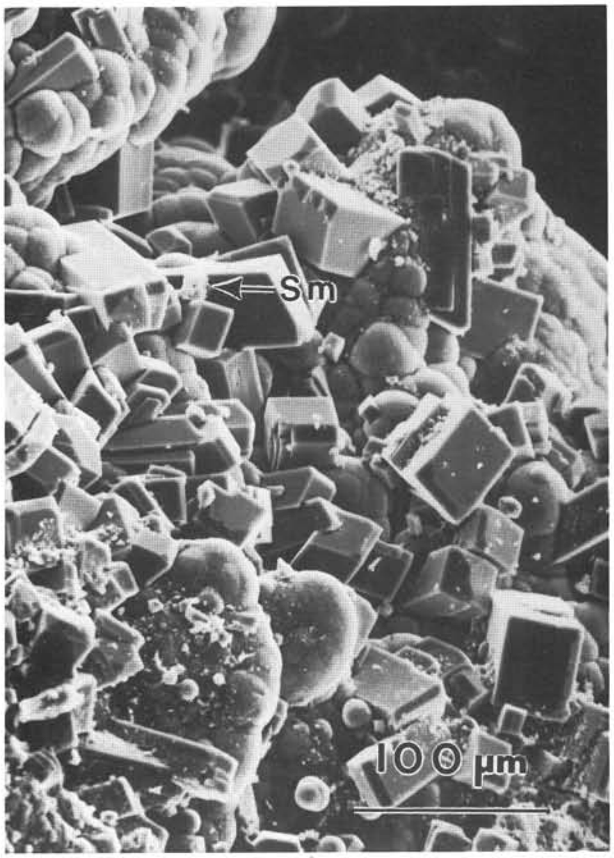

Figure 13. Scanning electron micrograph of a fracture filling at 983-m depth coated by blocky clinoptilolite crystals, later botryoidal β-cristobalite, and late smectite (Sm).

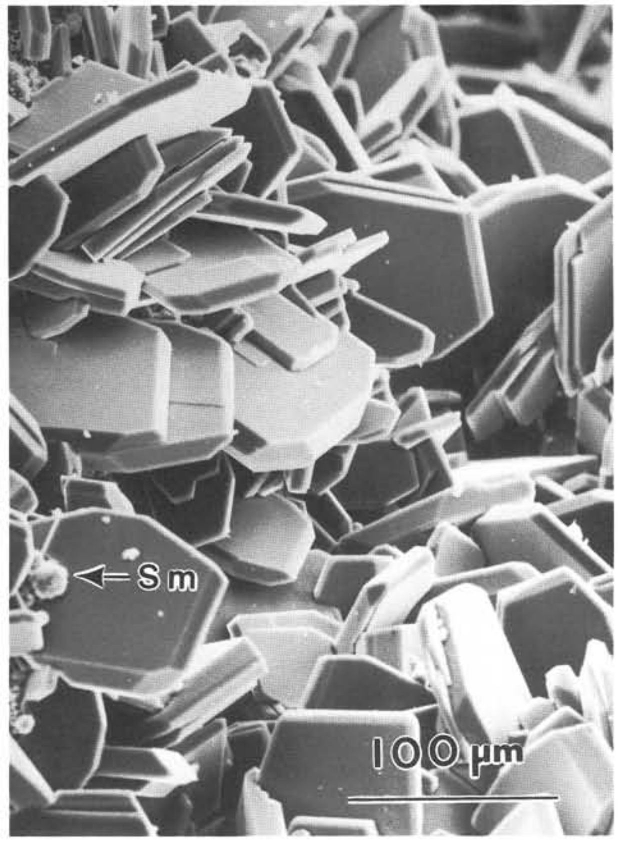

Figure 15. Scanning electron micrograph of tabular, "tombstonelike" clinoptilolite crystals and later smectite (Sm) lining a vesicle at 1,341-m depth.

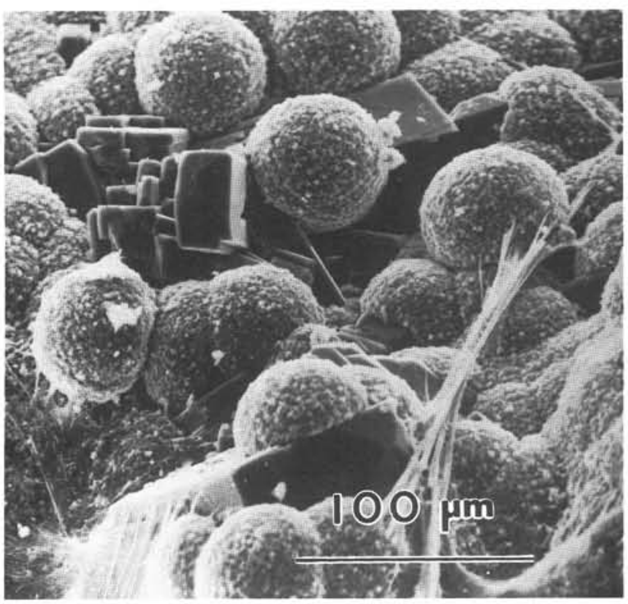

Figure 14. Scanning electron micrograph of a vesicle filling at 1,394-m depth consisting of blocky clinoptilolite, of later botryoidal α-cristobalite crystal clusters, and of still later fibrous mordenite.

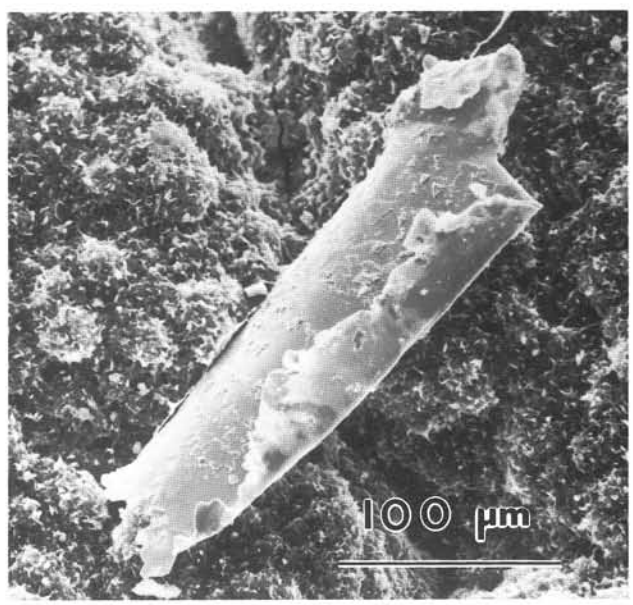

Figure 16. Scanning electron micrograph showing a deposit in an open space from 1,015-m depth consisting of native copper, later botryoidal clusters of β-cristobalite crystals, and still later smectite (fuzzy coating on β-cristobalite).

956 and 1,372 m, colorless, frosted, or bluish, smooth botryoidal silica (Figures 4 and 13) was identified as β-cristobalite in several X-ray diffraction analyses. Deposits of β-cristobalite alternate with similar-appearing botryoidal α-cristobalite between 1,061-m and 1,372-m depth. Below 1,372-m depth, spherical clusters of blocky α-cristobalite crystals (Figure 14) are the predominant silica phase.

Tiny, colorless, euhedral quartz crystals occur in vesicles from seven scattered drill core samples. Many other open-space white, colorless, yellow, or green massive silica deposits consist of cryptocrystalline chalcedony.

Other minerals

The only other secondary minerals in this drill core are calcite, apatite(?), adularia(?), and native copper. The first three minerals were identified only in X-ray diffraction analyses from depths of 663 and 675 m (calcite), 665 m (apatite?), and 1,293 m (adularia?); the modes of occurrence for these three minerals were not observed. Native copper occurs in two samples from near 1,015-m depth as an open-space deposit that appears to be earlier than botryoidal β-cristobalite and white smectite (Figure 16).

CONCLUSIONS

The paragenetic sequence of secondary minerals from drill core CTGH-1 (Figure 17) suggests that rock/water interaction, initially through alteration of basaltic glass and mafic minerals, provided sufficient Fe and Mg (Table 1) to form the earlier deposited secondary minerals. During later mineralization, K, Na, Ca, and Si were more prevalent constituents of the fluids, and the minerals that formed consisted mostly of zeolites and silica minerals.

The secondary mineral assemblage of the CTGH-1 drill core is similar to hydrothermal alteration mineralogy of upper Tertiary rock outcrops exposed in the Breitenbush-Austin Hot Springs area (Keith, 1988). Smectite and most of the zeolite minerals identified in the CTGH-1 drill core are compatible with the present low temperatures measured in the drill hole (Kristmannsdottir and Tomasson, 1978); silica minerals also can form at temperatures below 100 °C (Benson and Teague, 1982). Even though the depth of burial at the bottom of the CTGH-1 drill hole is nearly 1.5 km, the current high heat flow of the area (Blackwell and Baker, 1988) and the nearby hot springs (Figure 1) suggest that low-temperature hydrothermal alteration rather than burial diagenesis is responsible for the formation of alteration minerals in the CTGH-1 drill core. In a recent report on the genesis of zeolites, Gottardi (1989) indicates that hydrothermal environments usually produce euhedral crystals of a large number (six to eight) of zeolite minerals, whereas diagenetic processes result in fewer zeolite species that form smaller (10-20 μm) anhedral crystals. Euhedral crystals of 10 zeolite minerals found in the CTGH-1 drill core uniformly exceed 20 μm and support Gottardi's conclusions.

