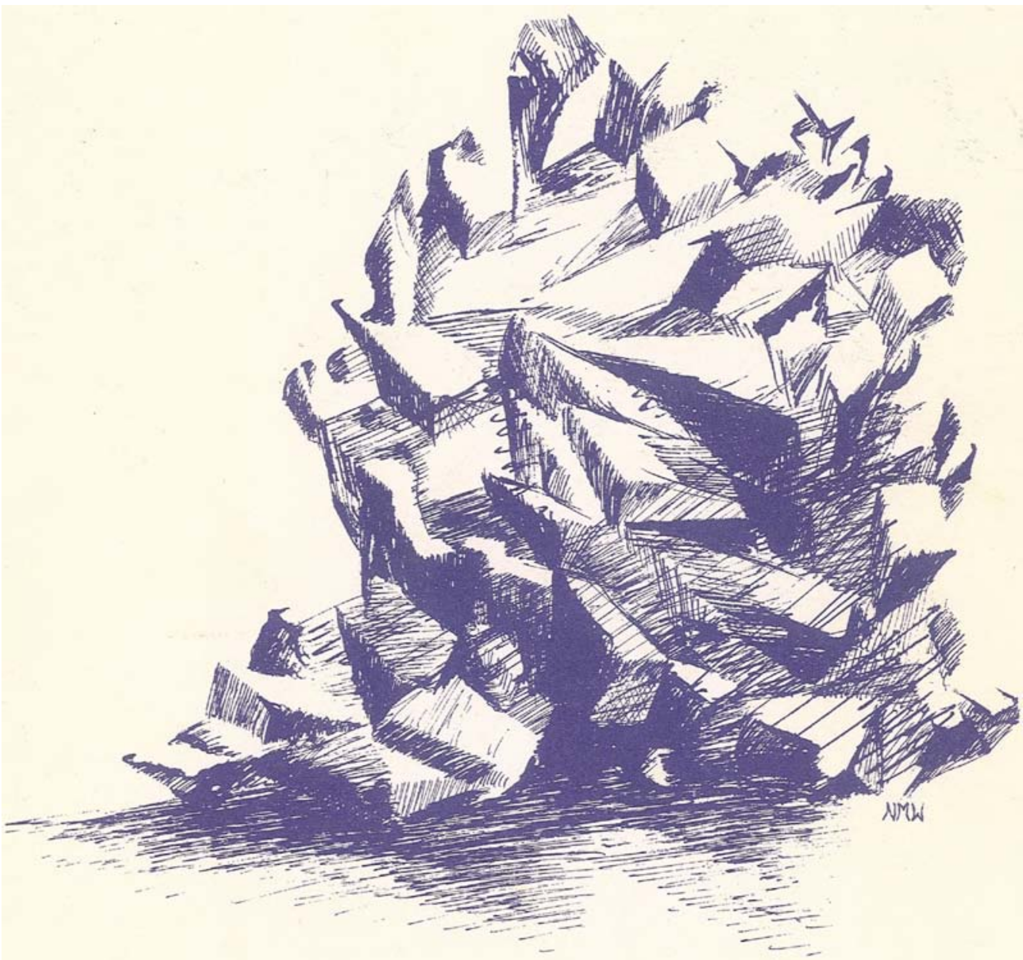
HANDBOOK 3

FLUORSPAR IN TEXAS

W. N. McAnulty, Sr.



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By

W. N. McAnulty, Sr.

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PREFACE

Fluorspar is a basic raw material in the chemical, metallurgical, and ceramic industries. Numerous deposits of fluorspar exist in Trans-Pecos and Central Texas, though up to the present these have been developed only on a limited basis. With the doubling of fluorspar consumption in the United States during the past decade, with depletion of many conventional deposits, and with expected shortages of this basic raw material in the near future, Texas deposits assume greater significance and increased potential for future development.

This Handbook, prepared by W. N. McAnulty, Sr., describes the occurrences, grades, geology, and prospects of development of Texas fluorspar deposits. Dr. McAnulty is a widely experienced economic geologist with special expertise in fluorspar exploration and development. He was formerly associated with The Dow Chemical Company and is presently Professor of Geological Sciences at The University of Texas at El Paso, having just completed tenure as Chairman of that department.

Fluorspar in Texas is one of hundreds of reports on Texas mineral resources published by the Bureau during the past 63 years. It will be of value to those interested in additional development of the State's vast mineral resources.

W. L. FISHER
Director

CONTENTS

Introduction 1
Acknowledgments 1
Uses of fluorspar 1
Hydrofluoric acid 1
Metallurgical uses 2
Ceramic and miscellaneous uses 2
Geology 2
Mineralogy 2
Origins and modes of occurrence 2
Mining and beneficiation 4
Mining 4
Beneficiation 4
Commercial grades and specifications 4
Fluorspar in Texas 5
Occurrences in Central Texas 5
Burnet County 5
Spring Creek area 5
Pavitte silver-copper prospect 8
Sheridan copper prospect 8
Other occurrences in Central Texas 8
Evaluation of occurrences in Central Texas 8
Occurrences in Trans-Pecos Texas 8
Brewster County 8
Christmas Mountains—Corazones Peaks district 8
Terlingua quicksilver district 11
Big Bend National Park 11
Evaluation of occurrences in Brewster County 11
Presidio County 11
Chinati Mountains 11
San Antonio Canyon "mine" 17
Burney "mine" 17
Hillside adit 17
Fluorspar prospect 17
Rock House area 18
Evaluation of occurrences in Presidio County 18
Jeff Davis County 18
Walter Mayfield prospect 18
Hudspeth County 21
Eagle Mountains district 21
Spar Valley 21
North orebody 23
South orebody 23
Rhyolite fault zone 23
Shaft 4 vein 24
Wind Canyon fault zone 24
Fox 4 prospect 24
Fox 1 and 3 prospects 24
Divide prospect 25
Deposit in southwestern part of section 45 25
Fox 9 and 10 prospects 25
Rocky Ridge deposits 26
Other occurrences 26
Deposits in the vicinity of Eagle Spring 26
Lucky Strike prospect 26
Deposits in sections 26 and 27 26
Evaluation of Eagle Mountains district 26
Sierra Blanca peaks district 27
Evaluation of the Sierra Blanca peaks district 28
Quitman Mountains district 28
Evaluation of the Quitman Mountains district 30
El Paso County 30
Franklin Mountains 30
References 31

FIGURES

1. Fluorspar imported through Texas ports of entry, 1950-1970 5
2. Fluorspar in Texas 6
3. Pace-and-compass map of Pavitte silver-copper prospect, Burnet County, Texas 7
4. The fluorite occurrences in the Christmas Mountains-Corazones Peaks area 10
5. Fluorite occurrences in the Terlingua quicksilver district, Trans-Pecos Texas 12
6. Fluorite occurrences in Big Bend National Park area, Brewster County, Texas 13
7. Index map, Chinati Mountains 14
8. Geologic map, West Chinati stock 15
9. Area of San Antonio "mine," alidade survey 16
10. Burney vein, alidade survey 18
11. Hillside adit, Brunton-and-tape survey 19
12. Fluorspar prospect, alidade survey 20
13. Eagle Mountains fluorspar district 22
14. Rhyolite fault zone 23
15. Fox 1 and 3 prospects 25
16. Divide prospect 25
17. Sierra Blanca peaks district, Hudspeth County 27
18. Diagrammatic cross section, Round Top laccolith, Sierra Blanca peaks district, Hudspeth County 27
19. Geologic map, northern Quitman Mountains 29

FLUORSPAR IN TEXAS

W. N. McAnulty, Sr.[1]

INTRODUCTION

Fluorspar, an aggregate of rock and mineral matter containing varying amounts of fluorite (CaF_2), is an important industrial mineral commodity for which there are no known substitutes in its major uses. Fluorspar consumption has increased rapidly in recent years, and from growth trends in the major user industries, during the next decade an even greater upsurge in consumption of all grades can be forecast. It will be difficult to find and produce enough fluorspar in the years ahead to supply the demands of the steel, aluminum, and fluorine-chemical industries. Remote and largely low-grade deposits in Brewster, Presidio, and Hudspeth Counties, Texas are assuming greater significance and probably will be exploited in the near future.

Fluorite is the principal fluorine-bearing mineral. Although phosphate rock commonly contains 2.5 to 3.5 percent fluorine (in apatite) and is potentially a large source, it will not become a major source of fluorine as long as fluorite is available. The principal uses of fluorspar are as a source of fluorine for making hydrofluoric acid, as a flux in metallurgy, and as a raw material in the manufacture of glass and enamel products.

Acknowledgments

Acknowledgment is made of information used from published reports by C. C. Albritton, Jr., V. E. Barnes, G. L. Evans, Elliot Gillerman, R. M. Huffington, J. F. Smith, Jr., and J. R. Underwood, Jr.; their papers are cited in the list of references.

Acknowledgment is also made to F. D. Albritton, Jr., The Dow Chemical Company, Dowdle Oil Company, and Rangaire Corporation for financial aid during several years while studies of fluorspar in Texas were under way.

Illustrations for this paper were prepared at the Bureau of Economic Geology under the direction of J. W. Macon, Cartographer. Cover sketch is by Melinda Wilson.

USES OF FLUORSPAR

Consumption of fluorspar in the United States has increased rapidly during the last 10 years. The amount consumed in 1969 (more than 1.33 million tons) was about 30 percent more than in 1965 and twice the amount used in 1961. In 1969, approximately 700,000 tons was consumed in the manufacture of hydrofluoric acid and 560,000 tons was used by steelmakers. Since 1960, the greatest increase in use has taken place in metallurgical-grade fluorspar. Annual consumption of "metspar" averaged 290,000 tons in the period 1961-65, of which 265,000 tons was for steelmaking; in 1969, consumption exceeded 600,000 tons and the 1970 figure was probably about 700,000.

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Hydrofluoric Acid

By a small margin, the chemical industry presently is the principal consumer of fluorspar, having used approximately 750,000 tons for the manufacture of hydrofluoric acid in 1971. Hydrofluoric acid is an essential compound for the manufacture of synthetic cryolite and aluminum fluoride for the aluminum industry and for many other chemical products, including fluorocarbons for aerosols, plastics, and refrigerants. It is also used as a catalyst in the production of high-octane gasolines. Hydrofluoric acid is used in making UF_6—a thermally stable uranium compound produced in the process for making enriched uranium metal used as a reactor fuel. Fluorine chemistry is in its infancy, and some of the discoveries to be made may be among the greatest achievements of modern chemistry. The organic fluorine industry in the United States is growing at a steady annual rate of 8 percent.

Metallurgical Uses

Fluorspar has been used as a flux in metallurgy for more than 400 years. Agricola, in *De Re Metallica*, written in 1556, mentioned the use of fluorspar. The second largest use of fluorspar today is in steelmaking. Substitutes have been and are being tried, but fluorspar remains by far the best available flux for use in the manufacture of steel and in other metallurgical processes. It increases fluidity of the slag and thereby speeds up the dissolution of limestone in the ore-flux mix, making lime more readily available for removal of sulfur and phosphorus.

The open-hearth method of steelmaking requires 3 to 5 pounds of metallurgical-grade fluorspar per ton of steel produced. The electric-furnace method requires 8 to 10 pounds per ton, and the basic oxygen furnace requires 10 to 15 pounds per ton of steel. During the next 10 to 15 years, open-hearth steelmaking is expected to be replaced by new basic oxygen or electric furnaces. Therefore, there will be a great increase in consumption of metspar by steelmakers.

Finely ground or powdery fluorspar concentrates cannot be used in the ore-flux mix. Gravel size (1- to 1.5-inch mesh) is generally specified, but recently, largely because of the scarcity of natural gravel material, pellets and briquets made from flotation concentrates are being used to a limited degree. It is likely that much more manufactured gravel will be used in the future.

Metallurgical grades of fluorspar are also used in iron foundries in the production of fine-grained castings and in the manufacture of special iron alloys such as ferrochromium and ferromanganese. It is used for its fluxing properties in numerous ways in the refractory, aircraft, and welding industries. Small amounts are used in magnesium reduction and in the smelting and refining of several metals.

Ceramic and Miscellaneous Uses

Estimate of world consumption of fluorspar by the glass, enamel and glaze, and other industries in 1970 was about 280,000 metric tons. Fluorspar is used as a flux and opacifier in making glass. It is used in the manufacture of enamels and glazes for coating metals. Fluorspar is also used in chemicals for water fluoridation; as a flux in the manufacture of portland cement, calcium cyanamide, mineral wool, and optical lenses; as a binder in high-temperature brick; and as an ingredient in dental preparations.

GEOLOGY

Mineralogy

Fluorite (CaF_2), the only simple fluoride mineral known, contains 51 percent calcium and 49 percent fluorine. It crystallizes in the isometric system and has perfect octahedral cleavage. It occurs in aggregates of cubic crystals, as coarse and fine granular masses, in banded and crusted veins, and in massive, sometimes cryptocrystalline bodies. Some of the larger commercial deposits are fine- to very fine-grained replacements of limestone and/or calcareous shale. Coarsely crystalline varieties occur in many colors—white, green, pink, blue, purple, yellow, brown, as well as clear and colorless. Some fine-grained varieties look earthy and are difficult to recognize without the aid of the petrographic microscope. Fluorite has a hardness of 4 on the Mohs scale and a specific gravity of 3.18.

Origins and Modes of Occurrence

Fluorite is a common mineral which forms and exists under a wide range of temperature and pressure conditions. It is therefore a common gangue mineral in a variety of deposits, but commercial deposits, minable just for fluorite, are relatively rare. In many occurrences it is found associated with galena, sphalerite, and barite, and in some places with celestite, strontianite, and witherite. Commonly, it occurs crystallized with calcite, quartz, and pyrite. Almost all commercial deposits appear to have formed directly or indirectly from fluids of magmatic origin. Commercial deposits are known in all types of host rocks as void filling and as replacement veins along faults, fractures, shear zones, breccia pipes, and other brecciated areas; as irregular-shaped replacement bodies in contact zones; and as extensive concordant (mantos) replacement deposits in limestones and calcareous shales. Weathering of primary deposits sometimes results in residual deposits of gravel spar.