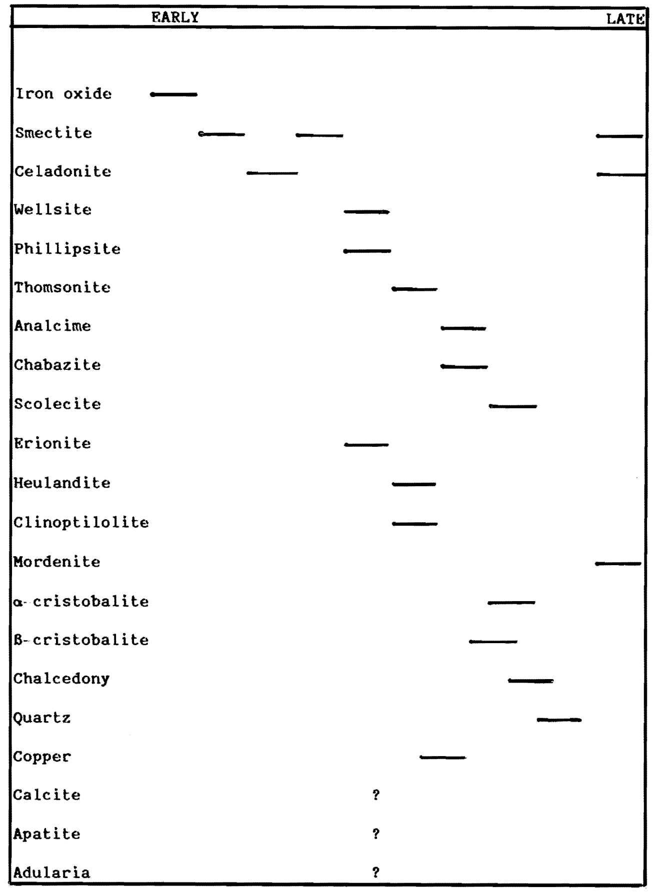

Figure 17. Approximate paragenetic sequence of hydrothermal minerals deposited in drill core from the CTGH-1 drill hole.

ACKNOWLEDGMENTS

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Should the pits be filled?

by Allen Throop, Mined Land Reclamation Program, Albany Office, Oregon Department of Geology and Mineral Industries

INTRODUCTION

What is the best way to use the natural resources of this country? At this time, there is no one answer to this question. Ultimately, the citizens of this country will have to decide. This article is intended to (1) explain some of the major differences between coal- and metal-mining techniques, and (2) show why returning the land to its approximate original contours after mining is acceptable to coal miners but strongly resisted by the metal industry.

The current intense exploration for gold in southeastern Oregon could lead to the development of a major new mine. The prospect of large open-pit mines in Oregon has resulted in the expression of serious valid concerns about environmental protection. The two most frequently asked questions are the following: (1) Will miners be required to fill in the hole when they are through? (2) Why do miners use cyanide? This article attempts to answer the first question. The second question was addressed in the January 1989 issue of *Oregon Geology* ("Cyanide in Mining," v. 51, no. 1, p. 9-11, 20).

The short answer to the question about filling in open pits is that it is economically not feasible and neither federal laws nor any state laws require that land mined for hard-rock metal be returned to pre-mine topography. Coal mines, however, are treated differently; land affected by coal mines must be returned to the approximate original contours. To understand the differences between common practices in the two industries, one needs to review the law and have some knowledge of basic geology and mining techniques.

In 1977, the U.S. Congress passed the Surface Mining Control and Reclamation Act (SMCRA). This law requires that the topography of surface mines be returned to the "approximate original contour" upon completion of mining. Contrary to popular belief, the law does not require the site to be returned to the actual original topography.

The following comparison of a coal mine and a metal mine is presented to demonstrate the differences between the two mining techniques. The two hypothetical examples are simple cases; in reality, each mining site is unique and presents special problems.

COAL-MINING TECHNIQUES

The first example is Breakeven Coal Company's Itsa Mine. The mine is located in the rolling hills of one of the Great Plains states. The coal is in a flat-lying seam that averages a thickness of 100 ft. The minable portion is 2,500 ft wide and 2 mi long. The contact between overlying shale and underlying limestone is sharp. The overburden, which is the material lying between the top of the coal deposit and the surface, ranges from 50 to 300 ft thick, with an average thickness of 150 ft. A cross section through the unmined area is shown in Figure 1a.

Breakeven Company obtains all of its permits and starts mining from the north end of its property. To reach the coal, Breakeven starts out with a drop cut down through the overburden and builds up a hill with the overburden that it has removed. After reaching the coal seam, Breakeven begins mining toward the south. Initially, the overburden is placed on the pile that was started during excavation of the drop cut. However, as soon as the coal is removed, the company starts putting overburden into the mined-out area (Figure 1b). As soon as backfilling begins and material is no longer being added to the original hill, the hill is contoured, covered with topsoil removed from the mine area, and revegetated.

Now a repetitive cycle is begun within the mine. The overburden is removed, slice after slice, carried over to the area from which coal was removed, and dumped into the mined-out area. Often this process is done with a huge dragline, such as the one shown in Figure 2. The rock is literally thrown from one side of the excavation to the other by the highly efficient machine. As the dragline moves along successive strips, loaders and trucks follow along behind, removing coal from the seam. As soon as it is piled up to the desired level, the overburden is contoured, topsoiled, and revegetated. The cycle is repeated until the south end of the mine is reached.

Compliance with the strict definition of "approximate original contour" would mean that overburden from the original drop cut would finally have to be hauled from the north end to the south end and used to fill the final cut. In this case, Breakeven will seek a variance from the rules to create a pond that, if carefully done, can be an important wildlife or recreation asset to the area. Creating the pond saves the company the large amount of money that would be needed to move the overburden from the north end of the mine to the south end.

"Approximate original contour" is achieved by having the hills, valleys, and slopes similar to those that existed prior to mining. However, the actual shape of the mined area can be completely different when compared to the original location of the hills and valleys. Depending on the ratio of the overburden to the coal, the approximate original contour may be above or below the elevation of the pre-mine topography.

Strip mining and restoration of the approximate original contour work well where the valuable mineral is tabular in nature, lies approximately parallel to the original ground surface, and is close enough to the surface for economical mining.

GOLD-MINING TECHNIQUES

Now let's look at Glittering Gold's Justa Mine in the Basin and Range country in one of the Far West states. The ore body is egg shaped and oriented with the point sticking up. However, the edges are irregular, and the amount of gold in the ore gradually tapers off as the depth gets greater. Perhaps the comparison with an egg would be closer to reality if you imagine that the egg shell broke shortly after it was emplaced, and the egg white seeped out into the surrounding rock.

At this mine, ore was found at the surface, so production can begin almost at once (Figure 3a). The miners realize that to get continued production, they must start stripping waste immediately. However, where Breakeven Coal knew that its mine would go down only to 200 ft and the waste could therefore be dumped relatively close to the edge of the mine, Glittering Gold realizes that its final pit edge will be over 1,000 ft away from where the ore crops out. Therefore, the overburden must be carried farther away from the initial excavation.

The sequence of mining is shown in Figures 3b through 3d. The bottom of Justa Mine will not be at the place where there is no more gold. Instead, all else being equal, it will be at the elevation where the cost of removing waste from the pit sides and hauling more ore from the pit bottom can no longer be justified by the grade and amount of ore exposed on the bottom.

A comparison of Figures 1 and 3 shows the major difference between a coal strip mine and the open pit of a metal mine. With good planning, overburden removal finishes at a coal mine when the last coal is removed. Final regrading and topsoiling closely follow the overburden replacement.

On the other hand, the metal mining companies object strenuously to filling in the pit because the job is more costly and

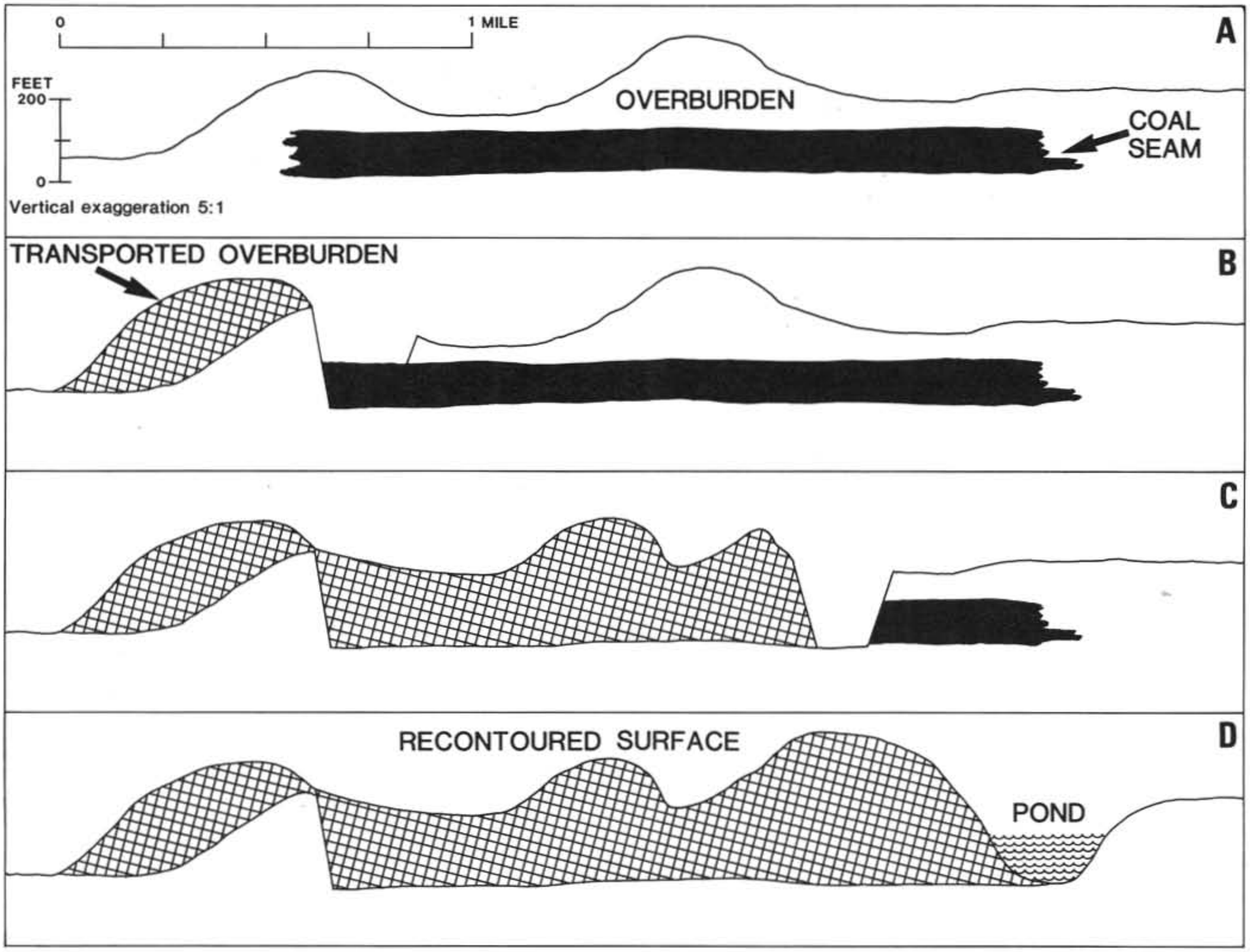

Figure 1. Cross sections of Breakeven's Itsa Mine, a coal mine where a flat-lying coal seam is covered by overburden ranging from 50 to 300 ft in thickness. Note vertical exaggeration. A. Pre-mine cross section, showing the original contour of land before mining begins. B. When the first cut is made, the overburden is built up into a hill until coal is finally exposed for mining. As soon as no new material is to be added to the overburden hill, the hill is contoured, covered with topsoil that was removed from the mine site, and revegetated to make it stable and not prone to landsliding. C. After coal is removed from a portion of the excavation, overburden removed from a different part of the mine is piled into the mined-out area, contoured, topsoiled, and revegetated. This cycle is repeated until the end of the mine is reached. D. The mine after mining has ceased, the land has been restored to the "approximate original contour," and a pond has been created for wildlife or recreational use.