Fluorine is a characteristic constituent of some alkaline magmas, and fluorite is usually associated with igneous rocks containing relatively high percentages of silica, soda, and potash, especially with highly alkaline intrusive rhyolites and granites. Fluorine-bearing fluids are believed to be late hydrothermal emanations from the same magma chambers that give rise to the intrusive igneous rocks with which fluorite is associated. Igneous materials not only intrude the country rock, contributing to ground preparation, but also supply the fluorine that reacts with the country rock and forms fluorite deposits in geologically favorable sites.

According to most theories of origin, fluorite is deposited from fluorine-bearing fluids moving upward and outward from a magma chamber along faults and fissures and through permeable rocks where the temperature, pressure, and chemical conditions are favorable. Hydrofluoric acid formed by hydrolysis could react with limestone or calcite encountered as it moves through the country rock to form fluorite ($2\ HF + CaCo_3 = CaF_2 + H_2O + CO_2$).

Fluorite is probably precipitated directly in available open spaces where decreased pressures and temperatures result in supersaturation of fluorine-bearing fluids. Where calcite or limestone ($CaCO_3$) is encountered fluorite is probably deposited both by reaction of hydrofluoric acid in the solutions with calcium carbonate and by replacement of carbonate ions in calcite or limestone by fluorine ions carried in solution. It is likely, therefore, that both void-filling and replacement processes contribute in varying degrees to the formation of a single deposit, and that both processes operate in recurrent cycles. Many of the larger commercial deposits appear to have formed under conditions of low temperature and pressure.

Apparently, ground preparation is important in the formation of fluorspar deposits; faults and fractures provide passageways for the fluorine-bearing fluids. Brecciated zones, especially those capped by relatively impermeable rock, provide sites favorable for void-filling and replacement deposits. In some places the permeability of the host rock has been enhanced by metamorphic processes—for example, by recrystallization or by metamorphosis of limestone to marble. The best host rocks are permeable, nearly pure limestone, underlying relatively impervious rocks. However, occurrences of fluorite in igneous and other rocks prove that presence of limestone or calcium carbonate is not essential to the formation of fluorite. In some deposits calcium may have been supplied by alteration of calcium-bearing primary silicate minerals in igneous rocks and/or by hydrothermal fluids.

Commercial deposits of fluorspar occur in many different forms, the most important of which are:

1. void filling and replacement of fissure veins
2. concordant bedding-replacement bodies in brecciated zones along bedding-plane faults
3. void-filling deposits in solution channels and caverns
4. void filling and replacement of collapse breccia masses in sinkholes and in partially collapsed caverns
5. void filling and replacement of breccias, permeable limestones, and calcareous shales in contact zones
6. void filling and replacement of brecciated limestones and calcareous shales along ring faults associated with cauldron subsidence and collapse
7. void filling and replacement of breccia pipes produced by fluidization
8. void filling and replacement of brecciated shear zones in limestones, calcareous shales, and igneous rocks
9. replacement of xenolithic masses or roof pendants of calcareous rocks in silicic igneous intrusions.

MINING AND BENEFICIATION

Mining

Both opencast and underground mining methods are used for mining fluorspar. Methods employed differ little if at all from those used for mining metallic ore deposits. Compared with metallic-ore mines, fluorspar mines are small, and the degree of mechanization varies greatly from mine to mine, depending on location, size, and shape of the deposit, rate of production, and the financial situation of the operator. Few fluorspar mines yield more than 500 tons per day (tpd); the great majority of them yield less than 100 tpd.

Beneficiation

Most crude fluorspar ore requires some kind of beneficiation to produce a saleable product. Fluorspar ore commonly is a mixture of fluorite, calcite, fine-grained quartz, and wallrock; some ores contain galena and sphalerite and a few contain barite or celestite and minor amounts of a variety of impurities (beryllium and scandium, for example). In the Illinois-Kentucky district, as well as in many districts in foreign countries, the deposits would not be commercial without the income from production of associated sulfide minerals.

Beneficiating methods include simple handpicking and cobbing, washing, screening, jigging, heavy-media (sink-float) separation, and froth flotation. A few small mines use handpicking and cobbing to collect lumps of high-grade fluorspar and produce a premium product. Washing, to remove clay impurities, may be done with mechanical devices such as log washers, vibrating screens, or trommels. Jigging is done at many small mines, but this method usually does not effect a high degree of separation; the heavy-media method is now used in place of jigging at many mines. The heavy-media process is generally successful when the ore can be concentrated without fine grinding. Some producers use both heavy-media (sink-float) separation and froth flotation, producing gravel spar by sink-float for the metallurgical market and treating undersized material from the heavy-media plant in a froth-flotation plant, producing either ceramic or acid grades. Some operators use the heavy-media process to produce a preconcentrate as feed for froth-flotation plants.

In order to convert the fine, powdery fluorspar concentrates produced by froth flotation into a form useable in steel furnaces it is necessary to compress the concentrate into briquets or pellets, using some satisfactory binding agent. As natural metallurgical-grade gravel spar is becoming more difficult to find in sufficient quantities to supply the demand, pelletizing and briqueting plants are now supplying much of the metallurgical-grade requirement. Three pelletizing plants are located in the port area of Brownsville, Texas.

COMMERCIAL GRADES AND SPECIFICATIONS

Fluorspar is marketed in three grades—metallurgical, ceramic, and acid. Metallurgical grades, used chiefly in steelmaking, specify a certain number of "effective units" of calcium fluoride (CaF_2), usually expressed as "effective percent of CaF_2." This figure is obtained by subtracting 2.5 times the percentage of silica (SiO_2) from the percentage of CaF_2 in the ore or concentrate. For example, a concentrate of ore containing 85 percent CaF_2 and 5 percent SiO_2 is 72.5 percent effective CaF_2. The grades commonly listed in market quotations are 60, 70, and 72.5 percent effective CaF_2.

Ceramic and acid grades are of higher purity than metallurgical grades and specifications are expressed in percentage of CaF_2. Ceramic grades range from 85 to 96 percent CaF_2. Acid grade, used chiefly in the aluminum and chemical industries, must contain 97 percent or more CaF_2. In addition, for some uses there are rigid restrictions on the amount of certain impurities in the 3 percent or less of material in the acid-grade product that is not calcium fluoride.

An aggregate total of only about 13,000 tons of fluorspar has been mined from deposits in Texas, but fluorspar has contributed a great deal to the economy of the State since 1950 and will contribute even more in the future. From 1950 through the first 10 months of 1971, a total of 6,675,175 short tons of fluorspar was imported through Texas ports of entry for consumption in the United States (fig. 1). Of the tonnage imported, 3,598,947 tons contained more than 97 percent CaF_2 (acid grade), and 3,076,228 tons contained less than 97 percent CaF_2 (ceramic and metallurgical grades, mostly metallurgical grade).

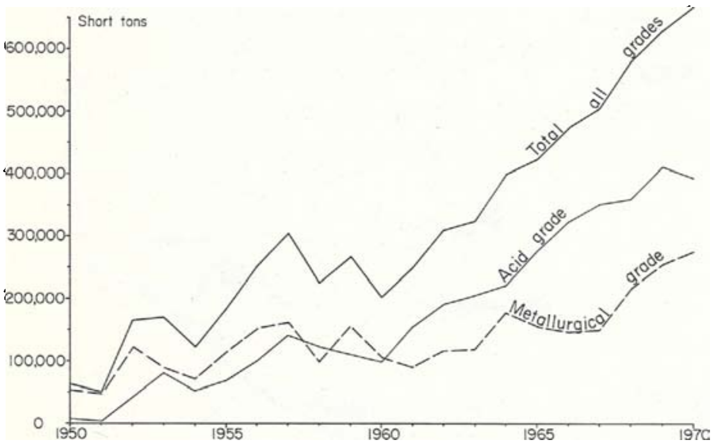

Figure 1. Fluorspar imported through Texas ports of entry, 1950-1970.

The value of these imports was $173,109,238. The ports of entry through which the bulk of tonnage passed are Brownsville, Eagle Pass, and Marathon; smaller amounts were imported through Houston, Laredo, Del Rio, Presidio, and El Paso. Large grading and shipping terminals are located at Brownsville, Eagle Pass, and Marathon; a flotation plant is located in Eagle Pass, and there are three pelletizing plants in the Brownsville area. Handling, beneficiating, and transporting fluorspar provide employment directly and indirectly for several hundred Texans.

Fluorspar occurrences are known at several places in Trans-Pecos Texas—in Brewster, Presidio, Jeff Davis, Hudspeth, and El Paso counties—and in the Central Mineral Region in Burnet, Llano, and Mason counties (fig. 2). However, almost all the tonnage mined was taken from deposits in the Eagle Mountains in Hudspeth County; a few tons were mined from a deposit in the Chinati Mountains, Presidio County, and from a deposit in the Quitman Mountains, Hudspeth County. None of the occurrences in Texas have been adequately explored.

I have examined all the known occurrences in Trans-Pecos Texas during the past 20 years; the deposits in the Chinati and Eagle Mountains, Presidio and Hudspeth counties, respectively, have been reevaluated since 1969. New deposits have been discovered around the Sierra Blanca peaks in Hudspeth County. Deposits in these areas, as well as in the Christmas Mountains, Brewster County, have commercial potential and will probably be exploited to some extent in the not-too-distant future.

Occurrences in Central Texas

BURNET COUNTY

Fluorspar occurrences are known in three areas in Burnet County—the Spring Creek area, the Pavitte silver-copper prospect, and the Sheridan copper prospect. I have not seen any of the occurrences in Central Texas, and the following statements are based on reports by Barnes (1936a, b; 1943).

Spring Creek Area

The fluorite prospect in the Spring Creek area is 5 miles west of Burnet on the Bailey place. This and other prospects in Burnet County were described by Paige (1912). Coarsely crystalline fluorite, along with small amounts of copper minerals and traces of gold and silver, occurs in thin veins and stringers and irregular-shaped bodies in the Valley Spring Gneiss (Precambrian). Barnes (1943) commented on the Valley Spring Gneiss and the fluoritization in the area as follows:

> In the vicinity of the fluorite prospects, a large number of pegmatites and aplitic granite dikes trending in many directions cut the Valley Spring Gneiss. These dikes appear to have been introduced after the Valley Spring Gneiss was folded. The Valley Spring Gneiss is complexly folded, and only a few folds are indicated on the accompanying pace-compass map [fig. 3]. The average strike of the Valley Spring Gneiss in this area is approximately east-northeast and the average dip is approximately 30° to the south-southeast. The fluorite prospects are roughly aligned in the same direction, and the fluorite must be distributed, therefore, throughout several hundred feet of the Valley Spring Gneiss. The manner in which the fluorite was introduced into the Valley Spring Gneiss needs to be

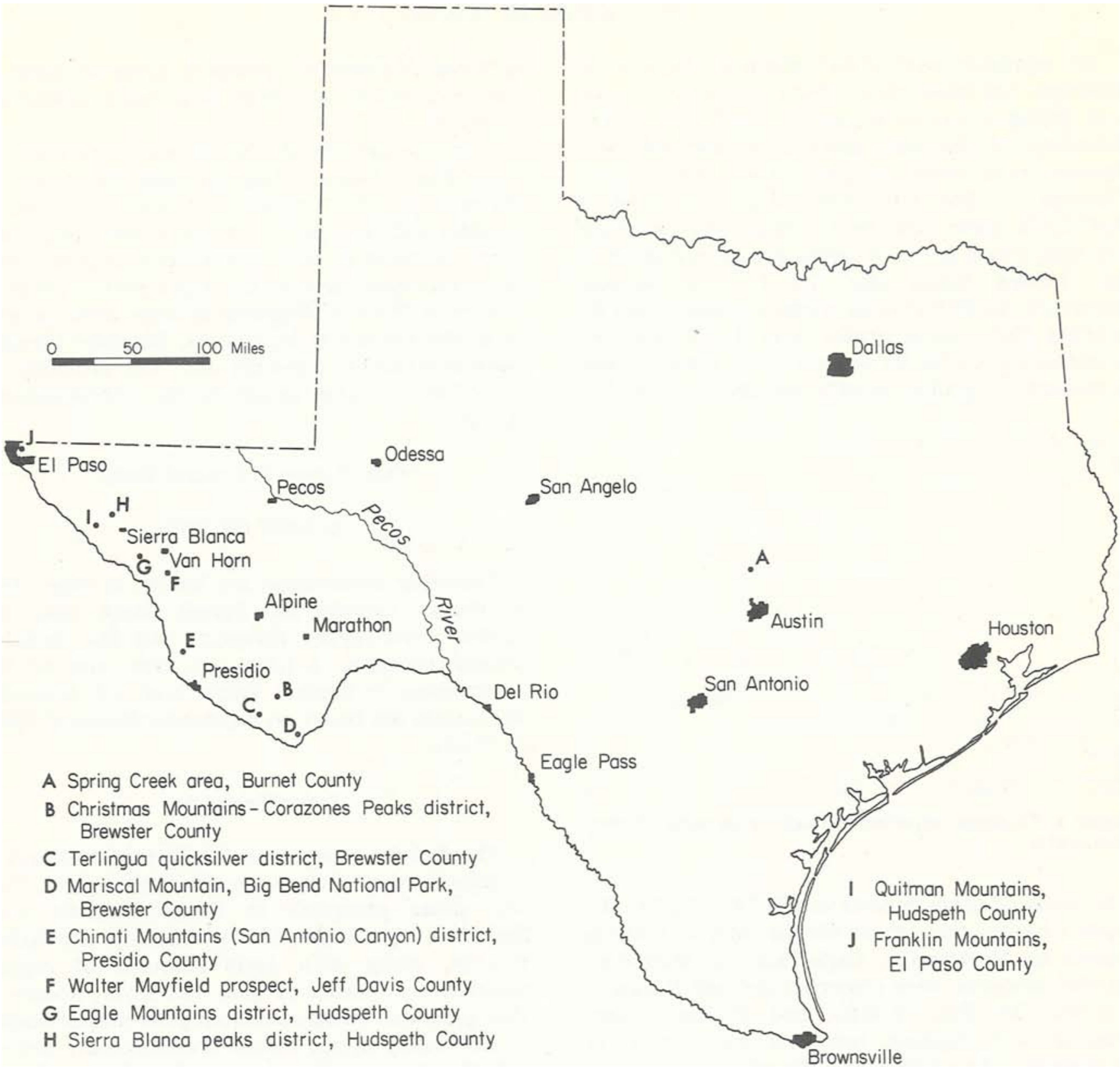

Figure 2. Fluorspar in Texas.

investigated. A suggestion of the source has recently been found during the examination of some pegmatitic dikes which are offshoots of the Town Mountain Granites. These pegmatites, located in Llano County southeast of Packsaddle Mountain, contain an appreciable amount of fluorite and topaz. It is likely that the fluorite of the Burnet area is derived from the same granites and may have been introduced during the period of pegmatite injection . . . . In all of the localities examined, the fluorite contains either chalcopyrite or alteration products of it, such as malachite and azurite. The amount of copper present appears to be insignificant. . .