Figure 2. Dragline used to move overburden from above the coal seam to a mined-out portion of the operation. The bucket of the machine is large enough to carry two pickup trucks.

cannot be started until mining is completed. Not only does this mean that it has to be done after income from the mine has stopped coming in, but it is more expensive than in the coal-mine situation because the rock must be loaded into trucks for a second trip and hauled back into the pit. Moving rock by truck rather than by dragline is far more expensive. Double hauling adds immensely to the cost.

Arguments in favor of backfilling an open pit:

1. Aesthetics: An abandoned pit may be aesthetically undesirable to some or unsafe.

2. Acid mine drainage: In some cases where the pit will naturally fill with water, minerals that have the potential to generate large amounts of acid can be controlled by dumping them into water-filled pits. In other cases, acidic waters in the pit bottom could be eliminated by filling in the pit.

Arguments against backfilling:

1. Economy: Post-production backfilling cost is large in terms of both dollars and fuel. Assuming an average backhaul of 1.5 mi (a 3-mi round trip), the hauling cost would be on the order

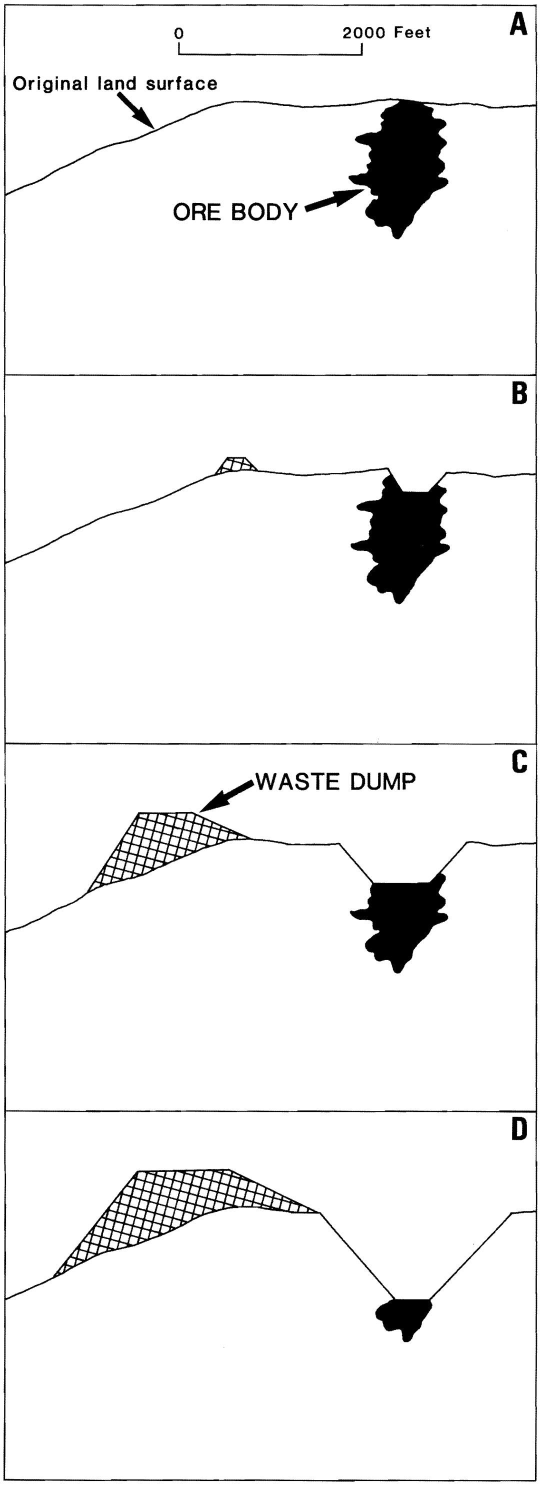

Figure 3. Cross sections of Justa Mine, a western U.S. gold mine developing an egg-shaped ore body. A. Pre-mine topography, showing the location and shape of the ore body. B. First cut into the ore body. Note how far away from the ore body the waste material must be transported, so that later excavations will not undercut the waste dump. C. Mine when about half of the ore body has been removed. Note how it is impossible to begin filling the pit at this stage without covering up some of the remaining ore. D. Mine site after the currently economic ore body has been removed. Waste has been piled some distance from the pit, and the waste pile can be contoured and seeded.

of $37 million, and approximately 1 million gallons of fuel would be consumed for backfilling a pit with 50 million tons of rock. This is the cost only of moving the rock in trucks. Considerable additional expense would be generated in such tasks as loading the trucks, maintaining haul roads, and overseeing the project.

2. Acid mine drainage: Rock with the potential for producing acid could be properly isolated when it is first removed from the pit. Digging the rock up and moving it a second time could increase the potential for causing environmental damage.

3. Stability: Many mines remove the side of a hill rather than excavate a hole in the ground. Final slopes blasted into hard rock are far more stable than loose material dumped back over the side of an excavated hill.

4. Future mining: Metal mines generally shut down because mining has become uneconomic under the price and mining methods of the day. The mineralization at the bottom of the excavation may well be economic again in the future. Is covering this resource wise?

Regardless of whether the pit is backfilled or not, the site cannot be returned to the original contour. During the blasting and milling process, open space is introduced into the rock. The volume of material to be disposed of can be twice as much as the volume of the excavation from which it came. Even if the pit is backfilled, large waste dumps and/or tailings piles would remain.

CONCLUSION

As stated at the beginning of this paper, there is no consensus on the best way to use our natural resources. Each type of mineral extraction offers its own problems. Each ore body is unique. Society has a need for minerals that are produced from the earth, but society also has the responsibility to produce those minerals while minimizing the long-term negative impact on the land. The debate over the best way to produce minerals that are needed to maintain our current standard and pattern of living, to maintain access to potential future resources, and to protect the environment will continue for many years. In order to have a meaningful debate, it is imperative that all parties understand current mining practices. □

April fireball lights up Oregon

by Richard N. Pugh, Cleveland High School, Portland

A major fireball event occurred over Oregon on April 13, 1990, at 8:35 p.m. PDT. At that time, the sun had set, but it was not totally dark.

The fireball entered the atmosphere off the Oregon coast near Florence. It was observed to move east-southeast and was last seen breaking up southeast of Christmas Valley.

The fireball was seen from Portland, Oregon, in the north to Christmas Valley, Oregon, in the east and to Redding, California, in the south. Most observers saw an object as bright and large as a full moon. The duration of the event was three to six seconds. The fireball was reported to be round to teardrop shaped and having a yellow to green color. Several observers reported seeing the fireball pulsating and changing colors as it "fell." Most observers saw a yellow to white tail of varying length. Many reports mentioned sparks coming off the fireball, and five reports mentioned disruption or breakup of the object near the end of its path. Two to four fragments were reported.

One report, from Philomath, Oregon, mentioned anomalous sound: A low, moaning/whistling sound was heard at the same time the fireball was seen. No sonic booms were reported.

These sightings have been reported to the Scientific Event Alert Network, Smithsonian Institution. Anyone with any additional information about this event or other fireball sightings should contact Dick Pugh, Cleveland High School, 3400 SE 26th Avenue, Portland, OR 97202, phone (503) 280-5120. □

Industrial minerals in paper: A chase for technical superiority*

by Hal McVey, P.O. Box 343, Rough and Ready, California 95975, and Peter Harben, P.O. Box 800, Morris, New York 3808, independent consultants specializing in market evaluations of industrial minerals on an international basis.

INTRODUCTION

Industrial minerals provide substance to the paper industry. They are utilized in substantial volumes in the manufacture of paper as pigments, fillers, and coating agents that contribute properties such as brightness, opacity, light weight, strength, and cost effectiveness. Perhaps more importantly from the suppliers' viewpoint, because most of these minerals have been upgraded by sophisticated processing, there is a commensurately large value-added factor that creates an impressive dollar volume for minerals destined for this end use. Minerals consumed as fillers and extenders in the North American paper market in 1988, for example, were valued at a record $1,000 million. Growth in consumption has been spurred by some of the technological changes discussed below plus a 200-percent increase in pulp prices since 1986. By far the bulk of this 5-million-ton-plus market is accounted for by titanium dioxide, kaolin, calcium carbonate, and talc.

Terminology

A basic conflict of terms emerges the moment that the industrial mineralist meets the paper technologist. What we in industrial minerals call "fillers" or "extenders" are called "pigments" in the paper trade. Since this article is written for *Industrial Minerals,* we will stick with our own terminology. Even so, this subject needs some clarification.