Fluorite is exposed in several prospect holes extending for a distance of one-half mile in the Spring Creek area in Burnet County [fig. 3]. Prospecting in the past has been confined to the shallow test pits and shafts. The prospecting done so far is inadequate either to prove or disprove the presence of fluorite in commercial quantities. It is true that the ore in sight is mostly of a milling grade, that the fluorite so far exposed is in irregular masses and stringers, and that in general the surface showings are discouraging, but as yet not enough prospecting has been done to determine the direction of the mineralized zone or any of its dimensions.

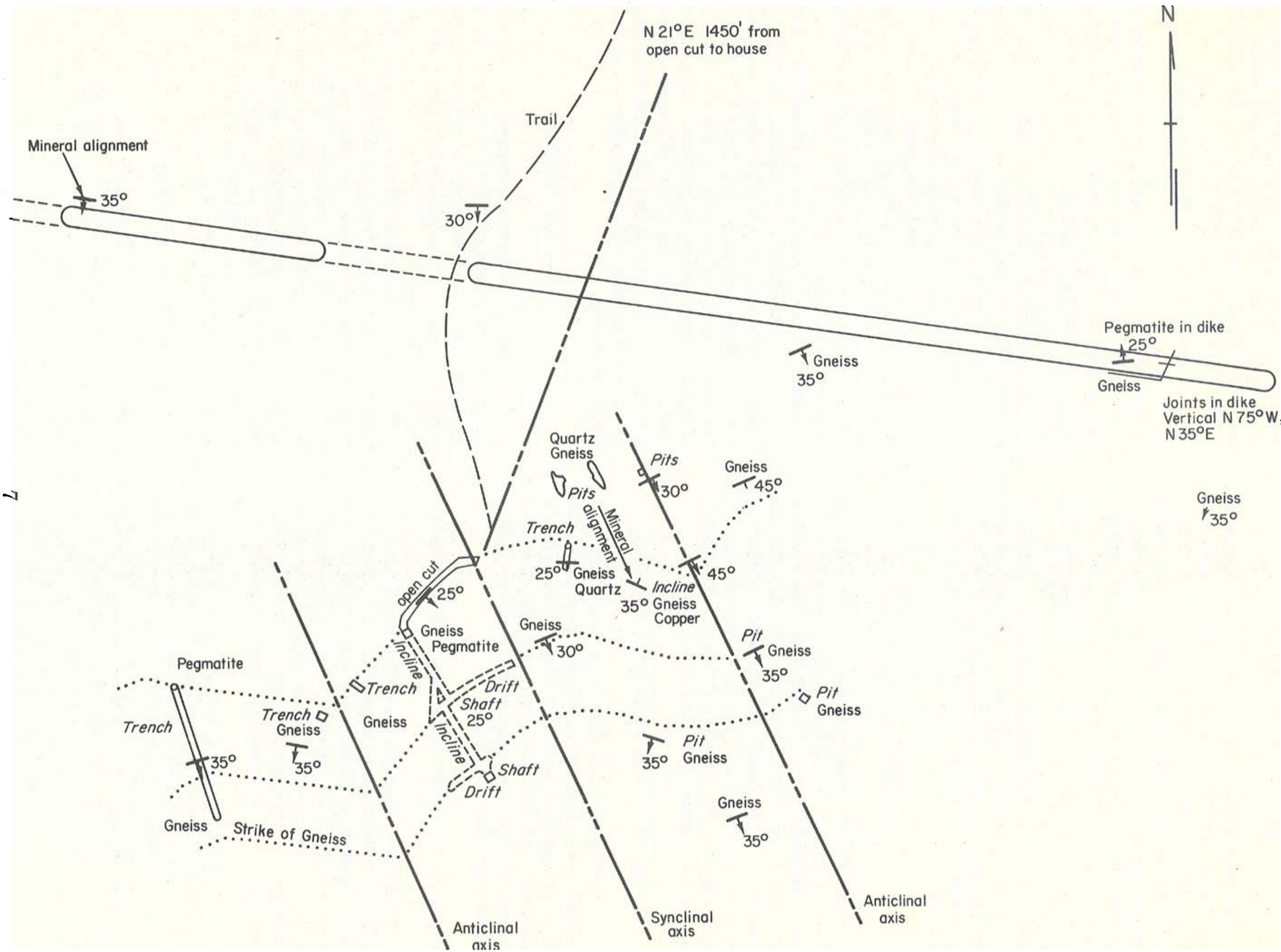

Figure 3. Pace-and-compass map of Pavitte silver-copper prospect, Burnet County, Texas (Barnes, 1936b).

Pavitte Silver-Copper Prospect

The Pavitte silver-copper prospect was described by Barnes (1936b). It is in the Spring Creek area, near the deposits mentioned above. The fluorite mineralization is in the Valley Spring Gneiss, where copper minerals (azurite, malachite, and chalcopyrite) have developed in a fluorite gangue. According to Barnes (1936b), this deposit is "a fissure deposit and not of a pegmatitic origin as might be thought from its association with a pegmatite dike. The mineral association, while not entirely conclusive, is suggestive of veins belonging to the hypothermal zone of deposition. The lack of structure in the ore helps to substantiate this conclusion."

Sheridan Copper Prospect

The Sheridan copper prospect is 6.3 miles due west of Burnet. The mineralization is in a vein in the Packsaddle Schist (Precambrian) and is similar to that at the Pavitte prospect. The vein material consists of chalcopyrite, tetrahedrite, malachite, azurite, and pyrite in a gangue of fluorite, quartz, and amphibolite (Barnes, 1936a); some molybdenite is associated with the chalcopyrite.

OTHER OCCURRENCES IN CENTRAL TEXAS

According to V. E. Barnes (personal communication), some fluorspar is revealed in prospect pits in coarse-grained bodies in Mason and Gillespie counties. The Gillespie County locality (7-19B) is shown in the northeast corner of the Hilltop quadrangle (Barnes, 1952).

EVALUATION OF OCCURRENCES IN CENTRAL TEXAS

In general fluorspar deposits in Precambrian schists, gneisses, and pegmatites are small and occur randomly. Therefore, it seems unlikely that large, commercial deposits exist in Precambrian rocks in the Central Texas region. Concerning fluorspar in the Llano region of Central Texas, Sellards and Evans (1946, pp. 369-370) stated:

> The fluorspar in the Llano region occurs in pegmatite dikes and as lenses and dilatory veins in Precambrian schists and gneisses. Some prospecting has been done at different times on deposits 5 miles west of Burnet in Burnet County. Much of the exposed fluorspar is coarsely granular material containing small amounts of such impurities as hornblende, biotite, copper carbonate, and metallic sulphides. Careful mill treatment, which would be practicable only in handling comparatively large tonnages, would probably eliminate all or nearly all of the objectionable mineral matter. The prospects in the Llano region have not yet revealed deposits capable of supporting profitable mining.

Occurrences in Trans-Pecos Texas

Commercial and/or potentially commercial deposits of fluorspar are present in the northern part of the Christmas Mountains, Brewster County; in the southwestern portion of the Chinati Mountains, Presidio County; and in the Eagle Mountains and the area of the Sierra Blanca peaks, Hudspeth County (fig. 2). Occurrences with little or no commercial potential are known in the Terlingua quicksilver district, Brewster and Presidio Counties; in the Walter Mayfield manganese prospect, Jeff Davis County; in the Quitman Mountains, Hudspeth County; and in the Franklin Mountains, El Paso County (fig. 2). None of the Trans-Pecos deposits or occurrences have been adequately explored and evaluated.

Nearly all the occurrences in Trans-Pecos Texas are closely associated with granitic or rhyolitic igneous intrusions (dikes, sills, plugs, laccoliths, stocks) and are similar in that respect to most of the large commercial deposits in Mexico. The type of fluoritization found in northern Coahuila and Chihuahua, Mexico, extends northwestward across the Rio Grande through Big Bend National Park, across the Big Bend area and far West Texas, and into New Mexico.

BREWSTER COUNTY

All known fluorspar occurrences in Brewster County are listed and described in some detail by McAnulty (1967). A summary of material in that publication and some later information are included in this report.

Deposits in Mariscal Mountain in Big Bend National Park may be equal in size and grade to large commercial deposits in the San Vicente district 5 to 10 miles southward across the Rio Grande in Coahuila. Several small deposits are known in the Christmas Mountains area as well as inside and outside Big Bend National Park; fluorite mineralization is also widespread throughout the Terlingua mercury district (figs. 4, 5, 6).

Christmas Mountains—Corazones Peaks District

The Christmas Mountains—Corazones Peaks district covers approximately 40 square miles of rough, mountainous terrain located just north of the northwest boundary of Big Bend National Park, within parts of the Paint Gap, Nine Point Mesa, Agua Fria, and Terlingua U.S.G.S. topographic quadrangles. The center of the district is about 85 miles south of Alpine, Texas.

The area of the Christmas Mountains and Corazones Peaks is geologically complex. The Christmas Mountains are made up in large part of highly faulted and intruded Cretaceous sedimentary rocks and a variety of igneous rocks. The Cretaceous strata are domed and deformed resulting from emplacement of dikes, sills, plugs, and irregular-shaped plutons of gabbro, basalt, rhyolite, and trachyte. Several of the larger intrusions produced considerable local deformation and faulting. East and West Corazones Peaks, pluglike bodies of sodic rhyolite, are among the most prominent topographic features in the district and form the northern boundary of the district.

Fluorspar was discovered in the Christmas Mountains in 1952 by geologists employed by The Dow Chemical Company, in the course of a project supervised by the writer. During 1955, Dow geologists found several other deposits and occurrences in the district (fig. 4). The first deposits discovered are in section 94, block G-4, D. & W. Ry. survey, in Santa Elena Limestone (Cretaceous) along and near the contact with a slightly discordant, tabular body of rhyolite. Fluorite was formed by replacement of the limestone, brecciated areas being more extensively replaced. Several small pods of fluorspar occur at intervals in the narrow contact zone. Fluorspar also occurs intermittently in the limestone in a 600-yard-long zone parallel to, but a short distance away from, the limestone—rhyolite contact. Veinlets of fluorite extend from the contact outward into the limestone for several feet.

The fine-grained, replacement-type fluorspar in these and other deposits in the district is similar in appearance and mode of occurrence to contact-metasomatic deposits such as those at Cuatro Palmas, Aguachile, Las Cuevas, Refugio, and others in Mexico. Grains of fluorite ranging from 0.01 to 5 mm in diameter make up a crystalline granular mosaic. The principal impurities are calcium carbonate and silica (largely in calcite and chert, respectively). The fluorpsar varies from light to dark purplish gray to purple. The average composition of four samples analyzed by the Central Laboratory of The Dow Chemical Company, Freeport, Texas, is: CaF_2, 71.5 percent; $CaCO_3$, 14.2 percent; SiO_2, 9.1 percent; $CaSO_4$, 1.1 percent. The CaF_2 content ranged from 60.3 to 81.4 percent.

Several fluorspar deposits crop out in contact zones around two rhyolite plugs, Hills 5460 and 4933 on the Paint Gap quadrangle, in section 131, block 4, H. E. & W. T. Ry. Co. survey; in section 4, block 11, C. A. Adams grantee; and in the section just north of section 4. The area containing these occurrences is shown on the Paint Gap quadrangle in the rectangle bounded by the following grid lines: on the south by 660,000; on the north by 665,000; on the east by 1160,000; and on the west by 1165,000.

Hill 5460 is composed of Cretaceous strata surrounding an intrusive core of rhyolite. The Buda Limestone crops out in an almost continuous band near the base of the hill. There are scattered erosional remnants of fault blocks of Boquillas Limestone on the slopes above the Buda outcrop. The largest outcrop of fluorspar in this area is along the Buda Limestone—rhyolite contact on the north side of the hill, where a block of Buda Limestone about 1,200 feet long and 200 feet wide rests on rhyolite and dips about 20°N. The limestone is fluoritized near the contact with the rhyolite. The deposit of fine-grained fluorspar has an average thickness of 5 feet along a length of about 1,000 feet, and it can be seen to extend downdip for 40 feet. A sample taken from the weathered outcrop contained 57.5 percent CaF_2. This outcrop is covered by a patented mineral claim owned by The Dow Chemical Company and is now being mined on a small scale.

Fluorspar crops out for 60 feet along the contact between Del Rio Clay and intrusive rhyolite at a place higher on the north slope of Hill 5460, about 1,000 feet south of the deposit described above. A composite sample taken over the outcrop contained 71.8 percent CaF_2. At this locality small "islands" of Del Rio Clay and Buda Limestone are surrounded by intrusive rhyolite, and the size of individual deposits of fluorspar depends on the size of the "island."

Three small outcrops of fluorspar are known on the western slope of Hill 5460, the largest of which (180 square feet) is exposed in a gully along a Buda Limestone—rhyolite contact. A sample from this deposit contained 83.5 percent CaF_2. Farther up the slope, about 300 feet northeastward, are several small outcrops of fluorspar surrounded by colluvium; approximately 800 feet south of this area is a small exposure (2 feet thick and 10 feet long) of fluorspar in Boquillas Limestone. A composite sample from all these outcrops contained 78.3 percent CaF_2.

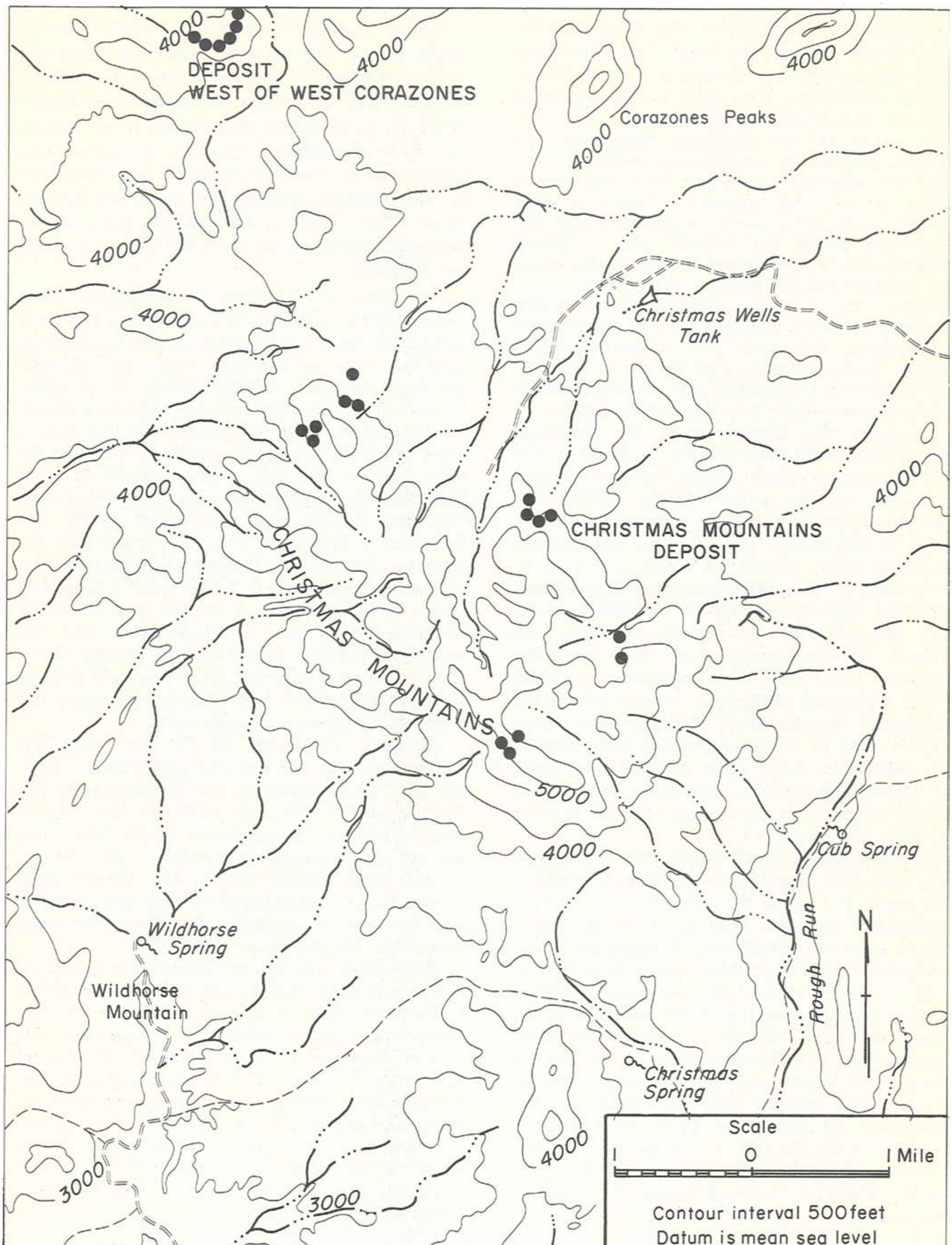

Figure 4. Fluorite occurrences in the Christmas Mountains—Corazones Peaks area.

Hill 4933, situated about 2 miles north of Hill 5460, is also composed of deformed Cretaceous strata resting on intrusive rhyolite. Limestone–rhyolite contacts are exposed at only a few places, where arroyos have cut through the thick colluvial cover, but fluorspar was observed at several places along both Buda Limestone–rhyolite and Boquillas Limestone–rhyolite contacts. All the outcrops of fluorspar are small, but there is appreciable fluorspar float in the colluvium on the slopes. A sample from one of the larger outcrops contained 67.2 percent CaF_2.

The northernmost fluorspar outcrops known in this district occur on a laccolithic structure about 1.5 miles northwest of West Corazones Peak. Small pods and veinlets of fluorspar occur in Santa Elena Limestone near the limestone–rhyolite contact.

Several small outcrops of fluorspar are known at different places in high and rugged portions of the Christmas Mountains; there are no roads into these areas, and the outcrops can be reached on foot only with considerable effort.

Terlingua Quicksilver District

Fluorite is a minor gangue constituent in many of the mercury deposits in the Terlingua quicksilver district (fig. 5). The Terlingua district extends southwestward across the Terlingua monocline from Study Butte almost to Lajitas and northwestward to the Solitario. Most of the district is in southwestern Brewster County, but a few mines are in southeastern Presidio County. Fluorite in small honey-colored cubes is abundant in many of the old mine and prospect dumps in the Mariposa–Black Mesa area, at the Fresno mine, and on Reed Plateau. Small veins, veinlets, and irregular-shaped pods are numerous in the district. The mineralization is generally in the Santa Elena Limestone and is commonly associated with collapse breccias in sinks.

Big Bend National Park

Fluorspar is exposed at several places on Mariscal Mountain in Big Bend National Park (fig. 6). This mineralization is a northern extension of that which produced large, high-grade deposits of fluorspar in the San Vicente district just south of the Rio Grande in Coahuila, Mexico. As mining is prohibited in National Parks, many geologically favorable areas within the Park have not been prospected.

Evaluation of Occurrences in Brewster County

All known occurrences of fluorspar in the Christmas Mountains–Corazones Peaks district are replacements of fine-grained limestones adjacent to or near contacts with intrusive rhyolite and are similar in this respect to some of the larger, high-grade deposits in Mexico. Some of the largest commercial fluorspar deposits in the world are of this type. However, most of the occurrences in this district appear to be too small to be minable at a profit. A few thousand tons of ore could be profitably mined from two or three deposits on the north slope of Hill 5460, and other occurrences on Hill 5460 and Hill 4933 merit exploration. The fluoritization exposed in these areas is in either the Buda or Boquillas Limestone, neither of which is as susceptible to replacement as is the underlying Santa Elena Limestone. The Santa Elena Limestone–intrusive rhyolite contact should be explored. It is doubtful that it would be economically feasible to spend the money required to build roads and explore the several occurrences known in the main body of the Christmas Mountains. Future exploration and mining in this district will be hampered by a real estate development in the area by Terlingua Ranch Company; much of the land has been purchased by this group and is being sold off in small "ranchette" tracts. A few tens of tons of fluorspar possibly could be mined from a deposit on Reed Plateau in the Terlingua quicksilver district, but few if any of the other known occurrences in the district appear to be commercial.

Deposits in Big Bend National Park constitute a potential reserve for the future—possibly during a national emergency.

PRESIDIO COUNTY

Chinati Mountains

The only known occurrences of fluorspar with commercial potential in Presidio County are in the southwestern Chinati Mountains, in the vicinity of San Antonio Canyon. In this area fluorspar occurs in fissure veins, associated with lead-zinc-copper-silver mineralization, and in a stock of porphyritic hornblende granite (McAnulty, 1972). Most of the occurrences are on the Mesquite ranch.

The Chinati Mountains are in south-central Presidio County (fig. 7); they extend southeastward from Pinto Canyon to Shafter, about 18 miles. Shafter, a ghost mining town, is 49 miles

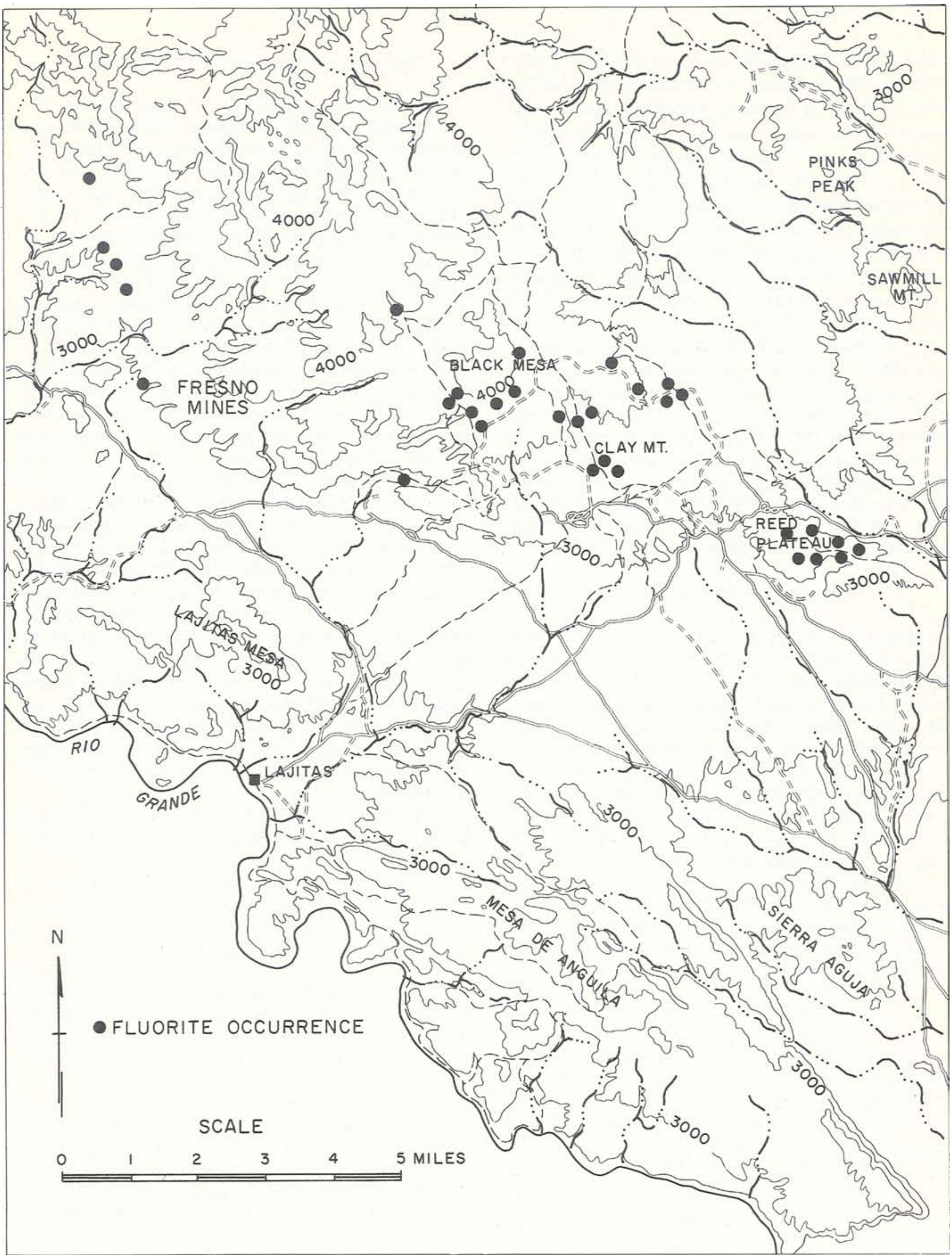

Figure 5. Fluorite occurrences in the Terlingua quicksilver district, Trans-Pecos Texas.

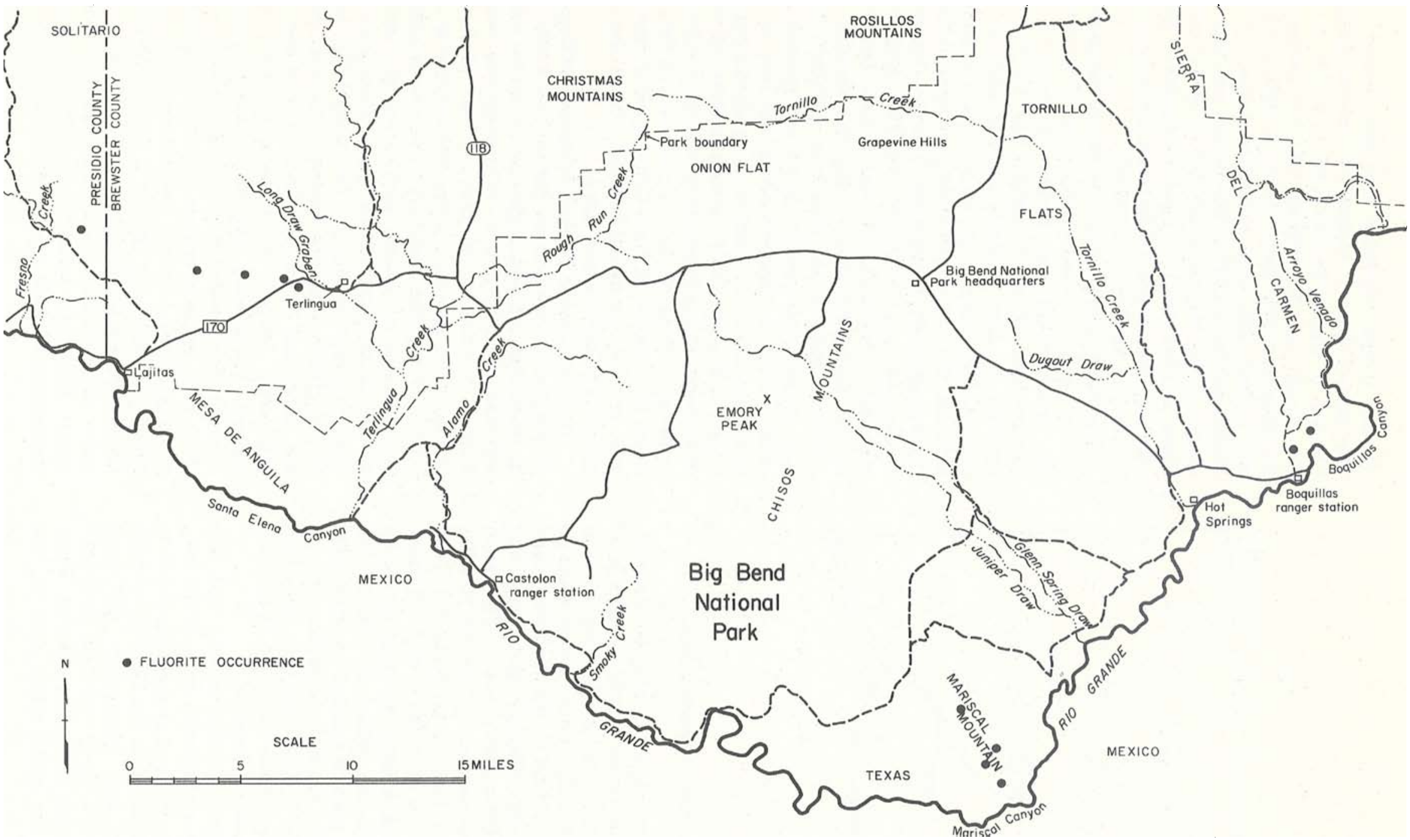

Figure 6. Fluorite occurrences in Big Bend National Park area, Brewster County, Texas.