For some time there has been an uneasiness within the industrial minerals industry with the nomenclature "filler" or "extender" minerals. The terms imply that these minerals are just rather low-cost dirt that contributes little else but volume or weight to paper, plastics, paint, rubber, and other manufactured items. This concept is far from the truth, since most of these minerals contribute beneficial properties. For example, in paper they improve the brightness, create opacity or resistance to show-through, cause ink receptivity or ink hold-out, provide glossiness or flatness, act as a pitch-control agent, as scavenger for anionic elements created by the chemicals used in the papermaking process, and, yes, do fill space in the pulp for a very definite reason as discussed below. However, due to the beneficial effects of industrial minerals, the term "functional fillers" seems to have emerged as the best descriptive adjective. We still use the words "filler" and "extender," but they are understood to have a more profound meaning than just space filler.

PAPERMAKING AND INDUSTRIAL MINERALS

The basic ingredient of paper is pulp. The selection of the types of pulp with different technical benefits and different prices is a world in itself and needn't concern us for the purpose of this discussion. We can assume that paper is a network of cellulose fibres with air spaces in between. A goodly portion of these spaces is filled by industrial minerals, wherein they are added at the wet end of the papermaking process. This means that the pulp, certain chemicals, and industrial minerals make up the slurry that is compressed and dried to form paper.

However, the type and quality of mineral used depends on the type of paper being manufactured. For example, tissue-type papers do not contain minerals. Groundwood pulp-type papers that are used to make newsprint, official airline guides, and telephone directories contain little or no filler (more on this later). Papers for magazines like *National Geographic* and *Hustler* or company annual reports contain up to 30 percent by weight of minerals. By way of general interest, the paper people use the term "ash" for the mineral content. This is derived by burning a piece of paper and weighing the residue, which is the ash or mineral content.

Quality and specifications

The paper industry is extremely demanding when it comes to quality and quality control. This is well illustrated in a later section (*USA Today* syndrome). However, the general qualities that are required from minerals in papermaking are as follows:

- Brightness — in most cases the higher the better. However, high brightness reduces opacity. See next item.
- Opacity and/or show-through — this is essentially the ability of paper to not show ink through to the other side of the page so that the reader of a news article does not see the Marlboro man peeking through from the following page.
- Bulk density — generally the lower the better.
- Abrasion characteristics — more correctly, lack of abrasion as would be caused by hard minerals such as silica.
- Particle size — the criteria are built around the 2-micron-size level.
- Particle size distribution — the distribution of the various sizes of the mineral is as important as the maximum and minimum particle sizes. Generally, the really fine particles of less than 0.25 micron are detrimental.
- Retention — a high percentage of the mineral must be retained in the slurry and end up in the paper in order to avoid an obvious loss.
- Rheology and viscosity — rheology is the science of the flow of matter (minerals) under stress. With paper machines traveling up to 4,000 ft/minute, the manner in which the minerals flow is of extreme importance.
- pH — the acidity or basicity of the mineral must be compatible with the process.
- Economy — this is a comparative evaluation. Cost might be determined by the mineral being at a lower cost than the pulp, as a lower cost replacement for titanium dioxide, or a higher cost because it adds something special to the paper and is, therefore, economical to use.

Titanium dioxide

The most highly prized and highly priced pigment used in paper is titanium dioxide made from a rutile, synthetic-rutile, ilmenite, ilmenite-slag, or leucoxene feedstock. The finely divided white powder is extremely white and bright (100 percent on a General Electric Brightness [GEB] scale of 100 percent), and its refractive index of 2.7 is the highest of any pigment used in paper. Thus even at modest concentration levels, titanium dioxide contributes greatly to brightness and opacity. In short, except for its high price, it is the ideal white pigment. In most cases, one of the prime functions of a filler is to reduce the amount of titanium dioxide pigment used in the manufacturing process. Although there has been a certain degree of success, and research is continually trying to increase this substitution, titanium dioxide remains the supreme pigment for papermakers.

Last April the tight TiO_2 market in North America gradually pushed up prices past the $1/pound mark for the first time when SCM Chemicals announced price increases for anatase grades to

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$1/pound and rutile grades at $1.02 and $1.03/pound. Despite these price increases and low stocks, demand for TiO_2 has continued to climb in response to the paper industry's push for whiter, lighter, and more opaque lightweight coated (LWC) and increased production of premium coated free-sheet grades. In 1988 the U.S. paper industry used 290,000 short tons of titanium dioxide, that is 27 percent of the total consumption. For the paper industry this represented a 2-percent rise in U.S. consumption over 1987, which was relatively low due to being supply-constrained (consumers continue to be on allocation based on their previous purchasing patterns). Expectations are that this will increase to 3 percent in 1989, given some easing of supplies and the continuation of the trend to better quality paper.

North American producers are all increasing production capacity of titanium dioxide pigment in a frantic effort to keep up with demand. Increases have been achieved through debottlenecking and running plants uncomfortably close to 100-percent capacity. Projects are underway to substantially increase capacity in North America. DuPont, the largest producer, is increasing its U.S. capacity from the current level of about 600,000 short tpa (tons per year—*ed.*) to 750,000 short tpa by 1991. 100,000 tons of this increased capacity will be at its DeLisle, Mississippi, plant. In July, DuPont announced plans to increase the capacity of its Altamira plant from 55,000 tonnes (metric tons —*ed.*) to 79,000 tonnes by the end of 1990. Kerr-McGee recently completed its 21,000-ton expansion at Hamilton, Mississippi, which brings capacity to 106,000 short tpa. Kemira Inc.'s 50-percent expansion of its Savannah, Georgia, plant to 110,000 short tpa is about complete, and SCM has completed a modest expansion at Ashtabula, Ohio. NL Chemicals is building a 90,000 short tpa plant at Lake Charles, Louisiana, which will be completed by 1991. Therefore, over the period 1988-1991, more than 300,000 short tons of capacity will be added to U.S. plants. In Canada, NL Chem Canada and Tioxide Canada will add 40,000 and 11,000 short tons of capacity by the end of 1990 to bring the national capacity to 137,000 short tons.

As mentioned previously, titanium dioxide's price tag has traditionally encouraged the replacement by other minerals—mainly kaolin, calcium carbonate, and talc—and one of the major objectives of industrial minerals companies and others is to find that almost-perfect replacement for TiO_2 pigment. To date, none have succeeded, although technological advances and compromises have helped to score some successes. For example, in some grades of uncoated paper up to 50 percent of the titanium dioxide can be replaced by fillers such as calcined kaolin, precipitated silica, or precipitated calcium carbonate, whereas in paper grades where opacity is essential, replacement is less than 15 percent.

Kaolin leads

As might be expected, the paper companies use that mineral or combination of minerals most readily available that fulfills a technical need and is competitively priced. There is a great deal of effort to develop new formulations based on what might be called a mineral cocktail, and substitution is always a strong possibility. In North America, kaolin clay is, and will remain, by far the largest tonnage industrial mineral used in papermaking. In 1988, around 4.5 million short tons of various types of kaolin was used, with its nearest rival, calcium carbonate, at less than 1 million short tons.

The general trend in kaolins has been toward greater sophistication and quality. First there was air-floated, then water-washed, followed by delaminated and calcined kaolin. Although water-washed has been the backbone of the kaolin industry with around 3 million short tons produced each year, it can be said that the quality of a No. 2 Filler produced in 1989 would be vastly superior to a No. 2 Filler produced in 1979. This improvement would be reflected in better consistency and improved particle size distribution. The same improvement would be noticeable in other grades.

Delaminated kaolin is what it sounds like, the laminated kaolin as it occurs in nature is broken down into thinner platelets to improve the brightness and opacity. Calcined kaolin gives a high brightness and lower bulk density; however, the high brightness is detrimental in that it reduces opacity.

Of course each of these improvements is made at a cost—air-floated clay would sell for about $50/ton, water-washed for something less than twice that amount at $100/ton, delaminated for over twice that amount with a price in the range of $250/ton, and calcined for about eight times the cost of the air-floated at $400/ton. Nevertheless, they all serve a purpose at their level of cost, or they would not be used.

The 5-percent growth in demand for calcined, delaminated, and premium coating grades in 1988 was powered by the strength of lightweight and premium coated paper market. Overall, North American producers shipped 7.5 percent more coated paper in 1988 compared with 1987, and mills operated at over 95 percent of capacity. In 1989, a further increase of 4 percent in consumption is expected, and capacity utilization will be near to 96 percent. This sustained growth in kaolin demand (despite replacement at some free-sheet mills by calcium carbonate) has been evident for several years and has kept prices firm. The buoyancy of the market has encouraged the main producers—Engelhard, ECC America, Georgia Kaolin, J.M. Huber, Nord Kaolin, and Thiele Kaolin—to expand production by 700,000 short tpa, and they are planning to introduce new products.

Another trend in kaolin is to try and locate deposits and develop mines closer to the point of use. This has been particularly noticeable in Canada and more especially in western Canada and the Pacific Northwest states of the U.S.A. In the latter case, the existing rail freight rates of $75-85/ton from Georgia is a significant cost that would be greatly reduced for a western producer. Three kaolin projects have been considered in Canada, one each in Ontario, Saskatchewan, and British Columbia. The two in Ontario and Saskatchewan are secondary deposits consisting of kaolin and silica sand that would be separated into those respective industrial mineral products. The deposit in British Columbia is a primary deposit that would not have the associated silica sand. None of these three is an imminent producer, but the search for a local source is ever present.

Some of the technical innovations by the kaolin producers in Georgia are of interest. One is the production of a "high-bulking pigment" that is accomplished through processing techniques. Ultrafine kaolin of less than 0.25 micron is optically inefficient, and therefore it is advantageous to stick these together to form larger particles (80-90 percent less than 2 microns). This creates a product with more air space, and the light bounces off these particles rather than passing through, thus creating superior opacity and hiding power. This technique can be used on both filler and coating clays.

One problem with mineral fillers is that they tend to weaken the sheet of paper. Taking the technique a step further, producers are now adding chemicals which increase the retention of the kaolin causing it to stick to the fibre. This results in a strong sheet of paper and still provides the benefits of the mineral—it is known as "high-bulking, high-strength pigment or filler." If the level of loading can be increased from 10 percent to 15 percent or even 18 percent using the newer kaolin at a lesser cost than fibre, then a savings is made on production costs combined with an improvement in quality.