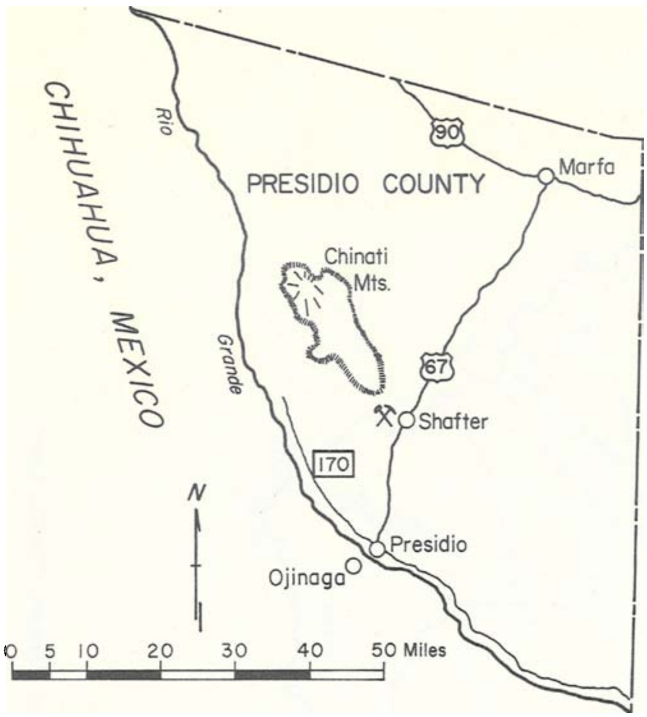

Figure 7. Index map, Chinati Mountains.

southwest of Marfa, via U.S. Highway 87. Presidio, a small town on the Texas—Mexico border, is 59 miles southwest of Marfa at the end of U.S. Highway 87. The Mesquite ranch covers approximately 42,000 acres of land on the southwest slope of the southwestern Chinati Mountains and adjacent relatively flat country below. The ranch headquarters may be reached by traveling 20 miles northwestward from Presidio on State FM Road 170, thence northward on a dirt road for 8 miles. San Antonio Canyon, a large reentrant carved by stream erosion into the southwest side of the Chinati Mountains, may be reached by continuing northward from the ranch headquarters over a rough ranch road for 7 miles. The U.S. Army Map Service Presidio topographic map (NH 13-8), scale 1:250,000, 1959, covers the area.

Until the summer of 1969, when I was permitted to make a reconnaissance study of the area, almost no geological work or prospecting had been done on the Mesquite ranch for 25 years because entry to geologists and prospectors had been refused by the owners. There was some small-scale mining and prospecting before the area was closed. Old workings in the northeastern part of San Antonio Canyon probably were made about 1900. The Burney "mine," located west of San Antonio Canyon, in section 38, block 60, G. S. & S. A. Ry. Co. survey (fig. 8) probably was first prospected for silver and gold about 1890. A 200-foot shaft and a short adit were excavated during the late 1930's and early 1940's. The Burney property was examined by engineers of the U. S. Bureau of Mines in 1943 and 1944, and the Bureau of Mines diamond core drilled 1,742 feet in six holes on the property in 1946 (Dennis, 1947).

The West Chinati stock, in which the mineralization occurs, has an outcrop area of more than 40 square miles and makes up most of the southwestern Chinati Mountains (fig. 8). It is well exposed in San Antonio Canyon and on the southwestern slope of the mountains. The contact between the stock and older overlying volcanic flows is exposed in upper San Antonio Canyon at an elevation of about 6,500 feet. The contact dips eastward in that area. All volcanic rocks have been eroded from the stock along the summit and southwest slope in the area west of Chinati Peak. The contact between the stock and sedimentary country rock is obscured along the base of the southwest side of the mountains by alluvial-fan and bolson sediments. Roof pendants and/or xenoliths of Cretaceous and Paleozoic limestones are known in the area. Contacts with Cretaceous and Permian strata are exposed in Pinto Canyon and around the west end of the mountains but not in the area covered by the Mesquite ranch.

The West Chinati stock is composed principally of porphyritic hornblende granite and is intruded by numerous dikes and plutons of various shapes and sizes. Dikelike bodies of microgranite ranging from a fraction of an inch to tens of feet in thickness are common. Dikes and irregular-shaped bodies of rhyolite porphyry, trachyte porphyry, and breccias of several rock types are present around the margins(?) of the stock. There are a few small outcrops of diorite. The porphyritic hornblende granite is highly weathered in outcrops on the slopes and on canyon floors. Divide areas are commonly capped by a more resistant, finer grained porphyritic granite—a hood zone(?). Beneath this protective hood the more typical stock rock exhibits intense spheroidal weathering at many places. Joint sets are well developed in the stock, especially sets striking E.-W. and N. 50° E. Closely spaced, steeply dipping joints form sheeted zones which weather more easily and form saddles across divide and summit areas. The topographic expressions of these sheeted zones are conspicuous

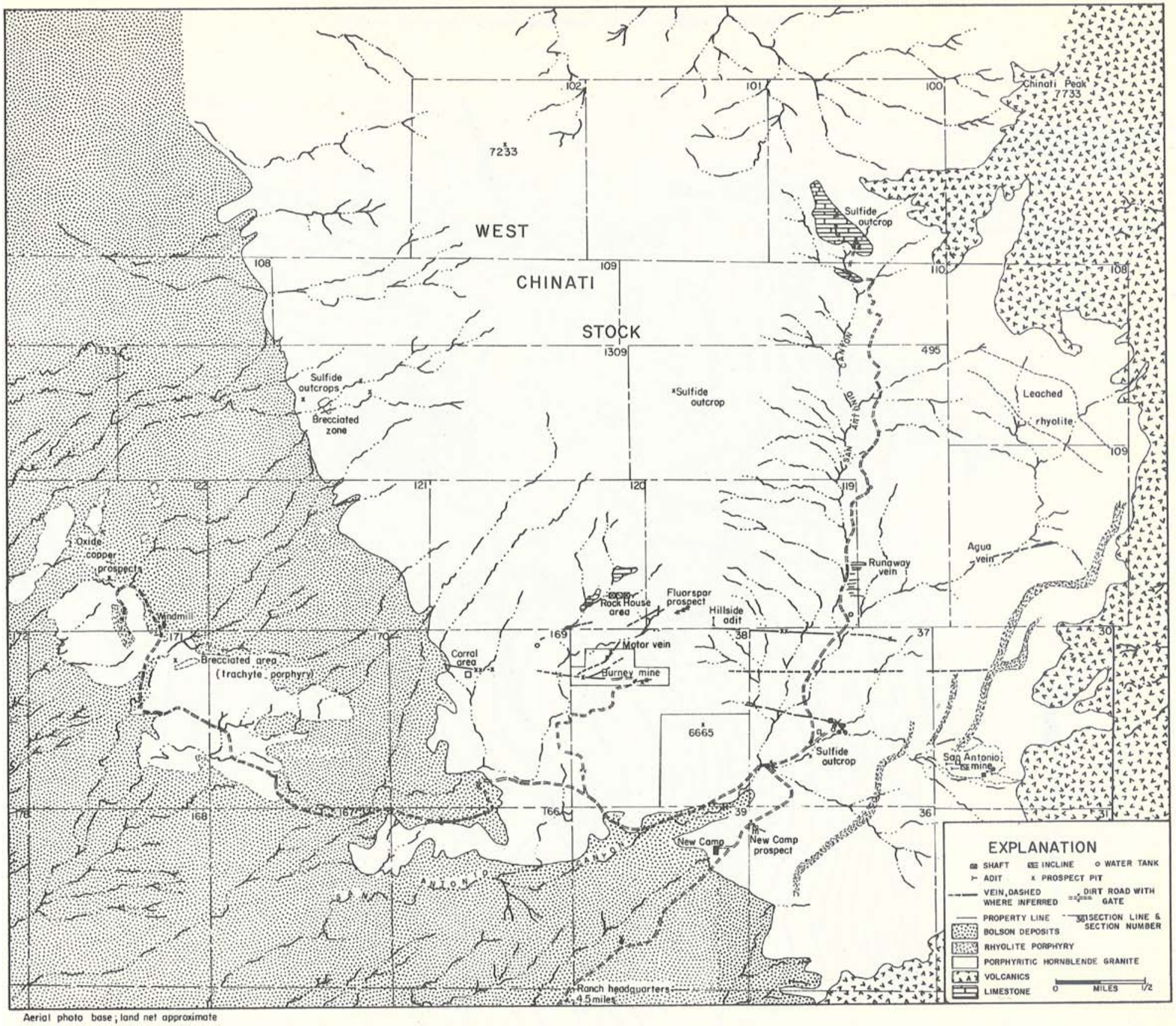

Figure 8. Geologic map, West Chinati stock.

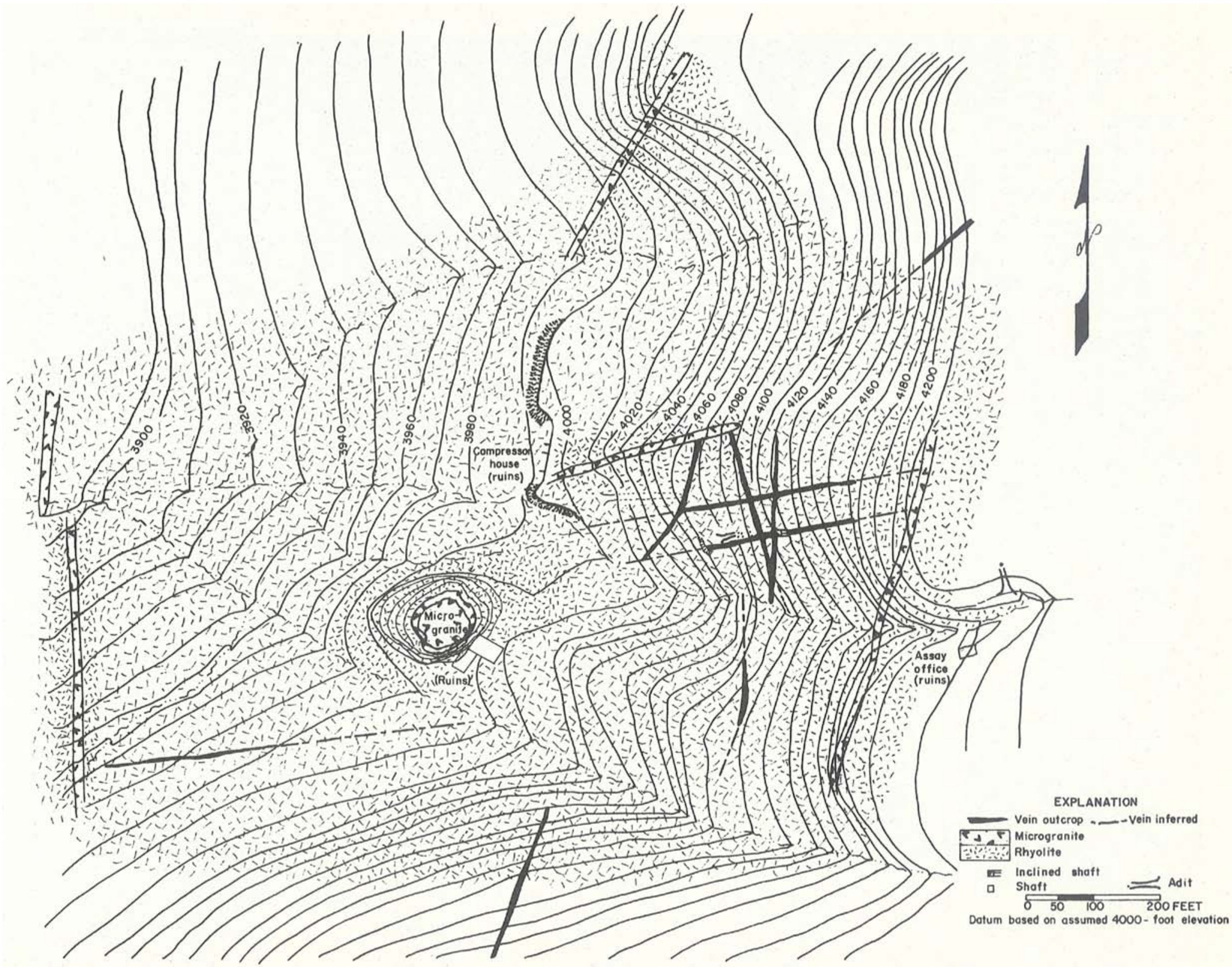

Figure 9. Area of San Antonio "mine," alidade survey.

and some extend essentially continuously for 2 or more miles. Mineralized veins are common in the sheeted zones.

The veins contain galena (PbS), sphalerite (ZnS), minor chalcopyrite ($CuFeS_2$), pyrite (FeS_2), fluorite (CaF_2), cerargyrite (AgCl), argentite(?) (Ag_2S), quartz, and manganese and iron oxides. Prior to 1942, there was sporadic small-scale mining and prospecting on veins in four areas, namely, the San Antonio Canyon "mine," the Burney "mine," the Hillside adit, and the Rock House area. Potentially economic veins also occur in several other areas (fig. 8), including the Fluorspar prospect and the Corral area (McAnulty, 1972).