USA Today syndrome

There is still another step which is based on what may be called the *USA Today* syndrome. Paper companies are constantly hunting a lighter weight paper that has greater opacity and less show-through. Quality expectations were heightened still further in the case of *USA Today*, a newspaper launched seven years ago, which has grown to a circulation of over 5 million, making it the third largest daily in the U.S.A. A major characteristic of the paper is the use of 4-color, high-quality printing for both advertising and editorial. This trend is being followed by others; for example, the *Los Angeles Times* and the *New York Times* are installing color press lines, and color printing is forecast to increase 20 percent annually. All this puts great demand on the supply of very high quality and brighter newsprint that has light weight plus opacity.

In addition to some standard tests such as ink absorption, the *USA Today* newsprint sheet is tested by a process that measures three-dimensional light color components on scales of black to white, green to red, and blue to yellow. In addition, the quality must be consistent for each of the 30 printing locations across North America. It was recently revealed that just eight newsprint mills in North America are able to meet *USA Today*'s quality standards, but many more are trying. The role of the mineral would appear critical in achieving the brightness, light weight, and opacity required for color printing on newsprint.

For the sake of discussion we can say that certain newsprint has a brightness of 55 percent, but that this is not bright enough. The paper company can use chemicals to bleach its pulp to a 65-percent brightness, but this causes two problems—as the brightness goes up the opacity goes down, and there is an increased effluent problem from the chemicals used as bleaching agents. Therefore, this is only partially acceptable. Another approach is to use a low bulk density clay with a high brightness. Calcined kaolin fits this requirement with a brightness of over 90 percent GEB, but, as usual, the high brightness also means lower opacity. In addition, calcined kaolin reduces the strength of the paper, so that the loading factor is limited to a maximum of 5 percent, and at more than $400/ton FOB, calcined kaolin is uneconomical over 3 percent.

The trend now is to create a mineral additive, consisting of kaolin and other minerals, that will agglomerate the ultrafines, be lightweight, and allow the brightness to be controlled from the 60's to 90's. In this way, there is no need to add a 90-percent-GEB clay to a 60-percent-GEB newsprint and thereby reduce the opacity. In other words, the mineral will be tailored to fit the specific need. In this case, the clay will sell for about one-half of the cost of the pulp or about one-third of the cost of titanium dioxide.

Calcium carbonate or PCC

The other large-tonnage mineral besides kaolin used in the paper industry has been "natural calcium carbonate," a term used for high-brightness, high-quality limestone or marble. There is no specified level when limestone or marble becomes calcium carbonate in the industrial minerals parlance, but a brightness of 80-85 percent GEB is a good dividing line. The North American paper industry consumes around 750,000 short tpa of this material, with a growth rate of around 15 percent per year. Several technological trends have allowed this growth to take place.

The pH or acid/base environment of making paper has an effect on the product. The Egyptians invented the papermaking process and used a basic or alkaline environment for production. Some of the papyrus produced is still extant today. However, in the industrialized era the production process was gradually changed so that an acidic method became dominant. In the past 20 years or so, papermaking based on the alkaline side has been gaining favor once again, most especially in Europe and more recently in North America. It is now estimated that almost 30 percent of the North American production of printing and writing paper (excluding newsprint) is alkaline. This is expected to exceed 45 percent by 1992.

A major drawback with paper produced in an acidic environment is that it is subject to rapid deterioration, as can be seen in the yellow pages that crumble after being on the shelf for just a few decades. This negative archival effect is highly detrimental. In the mill, the alkaline process has technical and economic advantages, particularly in the production of coated fine grades of paper. The pros and cons of the process and the conversion is a subject by itself. The main advantage from an industrial minerals viewpoint (and the paper company's) is the ability to load or fill the sheet with more minerals, including calcium carbonate, thereby replacing expensive pulp while at the same time maintaining paper strength. Some mills have experienced as much as a 10-percent increase in the loading factor which can be as high as 30 percent by weight (50 percent plus has been achieved in the laboratory).

Calcium carbonate is a good filler in paper, has many of the proper characteristics, including brightness, is more universally available than kaolin and is therefore commonly cheaper. However, a carbonate utilized in an acidic environment would create one of the great bubble baths of all time. However, with the advent of "alkaline sizing" it is possible to use calcium carbonate, and suppliers developed suitable grades with tighter size distributions, less abrasiveness, and containing less dispersant. The use of calcium carbonate by no means eliminates kaolin on a technical basis, but it does discourage its use in paper mills remote from a kaolin source.

With the coming of the alkaline sizing process to papermaking, several producers of calcium carbonate expanded production to meet the expected increase in demand. There was a spate of take-overs that rationalized the North American fine-ground calcium carbonate industry down to five major producers—Pfizer, Georgia Marble, Omya Inc., ECC America, and J.M. Huber—plus several minor producers. In addition, companies commenced exploration programs for high-brightness natural calcium carbonate deposits throughout North America. Although only one new high-quality calcium carbonate mine has been developed (in Washington State), expansions have created somewhat of an oversupply situation due to a lower than expected growth in the conversion to alkaline papermaking and the dramatic success of its synthetic equivalent (PCC).

Carbon dioxide (CO_2) is a by-product of the paper mills, and lime (CaO) can be brought to the paper mill from any nearby source. The CO_2 gas is bubbled through the lime to create a precipitated calcium carbonate with high brightness and good uniformity of size. The process can be regulated to produce different sizes and, thereby, different particle size distribution. There is invariably a substantial cost saving in transportation over fine-ground calcium carbonate as well as security of supply. For the most part, however, delivered prices are comparable.

The popularity of this concept has been such that ten satellite plants are currently in operation in North America, with five more starting up this year for a total capacity of 600,000 short tpa. The company spearheading the development of these so-called satellite plants is Pfizer, Inc., which will have a minimum of 11 plants operating by the end of the year, along with one each from Steel Brothers, Champion, Olin, and Finch Pruyn.

This 0.5-0.6 million short tons of PCC, used almost exclusively as a filler, largely detracts from the ultrafine ground calcium carbonate and kaolin. Nevertheless, both these products are essential filler minerals. In fact, recent technical studies are illustrating that a combination of PCC and kaolin can provide greater opacity, higher ash levels per unit of filler in the sheet, and moderate brightness. A study carried out by the State University of New York at Syracuse on mills in Wisconsin and Virginia illustrated that a combination of fillers reduced costs (despite the freight costs of the clay) for the same quality paper.

Talc

Talc is widely used in paper mills as a means of controlling the content of pitch contained in the wood pulp. Something in the range of 150,000 short tpa is used in North America for this purpose. As noted earlier, the Finnish and to a certain extent Scandinavian mills use talc as a functional filler, since the local material is of high quality and is more readily available than high-grade kaolin or calcium carbonate.

Some North America paper mills are now considering the utilization of talc as a function filler. This trend is being led by the Scandinavians with interests in North America and requiring a high-brightness talc of 93-94 percent GEB. At least one Canadian talc producer is on the verge of producing such a grade consistently and is optimistic about the reception in the marketplace.

Table 1. *Summary of North American paper*

	Production (1,000 short tons)			Operating rate
	1986	1987	1988	(percent)
Newsprint	5,630	5,842	5,971	99.3
Uncoated g'wood	1,540	1,485	1,617	86.7
Coated paper	6,263	6,860	7,410	96.9
Uncoated free-sheet	10,410	10,977	11,379	96.6
Bristols	990	1,044	1,130	98.0
Thin paper	247	251	221	71.5
Cotton paper	152	163	162	82.2
Kraft/industrial	5,117	5,072	5,207	92.0
Tissue	5,095	5,301	5,488	95.1
Total paper	35,444	36,994	38,585	95.8
Percent increase	4.3	4.4	4.5	—

Table 2. *Major North American new coated-paper expansions*

Company	Location	Capacity (1,000 tpa)	Startup date
Blandin Paper Co.	Grand Rapids, Minn.	220 CGW	1989
Champion Papers Consolidated	Bucksport, Maine	33 CGW	1989
Papers Inc.	Stevens Point, Wis.	60 CGW*	1989
Internatl. Paper Co.	Corinth, N.Y.	100 CF	1989
Champion Papers	Sartell, Minn.	—CGW	1989
Repap Enterprises Inc.	Newcastle, N.B.	200-260 CGW/CF	1989
Fraser Paper Ltd.	Madawaska, Maine	—CGW	1990
Westvaco Corp.	Wickliffe, Ky.	100 CF	1990
Champion Papers	Quinnesec, Mich.	265 CF*	1990
Scott Paper Co.	Skowhegan, Maine	215 CF*	1990
Scott Paper Co.	Muskegon, Mich.	30 CF	1990
Proposed			
Blandin Paper Co.	Grand Rapids, Minn.	250 CGW	n.a.
Boise Cascade Corp.	Rumford, Maine	—CGW*	1991
Bowater Southern	Calhoun, Tenn.	250 CGW*	n.a.
Fraser Paper Ltd.	Madawaska, Maine	—CGW*	n.a.
GNN/MD Papier	Millinocket, Maine	—CGW*	n.a.
James River Corp.	St. Francisville, La.	—CGW*	n.a.
Mead Corp.	Escanaba, Mich.	—CGW*	n.a.
Pentair Inc.	Niagara, Wis.	92 CGW	n.a.
Internatl. Paper Co.	n.a.	—CF	n.a.
Repap Enterprises Inc.	The Pas, Man.	—CF	n.a.

*New machines. CGW = coated groundwood; CF = coated free-sheet. Source: *Pulp and Paper Week.*

Other possibilities

The filler business is a battleground for substitution. R-and-D departments of suppliers are constantly striving to improve their products and secure additional markets, while the equivalent departments in consuming companies attempt to replace existing fillers with cheaper and/or technically superior varieties.

For example, Japan presently uses around 100,000 tpa of zeolites as a filler in paper. It is generally conceded that this usage would not be so high if high-quality kaolin clays were available domestically. However, despite the lack of high brightness, there are some benefits to the use of zeolites in papermaking. One major kaolin producer has experimented with clinoptilolite and has issued a patent for increasing the brightness to the mid-90's GEB. The initial target was believed to be carbonless carbon paper, but there is now a possibility of using higher brightness clino as a functional filler in newsprint-type paper. This is due to its ion-exchange capacity and possibly molecular-sieve attributes as a scavenger for deleterious chemicals used in the paper-production process. At least one U.S. producer of zeolites is investigating this end use.

There is some substitution potential from outside the mineral industry. For example, Rohm and Haas has been marketing its Ropaque OP-84 as a substitute for TiO_2 in paper coating since 1984. This is a hard, nonfilm-forming styrene/acrylic copolymer latex sphere with a core of water. As the coating dries, the water diffuses out of the core leaving a hollow, air-filled, lightweight sphere with a specific gravity of 0.81 (90 percent lighter than TiO_2). The resultant sphere has excellent light-scattering properties in that light is refracted four times—as it strikes the particle, enters the hollow sphere, strikes the other side of the interior surface, and exits the particle. In addition, the average inner diameter of 0.3 micron is about half the wavelength of light and is ideal for light scattering, and the sphere improves the spacing characteristics of the TiO_2 particles, which tend to pack or crowd. According to the manufacturer, the sphere provides lightweight and other coated paper with:

- Higher levels of gloss
- Greater smoothness for improved print properties
- Higher bulk without loss of gloss
- Lower coating weights without reducing coating thickness
- Improved gloss while maintaining opacity and brightness

Once again, the aim is to achieve high opacity while maintaining brightness and light weight and keeping costs in check. Research will continue to experiment with minerals, chemicals, and "other" materials to satisfy the ever-changing needs of the paper manufacturers.

OUTLOOK FOR NORTH AMERICAN PAPER

During the latter part of the Reagan administration, paper like many other manufacturing industries enjoyed bumper years. The growth has continued in the first months of the Bush administration, and the pundits are cautiously optimistic that growth will continue. The paper industry appears to be confident, with capital spending reaching a record $11,500 million in 1989. There is the ever-present talk of a "mild recession soon," but in the meantime capacity utilization is expected to remain above 95 percent and overall production to grow at 3 percent or better.

There is some variation in the fortunes of the various grades as illustrated in Tables 1 and 2. However, the grade most relevant to industrial minerals, coated paper, continues to grow apace. Consumption, mainly in commercial printing such as magazines, advertising inserts, and catalogues, increased over 8 percent in 1988, and industry analysts forecast a 4-percent increase in 1989. All this is good news for the mineral industry, and proves that subscribers to *Industrial Minerals* are supporting their own industry! ☐

DOGAMI works in many fields: Current activities summarized

Contributed by DOGAMI staff members; compiled and edited by Klaus Neuendorf

INTRODUCTION

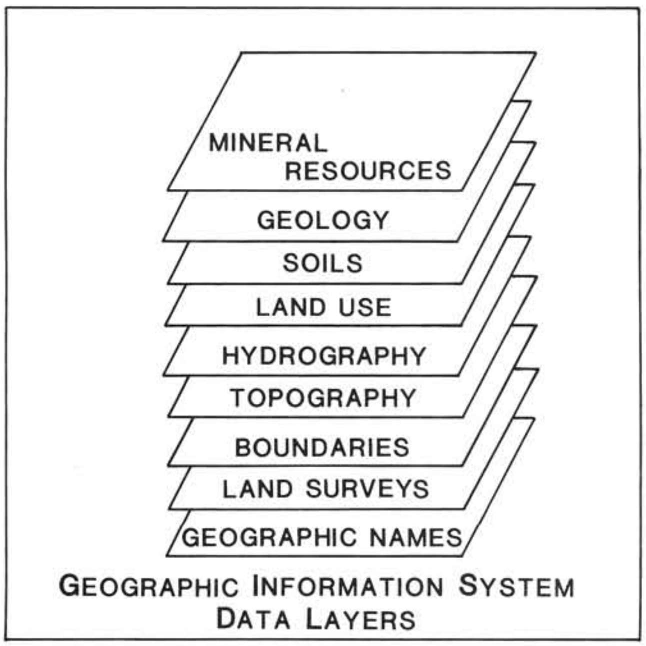
The following is a summary of current activities of the Oregon Department of Geology and Mineral Industries (DOGAMI), both in its main office in Portland and in its field offices in Albany, Baker City, and Grants Pass.

The Portland office serves as a base for most of the Department's major projects and programs. The Albany office is not a geologic field office in the strict sense but the base of the Department's Mined Land Reclamation Program, which has a mostly regulatory function.

PORTLAND

Statewide programs

Economic geology—Jerry Gray is continuing his work on the development of a mineral-resource database. This project includes cooperation with several federal and state natural-resource agencies. Ultimately, it will create a "mineral-data layer" to fit with other portions of Oregon's Geographic Information System (GIS) and a county-by-county mineral database for universal applications by industry, federal, state, and local governments.



Schematic diagram showing typical data layers in a Geographic Information System (GIS).

Ron Geitgey conducts statewide assessments of industrial minerals with attention to resources and markets. After completion of assessments of talc, bentonite, limestone, and silica by various staff members, Ron is currently focusing on pumice. Other industrial-mineral commodities will follow.

Earthquake hazard assessment—George Priest and Ian Madin are working on the development of a geologic database for assessing earthquake risks in Oregon.

A federal grant from the National Earthquake Hazard Reduction Program is funding production of maps of the geology of the Portland metropolitan area, especially areas with significant risk from earthquake shaking. This grant is also funding coordination with other groups and communication of the results to the public. Oregon Senate Bill 955, passed in the last legislative session, directs the Department to take the lead in coordinating assessment and mitigation of a wide range of natural hazards, including earthquakes. The Department recently received $230,000 from the State Emergency Board to set up a permanent seismic hazard assessment program for the state. This program includes the creation of geologic maps and of databases for soil geology and ground response.

Water-resource planning—Dan Wermiel coordinates the Department's participation in statewide water-resource planning and policy development. Currently, this work is focused on the creation of a geologic framework for the planning efforts.

Statewide regulatory activities

Energy minerals—Dennis Olmstead and Dan Wermiel perform the Department's regulatory task for energy minerals. The development of energy minerals, which include oil, natural gas, and geothermal resources, requires regulation to ensure conservation of resources, protection of the correlative rights of mineral owners, and the protection of the safety and environment of Oregonians.

Because geology plays a significant role in the formation of energy mineral resources and in the design and operation of wells that explore for these resources, geologic expertise is an integral part of the regulatory procedure. Thus, the Department has legislative authority to regulate oil, natural-gas, and geothermal exploration and production activities in Oregon. It has exercised this authority since 1949.

Dennis Olmstead checking pressure gauge at a disposal well in Mist Gas Field.

Geothermal exploration drill site of Anadarko Petroleum Company in the Alvord Desert, Harney County.

Regulatory activities include (1) technical evaluation of drilling, production, and well-abandonment programs, and (2) numerous field inspections of well sites before, during, and after drilling. Technical evaluations ensure proper engineering design of the drilling project and protect the correlative rights of mineral owners. Site visits include pre-drilling inspections, testing of blowout-prevention equipment, and inspections of well-plugging procedures and of proper site reclamation. Specialized inspections are also performed for such activities as the plugging of seismic shotholes.

A system of permits and bonds is used to ensure conformance with applicable laws and regulations so that the exploration for and production of energy mineral resources is conducted in a responsible manner. The permit includes technical details of the proposed drilling program, such as the casing program to protect ground-water resources. Close coordination with federal, state, and county agencies is designed to address various environmental and land-use concerns.

Currently, the only natural-gas field in the Pacific Northwest is located in Columbia County, Oregon. The Mist Gas Field, discovered in 1979, has been the most active drilling area in Oregon, averaging 14 wells per year. The recent completion of a natural gas storage project at the gas field requires additional regulation. Other wells are drilled each year throughout the State, requiring further regulatory activity.

Geothermal drilling operations are also regulated. Over the past few years, geothermal drilling has primarily been at the Newberry volcano area in Deschutes County, the Winema National Forest in Klamath County, the Alvord Desert in Harney County, and the Santiam Pass in Jefferson County. The Department's regulatory activities include the technical evaluation of the proposed drilling programs, field inspections during the drilling of the wells, and reclamation site inspections.

The records and cuttings from oil, gas, and geothermal wells are kept by the Department, and, after expiration of a confidentiality period, made available to the public. The Department maintains a warehouse to keep the cuttings, while the well records are located at the agency's main office. The records, which are used for research into the subsurface geology of the state, are continuously interpreted and reinterpreted. These data are integrated with existing data to appraise the state's potential for energy minerals as well as other mineral resources.

Regulatory activities also include legislative work and rule-making. Currently, this includes work on rules for the implementation of new laws, such as the new law regulating seismic shotholes. The law protects ground-water resources that may be affected by shallow oil and exploration holes and regulates reclamation of the affected land surface. Another current project is work on a revision of existing drilling rules.

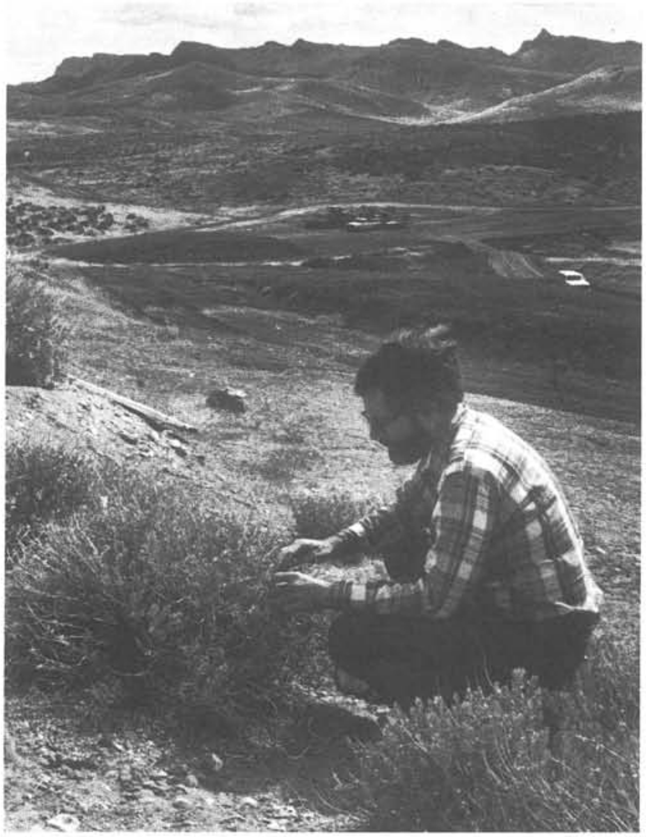
Mined land reclamation—The Mined Land Reclamation Program (MLR) operates from its base in Albany. Supervisor Gary Lynch and staff members Allen Throop, Frank Schnitzer, and Doris Brown (and soon-to-be-added new staff) regulate Oregon's surface-mining activities. This work includes statewide regulation of mining-related exploration, mine design, and subsequent land reclamation, both for aggregate and nonaggregate minerals. In cooperation with other regulatory agencies, MLR works toward protecting the environment and providing beneficial second use of the land.