SAN ANTONIO CANYON "MINE"

The San Antonio Canyon "mine" consists of several old adits, shafts, and prospect pits located in east-west-trending veins in the northeastern part of San Antonio Canyon (fig. 9). Apparently, silver was the metal sought. Fluorite, quartz, and altered porphyritic hornblende granite make up the bulk of the gangue. In the few places where veins can be seen, the ore minerals (galena and sphalerite) occur in narrow, interlacing (stockwork) veinlets in altered zones of stock rock ranging from 2 to 30 feet in width. Several dikes of rhyolite, rhyolite porphyry, and microgranite cut the stock in the area of the San Antonio Canyon "mine."

BURNEY "MINE"

The strongest fissure-vein mineralization observed in the district is in the Burney vein, on which the Burney "mine" is located, in section 38, block 60, G. S. & S. A. Ry. Co. survey (fig. 8). The Burney vein is in an east-west oriented sheeted zone in porphyritic hornblende granite. The vein is nearly vertical at and near the surface, but drilling by the U. S. Bureau of Mines in 1946 proved that it dips southward at lower levels (Dennis, 1947). A late dike of microgranite parallels and, in places, cuts the vein. The vein can be traced easily on the surface for about 3,000 feet west of the shaft, and its topographic expression can be seen for more than 2,000 feet farther westward (fig. 10). Eastward from the shaft, the vein does not crop out, but a topographic lineation extends from the shaft eastward across San Antonio Canyon into the area of the San Antonio Canyon "mine"—a distance of about 2 miles. The vein appears to be best developed along the segment between the shaft and the crest of a hill approximately 2,500 feet to the west. It varies from 1 to 25 feet thick in the outcrop along this segment.

The principal ore minerals are galena, sphalerite, and fluorite. Silver is present in cerargyrite, argentite(?), and galena. Minor amounts of chalcopyrite and oxidized copper minerals are present. The gangue minerals are quartz, minor pyrite, minor hematite and barite, and unreplaced, altered stock rock. The mineralization is irregular, in pods, and is the result of both replacement and void filling. Most of the fluorite occurs in veins and veinlets ranging from less than an inch to 3 feet in thickness. The fluorite veins pinch and swell and are discontinuous. Podlike masses of fluorite, along with galena and sphalerite, occur in brecciated zones. The fluorite is coarsely crystalline. The known fluorspar could not be mined profitably except as a coproduct with the metallic ores. Some of the thicker zones might be hand-sorted, but recovery of any significant amounts of saleable fluorspar would require flotation milling.

HILLSIDE ADIT

The Hillside adit is on a well-developed east-west-trending vein located about 0.75 mile northeast of the Burney "mine," in section 19 (fig. 8). It is high on the west slope of San Antonio Canyon and is accessible only on foot or on horseback. Old workings consist of an adit 135 feet long and an inclined (75°) winze to a depth of 125 feet below the adit floor, with short drifts in each direction on the vein at the bottom of the winze (fig. 11). The Hillside vein zone ranges from 3 to 30 feet thick. That segment of the vein cut by the adit contains a persistent seam of green, coarsely crystalline fluorite near the footwall; the seam varies from 4 to 30 inches thick. An irregular dike of altered microgranite is present along the hanging-wall side. Cerargyrite, along with small amounts of galena and sphalerite, is conspicuous in the vein material near the adit portal. A grab sample taken from an old pile of "ore" assayed 20 oz per ton of silver. The Hillside vein can be traced on the surface for more than a mile eastward and several hundred feet westward from the adit. An area immediately west of the adit shows strong mineralization and several veins in a faulted zone.

FLUORSPAR PROSPECT

The Fluorspar prospect is about 1,500 feet northwest of the Hillside adit, in section 119 (fig.

Figure 10. Burney vein, alidade survey.

12), and is accessible only on foot or on horseback. Green, coarsely crystalline fluorite is present in a vein which strikes N. 50° E. This vein crops out in a saddle for a distance of about 300 feet. Shallow pits along the outcrop expose a vein of fluorite ranging from 4 to 30 inches thick. The vein zone is about 20 feet thick and consists largely of altered porphyritic hornblende granite. Traces of galena and sphalerite were observed, and a sample from one of the test pits contained 3.8 oz per ton of silver.

ROCK HOUSE AREA

The Rock House area includes a mineralized swath that extends westward from the Fluorspar prospect for approximately 2 miles. Several old test pits and shallow workings are located on veins striking east-west and N. 50° E. in this area. The mineralization is similar to that in the fissure veins already described.

Evaluation of Occurrences in Presidio County

Numerous fissure veins within a large body of porphyritic hornblende granite, which makes up the bulk of the West Chinati stock, contain potentially commercial deposits of fluorspar and ore minerals of lead, zinc, silver, and copper. Silver and fluorspar probably have the highest values. The fluorspar is intermingled and/or so closely associated with the metallic ore minerals that it could not be mined separately at a profit. It appears that all mineralized vein material would have to be mined and that concentrates of marketable constituents would have to be made by differential froth flotation in a mill near the mines. This virgin territory merits careful geologic study and exploration, making use of all applicable geological, geochemical, and geophysical techniques.

In addition to the fissure-vein mineralization in this district, there are several areas in which the geologic relationships and mineralization appear favorable for porphyry copper deposits.

A well-planned, adequately staffed, and properly financed exploration program would probably be successful in this district.

JEFF DAVIS COUNTY

Walter Mayfield Prospect

Fluorspar is known at only one locality in Jeff Davis County—the Walter Mayfield manganese prospect located just south of the Jeff Davis—Hudspeth County line, about 4.5 miles south-

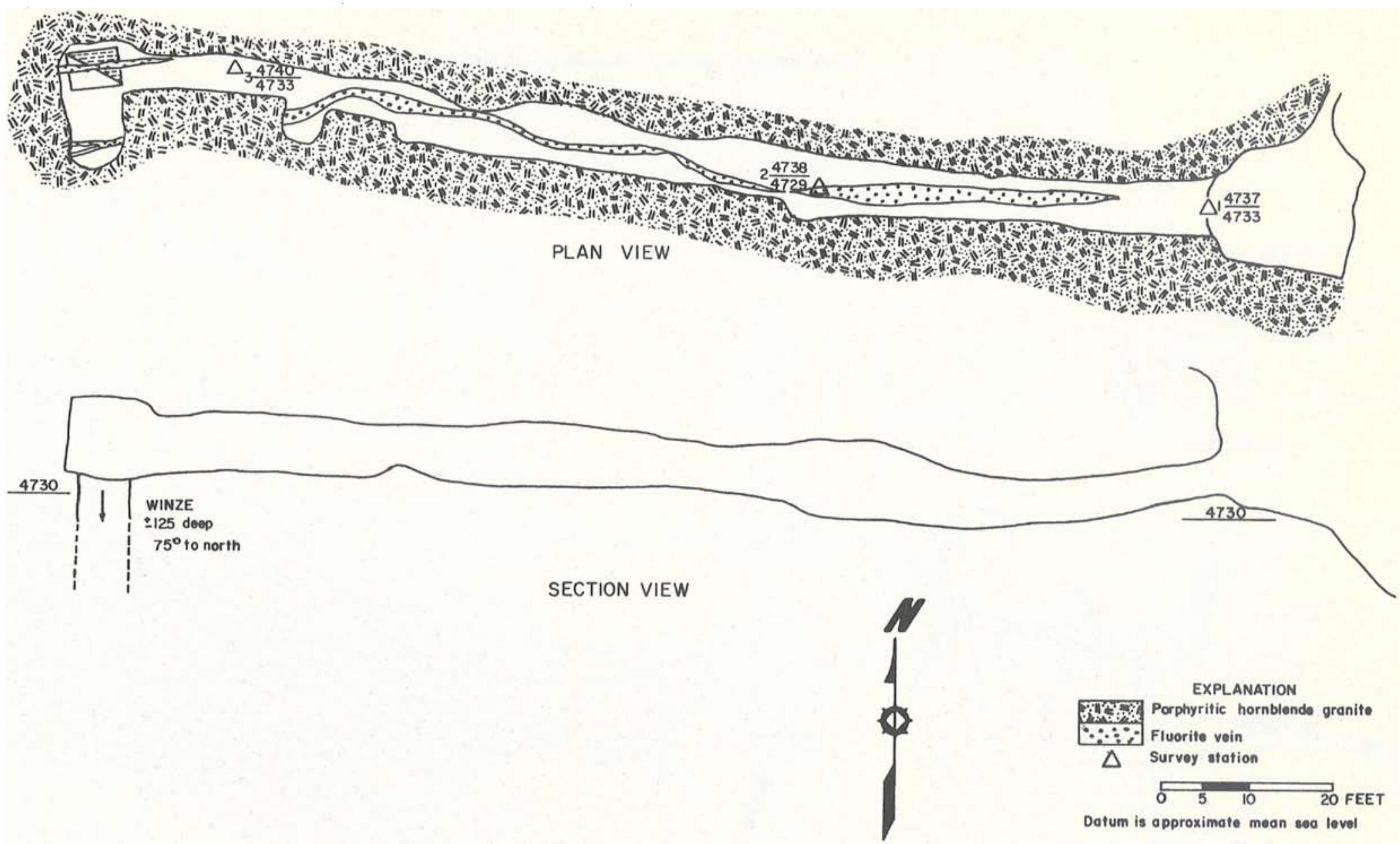

Figure 11. Hillside adit, Brunton-and-tape survey.

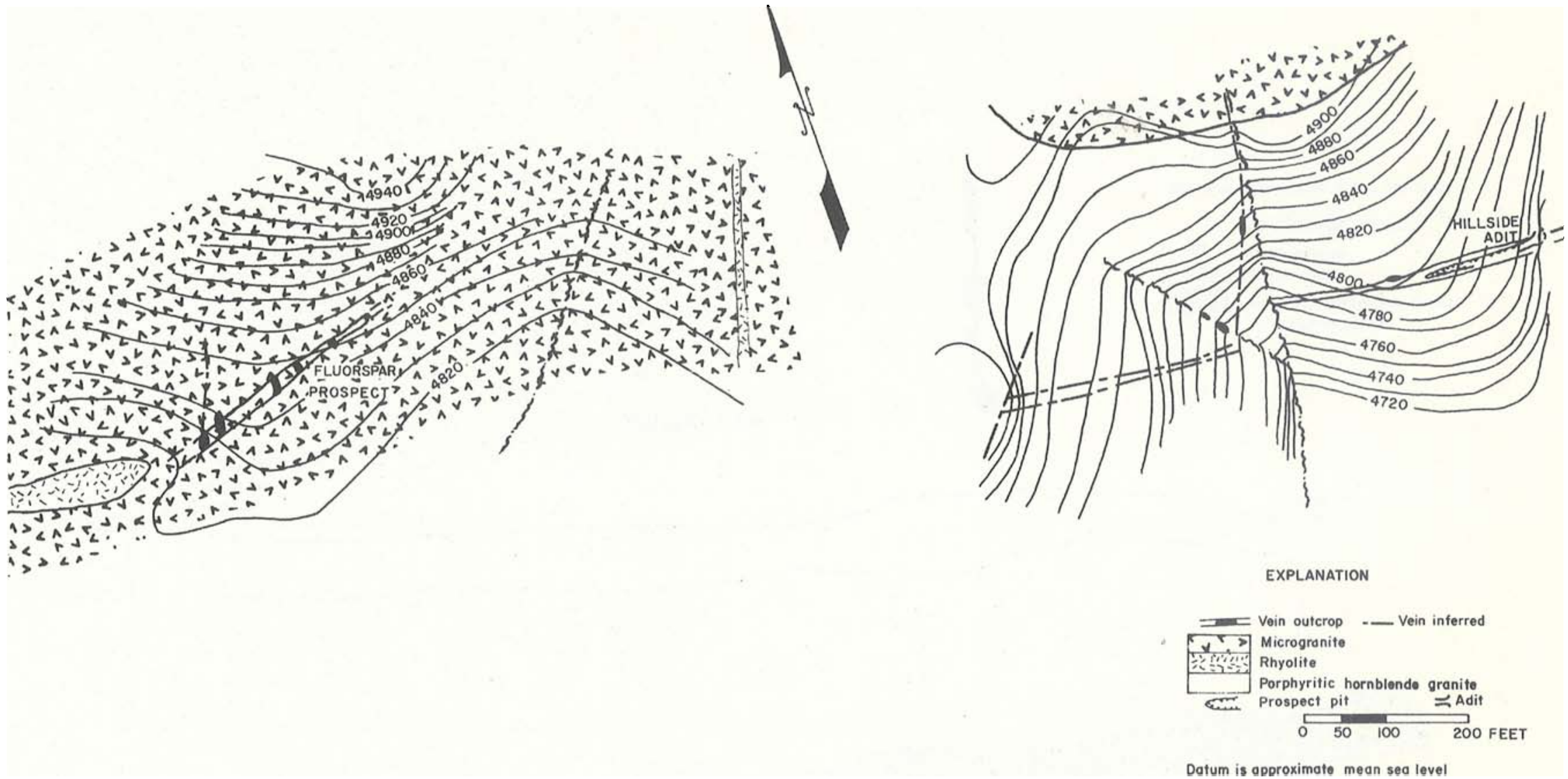

Figure 12. Fluorspar prospect, alidade survey.

southwest of Chispa siding on the Southern Pacific Railroad (fig. 2). This deposit was described by Baker (1935, pp. 507-508) and by Warren (1946, pp. 254-255). Fluorite is a minor gangue constituent in a fissure vein containing botryoidal and mammillary masses of hollandite, coarsely crystalline barite, hematite, and cryptocrystalline quartz. A small amount of handpicked manganese ore has been shipped from the prospect. The mineralization occurs in a fault zone of large displacement which strikes northwest and cuts Lower Cretaceous formations, dropping them down on the northeast. The old workings are near the top of the Finlay Limestone. Careful prospecting failed to reveal fluorspar elsewhere in this area.

HUDSPETH COUNTY

Fluorspar mineralization is widespread in the Eagle Mountains and in the Sierra Blanca peaks, and a minor occurrence is known in the Quitman Mountains in Hudspeth County (fig. 2). Nearly all of the fluorspar produced in Texas so far is from deposits in the Eagle Mountains.