Other programs

Placer Minerals Task Force—State Geologist Donald Hull co-chairs and staff member Greg McMurray coordinates the Oregon Placer Minerals Technical Task Force, a state/federal body established by the Governor of Oregon and the U.S. Secretary of the Interior. The Task Force recently produced a report summarizing the known black-sand resource in Oregon, its extent and quality, its economics, and the environmental aspects of mining such a resource.

The placer sands, found primarily off the coast of southern Oregon, contain chromium, titanium, gold, platinum, and zirconium. These minerals are economically important, and in some cases the metals are strategic. Production of such minerals has occurred onshore in Oregon in the past. During mineral shortages of World War II, the coastal terraces of southwestern Oregon and the mouth of the Columbia River were explored for chromium and titanium.

Additional basic research is needed to characterize the placer-minerals resource. The recommendation section of the Task Force's recent



Allen Throop of the Mined Land Reclamation Program is examining regrowth of sage planted on a reclaimed portion of a bentonite mine in Malheur County.

report proposes a sample-collection program for 1990 to accomplish this. The proposal includes a two-week oceanographic cruise off Cape Blanco and the Rogue River to collect vibracores and biological samples characteristic of the placer sands. The cruise is scheduled for September.

Offshore resources—Dennis Olmstead oversees completion of key onshore/offshore transects in areas of prime hydrocarbon potential. This program is a contribution to the federal/state processes to estimate resource potential.

Together, Olmstead and John Beaulieu also work on contributions to state policy development with regard to offshore resources.

Santiam Pass scientific drilling project—George Priest is overseeing the cooperative project of drilling a 1-km-deep hole at Santiam Pass in the Cascades for scientific study. A 914-m diamond-core hole to be completed this summer will explore the geologic history of the High Cascades and establish how much heat is flowing out near the crest of the range. The project is expected to yield important geophysical and geologic data and, possibly, aid in the development of a geophysical transect.

This project is part of a wider scientific drilling initiative started by the Department about four years ago to stimulate exploration of large-scale earth processes that have produced mountain ranges, volcanic eruptions, earthquakes, mineral deposits, and geothermal energy in the state.

Tyee Basin assessment—The Tyee Basin project is a five-year study of the hydrocarbon potential of a portion of the southwest Oregon Coast Range. The project was begun in July 1988 and will run through July 1993. The project manager is Gerald Black; his supervisor is George Priest, the Regional Geologist of northwest Oregon. A Steering Committee composed of major donors and landholders in the area provides overall direction.

The study area is an irregularly shaped region that occupies the axis of the Coast Range from a latitude of Glendale on the south to just south of Eugene on the north.

The Tyee Basin project was started in order to stimulate hydrocarbon exploration in the region. There has been long-standing

Charter research vessel Aloha, *to be used as platform during oceanographic cruise of the Oregon Placer Minerals Technical Task Force in September.*

View looking north from Tyee escarpment into Flournoy Valley, Douglas County, the area of the Tyee Basin assessment project. White Tail Ridge in middle distance is composed of deltaic-facies sedimentary rocks capped by continental-shelf-facies sandstones.

interest in the oil and gas potential of the southern Coast Range, and there has been significant drilling there since the early 1900's. This drilling activity includes the Mobil Sutherlin No. 1 well, which is, at 13,177 ft, the deepest hole ever drilled in the state. As recently as 1985, Amoco Production Company drilled two holes to depths of 4,428 and 11,330 ft in the axis of the Coast Range northwest of Sutherlin. At the present time, however, there are no active exploration programs by any of the major oil companies, no lands are under oil and gas leases, and no new wells are contemplated.

DOGAMI believes that the Coast Range in southwestern Oregon has the potential to produce commercial quantities of hydrocarbons and therefore put together a consortium of private and public donors to finance a modest exploration program. Contributors to the study include federal institutions (U.S. Bureau of Land Management and USDA Forest Service), private corporations (Weyerhaeuser, GCO Mineral Company, Menasha Corporation, and the Douglas County Industrial Development Board), and state agencies (DOGAMI and the Division of State Lands). Approximately $110,000 of State Lottery funds are also supporting the work during the present biennium.

To attract the oil companies back into the area, it is necessary to know why they left in the first place. The main reasons were that they did not see good source rock potential, did not see evidence that the area was thermally mature enough to produce oil and gas, did not find particularly good reservoir rocks, and did not understand the stratigraphic framework of the region.

DOGAMI's goals, then, are to provide more source-rock, thermal-maturation, and porosity and permeability data and to improve the quality of the mapping in the basin so that industry understands the geology.

During the first year of the project, the Steering Committee laid out a specific agenda designed to accomplish its long term goals. The specific items on the agenda include:

- 1. Publish a compilation geologic map of the entire Tyee Basin. The map would include every available source of geologic data for the region.
- 2. Compile and publish all available geochemical data.
- 3. Complete a three-dimensional fence diagram. The purpose of this diagram is to tie surface geologic data to subsurface well and geophysical data.
- 4. Conduct detailed geologic mapping to solve specific stratigraphic problems and search for potential reservoir rocks.

A subcontract to accomplish items one and two above was awarded to Alan and Wendy Niem of Oregon State University. The compilation map and accompanying geochemical data were published in March 1990 as DOGAMI Open-File Report O-89-3. The map is a major contribution to the understanding of the geology of southwestern Oregon. The Niems managed to obtain permission to release a large quantity of formerly proprietary oil company data that are included on the map. The Niems are also completing the fence diagram.

Gerald Black completed the field work on a detailed map of the Reston 7½-minute Quadrangle in 1989. In 1990, Black will start mapping in the Camas Valley 7½-minute Quadrangle. By the end of the project, a detailed mapping transect across the southern Coast Range at a scale of 1:24,000 will have been completed.

Technical support

Laboratory—Field studies must be integrated with a variety of analytical techniques for identification, analysis, and age determination of minerals and rocks. Geochemist Gary Baxter and technician Chuck Radasch provide chemical, physical, and mineralogical testing and analyses of samples as needed by all staff geologists in their projects.

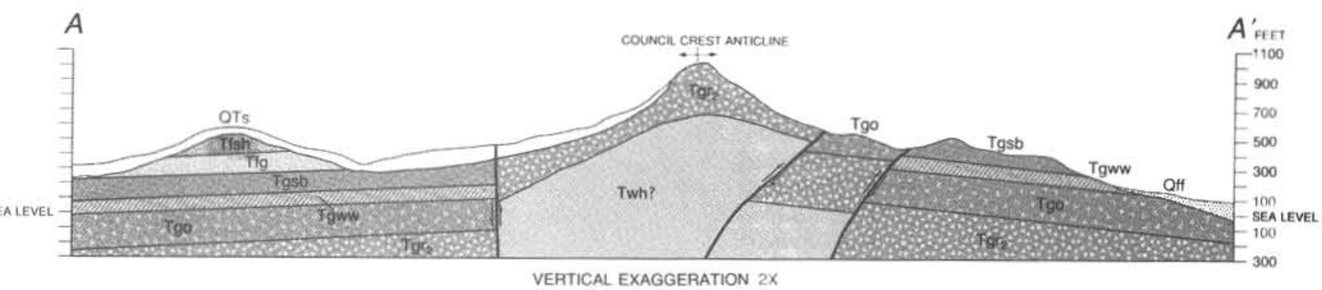
REGIONAL ACTIVITIES

In the Department offices in Portland, Baker City, and Grants Pass, one geologist is identified as Regional Geologist. In addition to regular duties and project work, the Regional Geologist serves the public in matters concerning regional geologic issues and assists local government by contributing to geologic data needs and periodic reviews of county land-use plans.

Northwest (Portland)—As Regional Geologist, George Priest is currently collaborating with Ian Madin to conduct geologic mapping in the Portland area. This mapping is focused mainly on the ongoing studies for earthquake hazard assessment.

In response to new evidence in earthquake research indicating that the "Big One" looms in Oregon's future, DOGAMI is working on an earthquake hazard assessment program for Oregon. Ian Madin

GEOLOGIC CROSS SECTION



A black-and-white version of one of the three colored cross sections included in the first geologic map published in 1989 in connection with the ongoing studies for earthquake hazard assessment in the Portland metropolitan area (DOGAMI map GMS-59). The diagram shows a southwest-northeast-trending section of the area just south of downtown Portland and includes several previously unrecognized faults.

is currently preparing basic geology maps for the Portland metropolitan area in an attempt to locate areas in which soil conditions may increase or reduce earthquake damage. This mapping program also seeks to identify faults in the area and determine whether they are active and capable of generating significant earthquakes.

To date, numerous faults have been located, at least one of which has been active during the last half-million years. The earthquake hazard geology maps for Portland have been released (see page 94). For the rest of 1990, mapping will continue in Clark County, Washington, where a potentially active fault has been recently identified by U.S. Geological Survey seismologists, and in the Damascus area (Clackamas County, southeast of Portland), where more active faults are expected to be present.

Future plans include work on evidence of prehistoric earthquake activity along the coast of Oregon and mapping earthquake hazard geology for the Willamette Valley urban areas. In addition to carrying out research on earthquake hazards, Ian Madin and George Priest are beginning a new program of contracted earthquake hazard assessment using funds recently supplied by the Legislative Emergency Board. This new program also includes the hiring of a geotechnical earthquake engineering specialist.