Eagle Mountains District

The Eagle Mountains cover an area of approximately 125 square miles in southeastern Hudspeth County. Eagle Peak, the highest point (elevation 7,496 feet), is 17 miles southwest of El Paso. This mountainous area is the highest part of a generally northwest-trending highland, surrounded by partially filled intermontane basins, that begins approximately 150 miles to the southeast near Ojinaga, Chihuahua, Mexico (Underwood, 1963).

The Eagle Mountains mass is a synclinal horst (flanked by grabens) in which thick sections of rocks ranging in age from Precambrian to Recent are well exposed; these include about 5,000 feet of Precambrian metasediments, more than 1,000 feet of Permian limestone, about 7,000 feet of Cretaceous marine sedimentary rocks, more than 3,500 feet of Tertiary extrusive igneous rocks (rhyolite, trachyte, andesite, and tuffs), numerous small rhyolite and diabase dikes and sills, and a central syenite stock. Extrusive igneous rocks surround the Eagle Mountains stock, and they are ringed by well-exposed sedimentary rocks. Dikes and sills cut all rock types and are present throughout the area. Faults, joints, and fractures are common, east-west- and northeast-trending, high-angle normal and reverse faults being most typical. The faults cut all rocks except late rhyolite and diabase dikes. Well-developed joint and fracture systems parallel the major faults; fluorspar occurs at many places along the faults and associated joints and fractures. The Rhyolite and Wind Canyon fault zones contain appreciable quantities of fluorspar (fig. 13).

More than 30 occurrences of fluorspar are known in the Eagle Mountains, most of which are in block 68, township 9 (fig. 13). Fluorspar was discovered in this district in 1919, but no ore was shipped until 1943. The U. S. Bureau of Mines conducted a program during 1943-45 designed to evaluate the commercial potential of the district, which included geologic mapping, diamond drilling, trenching, and sampling. The results of the project were published by the U. S. Geological Survey; for detailed descriptions of the Eagle Mountains deposits, see Gillerman (1948, 1953) and Evans (1946). Prospecting during 1942-48 resulted in discovery of fluorspar at several widely scattered places in the Eagle Mountains, especially in fissure veins in fault zones, northwest, southeast, south, and southwest of previously known deposits in Spar Valley. A 50-ton flotation plant was put in operation in Spar Valley in fall of 1945, and acid-grade concentrate was produced intermittently during 1945-46. Subsequently, the mill setup was changed to produce ceramic-grade concentrate. From October 1945 to January 1949, a total of about 2,750 tons of acid- and ceramic-grade fluorspar concentrates was shipped. From November 1943 to October 1945, approximately 8,450 tons of metallurgical-grade fluorspar was shipped. Shipments from deposits in the Spar Valley area totaled about 11,400 tons.

Fluorspar was discovered in the Eagle Springs area of the Eagle Mountains in the spring of 1943, and about 600 tons of metallurgical-grade fluorspar mined from deposits in that area was shipped in 1943. Fluorspar was discovered in the Rocky Ridge area in November 1943. Although an appreciable amount of exploratory excavating and sampling was done on Rocky Ridge deposits, little or no fluorspar was ever shipped. From 1952 until 1970, the Eagle Mountains district received little attention.

SPAR VALLEY

Most of the fluorspar mined in the Eagle Mountains was taken from deposits along Spar Creek, in the upper part of Spar Valley, section 35. Spar Valley, a major drainage to the southeast in the east-central part of the Eagle Mountains, is developed along the northwest-trending Spar

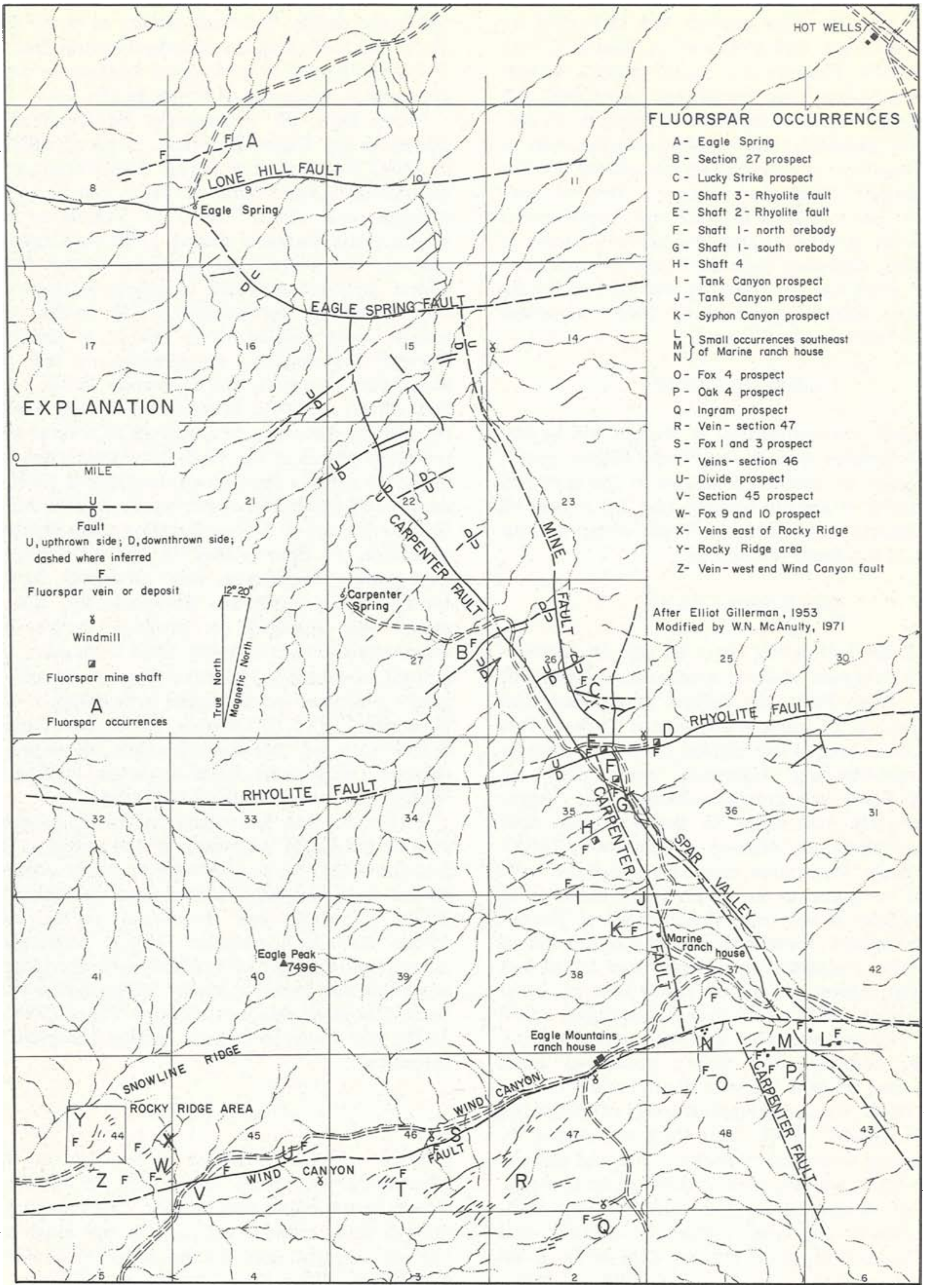

Figure 13. Eagle Mountains fluorspar district.

Valley fault. Several northwest- and northeast-trending faults intersect in the area where the deposits are located (Underwood, 1963). The only significant bedding-replacement deposits known in the district occur in this area—the North and South orebodies.

North orebody.—The North orebody in Spar Valley, section 35 (fig. 13) has yielded most of the fluorspar produced in the district. It is a bedding-replacement and void-filling deposit consisting of two or three beds of high-grade fluorspar separated by thin beds of shale. The fluoritization is confined to brecciated zones along bedding-plane faults in the Finlay Limestone (Cretaceous). The fluoritized zones are overlain by shales and nodular limestones of the Benavides Formation. They dip 40°—45° SW., conforming with the bedding of the host formation. The thickness of the fluoritized zones varies from 5 to 45 feet. The mineralization terminates against the Mine fault about 200 feet downdip from the surface. Only high-grade material was mined and an appreciable amount of ore remains in the old workings. Two samples taken across a 6-foot face in the lower part of the old workings, near Shaft 1, contained 72.61 and 80.75 percent CaF_2, respectively. Samples taken underground by the U. S. Bureau of Mines, across both high-grade and low-grade zones, contained an average of 58.38 percent CaF_2. A minimum of 35,000 tons of minable ore with an average CaF_2 content of 35 percent is estimated to remain in this deposit.

South orebody.—The South orebody is in Spar Valley, about 1,000 feet southeast of the North orebody; it is actually an extension of the North orebody, but some of the mineralization may be of a different type. It is predominantly a bedding-replacement deposit, like the North orebody, with a minor amount of void filling. The ore zone lies immediately above the *Toucasia* reef beds in the lower part of the Finlay Limestone. It dips 30°—35° SW., as does the host rock. The principal outcrop of fluorspar is in a red siliceous limestone near the contact with intrusive rhyolite. The shape of this outcrop suggests that the underlying orebody may be a pipe.

The U. S. Bureau of Mines drilled four diamond core holes (nos. 16-19) in this area, two of which penetrated fluorspar (Gillerman, 1953). A hole drilled in search of water, well 3, cut 65 feet of low-grade fluorspar, beginning just beneath the surface. Fluorspar crops out at intervals over a distance of about 500 feet northwestward from well 3 to Little Spar Creek. According to Gillerman (1953), fluorspar penetrated in diamond-drill hole 16 averaged 35 percent CaF_2 and about 54 percent SiO_2, through an average thickness of 10 feet. The whole area has undergone extensive alteration; the limestone has been altered to white clay over sizable areas, and in the area around the pipe, iron oxides impart a dark red color to the fluoritized rock.

RHYOLITE FAULT ZONE

The Rhyolite fault is one of several major east-trending normal faults in the Eagle Mountains (fig. 13). Where it crosses the upper end of Spar Valley (fig. 14) it has produced an apparent horizontal displacement of about 3,000 feet and dips 60° S. The fault is traceable both eastward and westward from Spar Valley for several miles. At some places along the fault, breccia zones up to 40 feet wide and several hundred feet long are fluoritized. Fluoritized fault breccia is well exposed in shafts 2 and 3 (fig. 13). Several hundred tons of high-grade fluorspar were mined from Shaft

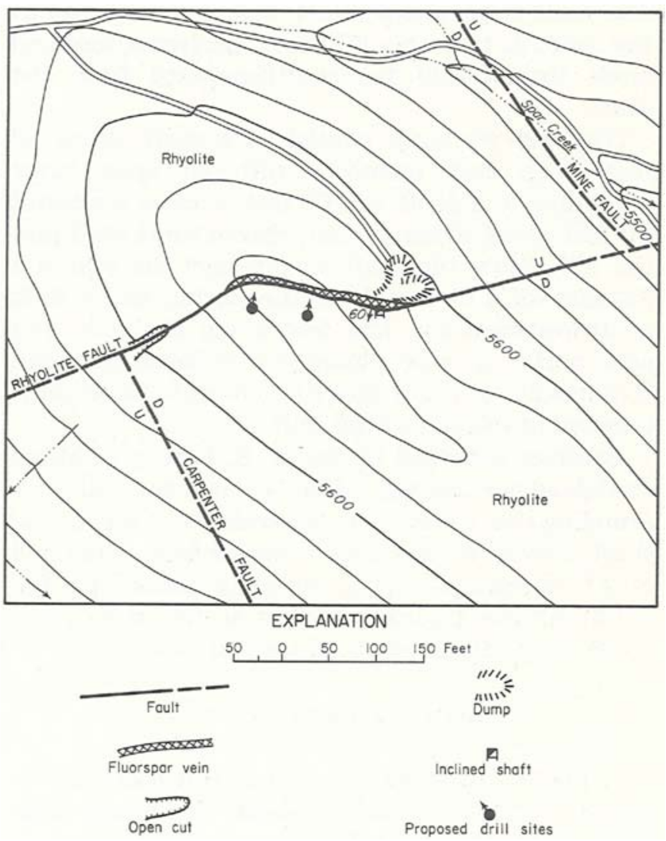

Figure 14. Rhyolite fault zone (after Gillerman, 1953).

2. The workings are in rhyolite and extend to a depth of 150 feet below the surface. The thickness of the fluoritized breccia in the Shaft 2 workings ranges from 5.5 feet to more than 20 feet. On top of the hill just above Shaft 2 several closely spaced parallel veins form a fluoritized zone about 60 feet wide at the surface.

Composite samples taken by the U. S. Bureau of Mines at several places along the vein in the Shaft 2 workings contained an average of 57.32 percent CaF_2 and 31.59 percent SiO_2. Another sampling taken across the full width of the vein (12 feet), on the surface near Shaft 2, contained 28.71 percent CaF_2 and 64.28 percent SiO_2. At Shaft 3 the fault cuts Cretaceous limestones, shales, and sandstones. Fluoritized breccia exposed in Shaft 3 contains a mixture of the Cretaceous sedimentary rocks and rhyolite fragments.

SHAFT 4 VEIN

Shaft 4 was sunk on a fluorspar vein in a fault zone striking N. 62° E. and dipping 60°—75° SE. (fig. 13). The host rock is rhyolite. The shaft and an adit are on the side of a hill about half a mile southwest of Shaft 1 in Spar Valley, in section 35. The fault zone, about 6 feet wide in the vicinity of the shaft, is traceable 600 feet southwestward and more than 3,000 feet northeastward from the shaft.

The old workings consist of a shaft about 30 feet deep that connects with an open stope extending to a depth of 100 feet or more for about 50 feet along strike, an adit driven southward into the hill below the shaft to intersect the vein at a distance of 175 feet from the portal, and a drift southwestward for 125 feet along the vein. The adit portal is now closed by collapse material. Reportedly, a 5-foot face of high-grade fluorspar is exposed at the end of the drift.

Samples collected by the U. S. Bureau of Mines contained an average of 51.45 percent CaF_2. A sampling that I made across a width of 3 feet in the shaft, about 30 feet below the surface, contained 60.47 percent CaF_2; a sampling across the full width of the fluoritized zone at the same place (6.75 feet) contained 36.18 percent CaF_2.