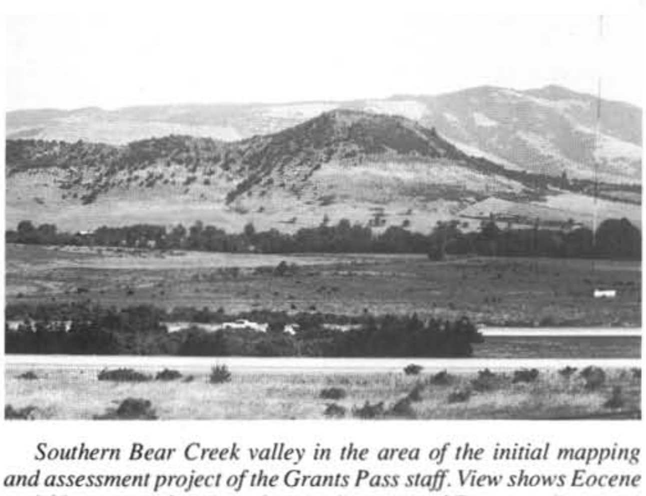
George Priest also supervises geological and geophysical studies throughout northwestern Oregon.

Southwest (Grants Pass)—In October 1989, the Grants Pass Field Office was restaffed and moved to a new location at 5375 Monument Drive. New geologists are Tom Wiley, Regional Geologist, and Frank Hladky, Resident Geologist. Kathleen Murphy is currently filling the position of office specialist.

In order to select a research program for the office, Wiley and Hladkey reviewed geologic, mining, hazard, and land-use data for southwestern Oregon. Project ideas that resulted from this review were discussed with scientists and planners in industry, academia, and government agencies.

The field office staff decided to undertake a multi-year project of mineral-resource assessment and geologic mapping of the area covered by the east-central portion of the Medford 1° by 2° quadrangle. This area covers parts of Jackson and Douglas Counties and includes the cities of Ashland and Medford. It encompasses the southern part of the Western Cascades and parts of the High Cascades and Klamath Mountains. Mineral resources that may occur in the area include aggregate, asbestos, bentonite, clay, copper, decorative rock, diatomite, dolomite, gold, iron, lead, limestone, manganese, mercury, natural gas, nickel, pumice, silica, silver, soapstone, talc, zeolite, and zinc.

Much of the project area is experiencing rapid population growth. In this situation, the detailed geologic maps that result from this project will, above all, provide land-use planners with improved mineral-resource and geologic-hazard inventories. Mapping will proceed by 7½-minute quadrangles, beginning with the Boswell Mountain Quadrangle north of Medford.



Southern Bear Creek valley in the area of the initial mapping and assessment project of the Grants Pass staff. View shows Eocene and Oligocene volcanic rock in the distance and Eocene sedimentary rock capped with Tertiary intrusive rock in the middle foreground.

East (Baker City)—Geologists Howard Brooks and Mark Ferns and office specialist Janet Durflinger serve the eastern part of Oregon in the Baker City Field Office.

The geologic studies in the area are currently focused on the Boise Sheet mapping project, an ongoing cooperative effort of DOGAMI, the USGS, and Portland State University (PSU) to map the Oregon part of the Boise 1° by 2° Quadrangle in the Owyhee region in southeastern Oregon. DOGAMI interest in the region began in 1982, when the Department made a geochemical survey of Wilderness Study Areas (WSAs) for the U.S. Bureau of Land Management. USGS personnel began mapping selected WSAs in 1984; DOGAMI mapping began in 1987; PSU's involvement started with the establishment of annual field camps in the same year.

Succor Creek, Owyhee Mountains, southeastern Oregon. This is part of the area to be covered by the geologic map of the Boise 1° by 2° Quadrangle, the major current concern of the Baker City Field Office. Photo courtesy Oregon State Highway Division.

The major goal of the project is to provide geologic maps that are usable for mineral-resource investigations and land use planning. The recent discoveries of gold in several parts of the region, including some WSAs, underscores the need for detailed geologic maps—not only to assist in identifying and evaluating mineral resources for future public needs but also to aid in the resolution of land use conflicts.

The mapping effort has yielded a number of 7½-minute quadrangle maps (scale 1:24,000): To date, 12 have been completed and published; others are in various stages of completion. A geologic map of the entire area will be compiled and published at a scale of 1:100,000 after the mapping has been completed. □

MINERAL EXPLORATION ACTIVITY

MAJOR METAL-EXPLORATION ACTIVITY

Date	Project name, company	Project location	Metal	Status
April 1983	Susanville Kappes Cassiday and Associates	Tps. 9, 10 S. Rs. 32, 33 E. Grant County	Gold	Expl
May 1988	Quartz Mountain Wavecrest Resources Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
June 1988	Noonday Ridge Bond Gold	T. 22 S. Rs. 1, 2 E. Lane County	Gold, silver	Expl
September 1988	Angel Camp Wavecrest Resources, Inc.	T. 37 S. R. 16 E. Lake County	Gold	Expl
September 1988	Glass Butte Galactic Services Inc.	Tps. 23, 24 S. R. 23 E. Lake County	Gold	Expl
September 1988	Grassy Mountain Atlas Precious Metals, Inc.	T. 22 S. R. 44 E. Malheur County	Gold	Expl, com
September 1988	Kerby Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	Expl, com
September 1988	Jessie Page Chevron Resources, Co.	T. 25 S. R. 43 E. Malheur County	Gold	Expl
October 1988	Bear Creek Freeport McMoRan Gold Co.	Tps. 18, 19 S. R. 18 E. Crook County	Gold	Expl
December 1988	Harper Basin American Copper and Nickel Co.	T. 21 S. R. 42 E. Malheur County	Gold	Expl
May 1989	Hope Butte Chevron Resources, Co.	T. 17 S. R. 43 E. Malheur County	Gold	Expl, com
September 1989	East Ridge Malheur Mining	T. 15 S. R. 45 E. Malheur County	Gold	App
June 1990	Racey Billiton Minerals USA	T. 13 S. R. 41 E. Malheur County	Gold	Expl
June 1990	Grouse Mountain Bond Gold Exploration, Inc.	T. 23 S. Rs. 1, 2 E. Lane County	Gold	Expl
June 1990	Freeze Western Mining Corporation	T. 23 S. R. 42 E. Malheur County	Gold	Expl

Explanations: App=application being processed. Expl=Exploration permit issued. Com=Interagency coordinating committee formed, baseline data collection started. Date=Date application was received or permit issued.

EXPLORATION AND BOND CEILING RULES

The rules covering exploration activity that exceeds one total acre of disturbance or on which a drill hole greater that 50 ft deep is drilled are scheduled to be be presented for adoption at the July 9 meeting of the Governing Board of the Oregon Department of Geology and Mineral Industries (DOGAMI). Companies that fall under the new rules must contact the Mined Land Reclamation Program (MLR) office immediately at the location given below.

Rules governing an increased bond ceiling for some metal mines are also scheduled for adoption at the meeting of the Board.

MINING ISSUES FORUM

A one-day meeting to discuss numerous aspects of the impact of large-scale gold mining in Oregon is scheduled for September 8, 1990, in Bend. Speakers from the industry, environmental groups, elected officials, and regulatory agencies will present a wide range of views and opinions on the subject. More information is available from the MLR office.

STATUS CHANGES

Applications for exploration permits were received from Billiton Minerals, Bond Gold, and Western Mining Corporation, and permits will likely be issued in June.

The Bond Gold application of March 1990 for the Red Jacket site in Jefferson County was withdrawn.

Formosa Exploration, Inc., has received an operating permit for its Silver Peak site, which is therefore no longer listed above.

The Chevron Resources exploration site formerly called "QM" has been renamed "Jessie Page."

All readers who have questions or comments about exploration activities in Oregon should contact Gary Lynch or Allen Throop at the MLR office, 1534 SE Queen Avenue, Albany, Oregon 97321, phone (503) 967-2939. □

DOGAMI publications released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released two new publications:

Released June 4, 1990: ***Earthquake-Hazard Geology Maps of the Portland Metropolitan area, Oregon***, by staff geologist Ian Madin. DOGAMI Open-File Report O-90-2, 21 p., 8 maps (scale 1:24,000), price $9.

The maps are one-color diazo paper reproductions, approximately 25 by 30 in. Each map covers one of the following 7½-minute quadrangles: Beaverton, Gladstone, Hillsboro, Linnton, Lake Oswego, Mount Tabor, Portland, and Scholls. These maps are a product of an ongoing earthquake-hazard assessment that is being carried out by DOGAMI with funding from the National Earthquake Hazards Reduction Program. The maps provide a fundamental geologic base for future detailed studies of variations in earthquake hazard due to local geologic conditions. They also contain information about known or suspected faults in the Portland area and can be used for a crude assessment of relative earthquake hazard.

Released June 22, 1990: ***Geology and Mineral Resources Map of the Mitchell Butte Quadrangle, Malheur County, Oregon***, by M.L. Ferns, DOGAMI, and K.M. Urbanczyk, Washington State University. DOGAMI Geological Map Series GMS-61, 1 map (scale 1:24,000), price $4.

The Mitchell Butte 7½-minute Quadrangle is located north of Owyhee Dam and south of the city of Vale. The two-color map of the quadrangle describes surficial and bedrock geologic units and geologic structure both on the map and in two geologic cross sections. The approximately 27- by 38-in. map sheet also contains brief discussions of the quadrangle's mineral-resource potential and its ground-water resources and shows results of rock-sample analyses in two tables. While gold is the main potential mineral resource of the area, both natural-gas and geothermal-energy resources may occur.

This publication represents another step in the Boise Sheet mapping project, an ongoing study of southeastern Oregon areas with a potential for mineral resources. A description of the project is given in the summary of current DOGAMI activities on page 93 (Baker City Field Office) in this issue.

For ordering information, see page 96 of this issue.□

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GEOLOGICAL MAP SERIES

		Price	√
GMS-4	Oregon gravity maps, onshore and offshore. 1967	3.00	
GMS-5	Geologic map, Powers 15-minute Quadrangle, Coos/Curry Counties. 1971	3.00	
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GMS-8	Complete Bouguer gravity anomaly map, central Cascade Mountain Range. 1978	3.00	
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GMS-14	Index to published geologic mapping in Oregon, 1898-1979. 1981	7.00	
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