WIND CANYON FAULT ZONE

A major east-trending normal fault that extends across the district, cutting both Cretaceous sedimentary rocks and Tertiary igneous rocks, is known as the Wind Canyon fault (fig. 13). This fault or fault zone is characterized by numerous large fluoritized and silicified breccia zones and many associated parallel and subparallel faults. Fluorspar deposits in or near the Wind Canyon fault zone probably have the greatest commercial potential in the Eagle Mountains. Among the several interesting prospects are, from east to west: Fox 4; Fox 1 and 3; an area near the divide between Wind Canyon and Broad Canyon in the eastern part of section 45; a deposit in the southwestern part of section 45; Fox 9 and 10; and a sizeable outcrop about 1,000 feet southwest of Fox 10 in section 44.

Highly fluoritized deposits crop out at several places along the fault between the occurrences mentioned.

Fox 4 prospect.—The Fox 4 deposit is in the northern part of section 48, about 0.75 mile due east of the Eagle Mountains ranch house. Some of the mineralization is exposed in three trenches and a test pit about 16 feet deep in a mineralized zone approximately 100 feet long and 6 feet wide. Within the fluoritized zone there are veinlets of high-grade fluorspar, part of which was formed by replacement of Buda Limestone (Cretaceous) and part of which was chemically precipitated in open spaces. Four samples taken from the trenches dug by the U. S. Bureau of Mines contained an average of 42 percent CaF_2.

Fox 1 and 3 prospects.—The Fox 1 and 3 prospects are on a fissure vein in the Wind Canyon fault zone, in section 46 (fig. 13). A trench across the vein at the west end of the outcrop exposes a fluoritized zone to a depth of 10 feet and across a width of 22.5 feet. The mineralized zone, ranging from 6 to 20 feet in width, crops out up and over the hill eastward from the cut for a distance of about 450 feet (fig. 15). Just west of the trench the zone is covered by alluvium but it crops out again across the valley, about 400 yards distant, and continues more than 2 miles westward. The vein or mineralized zone strikes N. 72°—75° E. and dips 65°—70° NW. There are numerous narrow silicified veins and veinlets, some of which contain fluorite, on either side of the principal vein at Fox 1 and 3 in joints striking N. 50°—55° E. The trench across the principal zone exposes a high-grade vein of coarsely crystalline fluorspar 2 to 4 feet wide. A sample cut across the full width of the zone exposed in the excavation, including a 3-foot width of slightly fluoritized silicified breccia, contained 25.05 percent CaF_2. A sample across 12 feet of the richer fluoritized zone contained 50 percent CaF_2. The host rock is syenite, part of the Eagle Peak stock; it is albitized and silicified in this area.

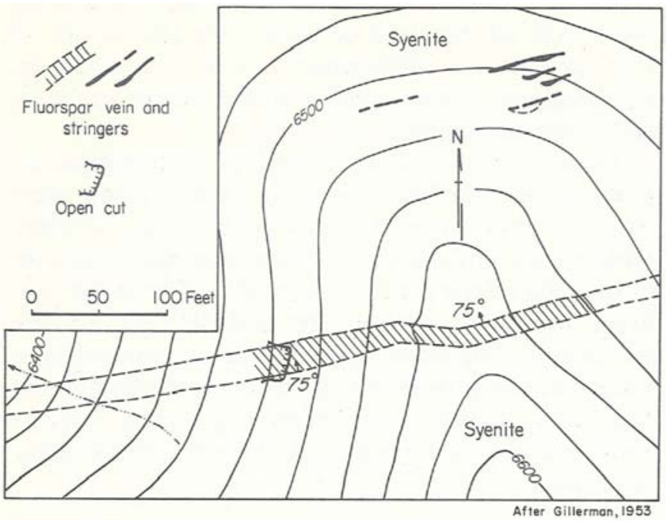

Figure 15. Fox 1 and 3 prospects.

Divide prospect.—The Divide prospect is located near the divide between Wind Canyon and Broad Canyon drainages, in the eastern part of section 45 (fig. 13). Two faults intersect in this area, one believed to be the Wind Canyon fault with a strike of N. 75° E. and the other with a strike of N. 60° E. (fig. 16). The fluoritized zone is more than 50 feet wide around the intersection of the two faults, and a fluoritized-silicified brecciated zone is present along each fault for more than 300 feet eastward from the point of intersection. The host rock is volcanic tuff. A sample cut on the surface across a width of 58 feet contained 10.12 percent CaF_2. The fluoritized rock on the surface is not of ore quality, but chances are good that the grade increases at depth.

Deposit in southwestern part of section 45.—A deposit on the Wind Canyon fault in the southwestern part of section 45 (fig. 13) appears to be one of the best in the district. A fluoritized-silicified zone around the intersection of two faults is about 70 feet wide over a length of 150 feet. The mineralized zone is partially exposed in a trench located near the intersection of a fault trending N. 60° E. and another striking N. 75° E. The cut is on the main Wind Canyon fault and reveals a fluoritized zone 27 feet wide. Fluorspar occurs in high-grade veins, stringers, and pockets, and as partial replacement of fault breccia and gouge. The host rock is rhyolite. It is estimated that the fluoritized zone contains an average of 50 percent CaF_2. Mineralization extends eastward from the cut for 600 feet with silicified and fluoritized rock standing like a wall above the surface. This mineralized zone can be traced in intermittent outcrops for more than a mile westward from the cut. Also, there are closely spaced outcrops of fluoritized breccia along the Wind Canyon fault between the cut and the Divide prospect, approximately 0.75 mile to the east. In fact, it appears that the Wind Canyon fault zone is almost continuously fluoritized from the Fox 1 prospect to Rocky Ridge, a distance of about 14,000 feet.

Fox 9 and 10 prospects.—In the eastern part of section 44 (fig. 13) several fluorspar-bearing veins striking N. 40°–55° E., along small faults probably related to the Wind Canyon fault, are present in rhyolite over an area centered about 1,500 feet west-northwest of the deposit in section 45 discussed above. Fluorspar crops out intermittently for 1,400 feet along one of the veins. Another fluorspar vein in this area is 4 to 5 feet wide and can be traced 100 feet along strike. A third vein, which has been explored in two shallow test pits about 450 feet apart with a difference in elevation of 100 feet, contains high-grade fluorspar in zones up to 12 feet wide.

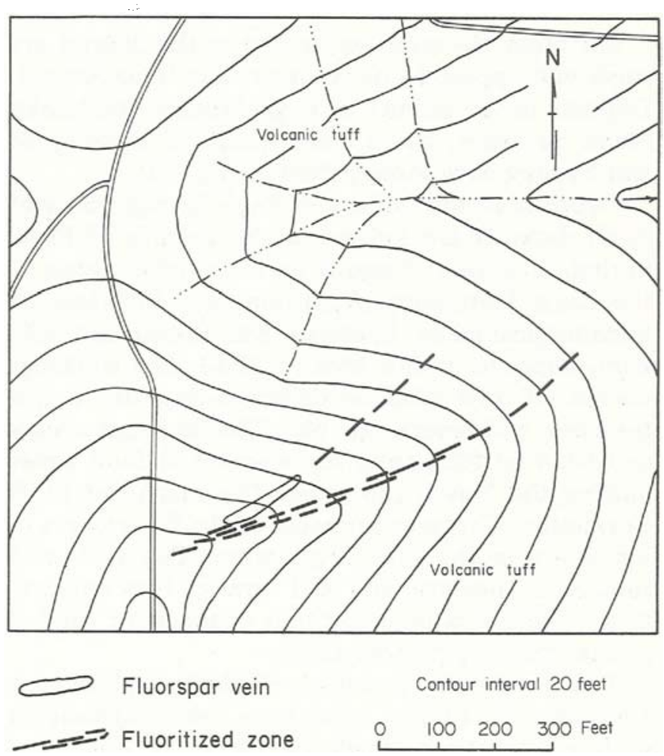

Figure 16. Divide prospect.

About 1,000 feet southwest of the upper test pit on the Fox 10 prospect, in section 44, there is a strongly fluoritized outcrop of silicified breccia on the trend of the Wind Canyon fault. The outcrop is 12 to 15 feet wide and about 300 feet long. It is covered on the west end by alluvium. Both coarse-grained void-filling and fine-grained replacement fluorspar are abundant in the silicified rhyolite breccia.

ROCKY RIDGE DEPOSITS

Several small deposits of fluorspar are present within a structurally complex area known as Rocky Ridge, located at the west end of Snowline Ridge about 1.75 miles southwest of Eagle Peak, in section 44 (fig. 13). Rocky Ridge is an isolated, highly faulted, brecciated, and altered block of Cretaceous (Bluff) limestone, sandstone, and quartzite, cut by rhyolite and diabase dikes. The extent of Rocky Ridge deposits has been explored in numerous test pits, trenches, and adits. Both replacement and void-filling deposits occur in fissure veins and in irregular-shaped masses. Reserves in this area are estimated to be approximately 30,000 tons of ore containing an average of 35 percent CaF_2.

OTHER OCCURRENCES

All other occurrences known in the district are small and appear to be commercially unimportant. Deposits in the vicinity of Eagle Springs, the Lucky Strike prospect, and a few deposits in sections 26 and 27 may have some potential (fig. 13).

Deposits in the vicinity of Eagle Spring.—Several small deposits are known in the vicinity of Eagle Spring, in sections 8 and 9, on the northern edge of the Eagle Mountains. Approximately 600 tons of metallurgical-grade fluorspar was mined and sold from deposits in this area in 1943. Old workings consist of two adits on different deposits, a few trenches, and several test pits. The fluorspar occurs as both void filling and replacement in fault zones cutting the Hueco Limestone (Permian) and Bluff Formation (Cretaceous); most of the fluorspar is in limestone in the Bluff Formation. The veins and replaced zones are thin and erratic. Past exploration in this area indicates that chances for finding commercial deposits are slight.

Lucky Strike prospect.—Bedding-replacement fluorspar in Finlay Limestone was exposed in surface excavations made by the U. S. Bureau of Mines on the Lucky Strike prospect, near the center of section 26. Thick overburden in this area obscures the exact geologic relationships and more work will be required to determine the nature of this occurrence (Gillerman, 1953). A bedding-replacement deposit similar to the North orebody may exist in this area.

Deposits in sections 26 and 27.—Fluoritization along small northeast-trending faults, along with irregular dikes and stringers of rhyolite, is fairly widespread in Cretaceous limestones and marls on either side of the northwest-trending Carpenter and Mine faults in sections 26 and 27. All of the occurrences observed appear to be noncommercial; however, the possibility of commercial deposits in this area cannot be ruled out, and careful prospecting could result in the discovery of larger deposits.

EVALUATION OF EAGLE MOUNTAINS DISTRICT

Fluorspar mineralization is widespread in the Eagle Mountains as bedding replacement in limestone and in fissure veins along faults that cut a variety of igneous and sedimentary rocks, where geologic relationships are favorable for commercial deposits of fluorspar. Fissure veins along major east-west- and northeast-trending normal faults appear to have the greatest potential for large reserves. However, brecciated zones along bedding-plane faults, such as at the North and South orebodies, contain commercial deposits. Limestone—rhyolite contact zones crop out over a large area in the southeastern part of the district, and prospecting in that area could result in discovery of large contact-replacement deposits. Areas south of Wind and Broad Canyons are geologically favorable for fluorspar deposits. Careful geologic prospecting along all major east-west- and northeast-trending faults in the district would almost certainly result in discovery of many deposits not known at present.

Known deposits in fissure veins along the Rhyolite and Wind Canyon faults and along the smaller fault at Shaft 4 contain more than a million tons of fluorspar with an average CaF_2 content of 35 percent. Bedding-replacement deposits such as the North and South orebodies probably contain 50,000 to 65,000 tons of 40 percent fluorspar; the Rocky Ridge deposits probably contain 30,000 to 40,000 tons of 35 percent fluorspar. All other known occurrences may have an aggregate total of 25,000 to 35,000 tons of low-grade fluorspar. These estimates must be considered inferred because of the lack of exploration and sampling data; they are based largely on knowledge of the geologic character of the deposits, on assumed continuity or repetition for which there is geologic evidence, and on comparison with deposits of similar types elsewhere.

Exploration and mining of fissure-vein deposits will be costly. The CaF_2 content is low, but the coarsely crystalline fluorite probably can be separated from the cryptocrystalline quartz gangue relatively cheaply by sink-float (heavy-media) beneficiation. The central part of the district is about 15 miles from the Southern Pacific railroad and 20 miles from the Texas Pacific railroad, so transportation to a railhead would be relatively cheap.

Sierra Blanca Peaks District

In 1968, I discovered fluorspar at several places high on the slopes of the Sierra Blanca peaks (fig. 2). Intermittent prospecting during 1969-1971 resulted in discovery of 45 outcrops of fluorspar on Sierra Blanca Peak, Little Sierra Blanca Mountain, Round Top, and Little Round Top (fig. 17). Drilling, trenching, and sampling are underway at the present time. The commercial potential of the district cannot be evaluated until more data are available.

The geology of the Sierra Blanca peaks was studied by Albritton and Smith (1965). This group of laccolithic peaks is located between the Quitman Mountains and Devil Ridge on the south and the southern escarpment of the Diablo Plateau on the north. Sierra Blanca Peak, the largest and highest of the group, has an elevation of 6,894 feet and rises approximately 2,000 feet above the surrounding flats. According to Albritton and Smith (1965) the floor of each of the laccolithic masses is above the Cox Sandstone (Cretaceous). Cretaceous formations above the Cox Sandstone (Finlay Formation and Washita Group formations) were deformed by the intrusions; steeply dipping beds on the flanks indicate that Washita and younger Cretaceous formations were domed over the laccoliths. Erosion has exposed the rhyolite core that now forms the summit of each of the peaks. The laccolithic bodies are not symmetrical mushroom-shaped masses with flat, conformable floors. At places on the slopes of each of the peaks Cretaceous beds dip toward the mountain at angles ranging from 5 to 30 degrees, whereas elsewhere beds of the same formations dip steeply away from the mountain (fig. 18). The irregular floor of the laccolithic mass is exposed in a few arroyos on the

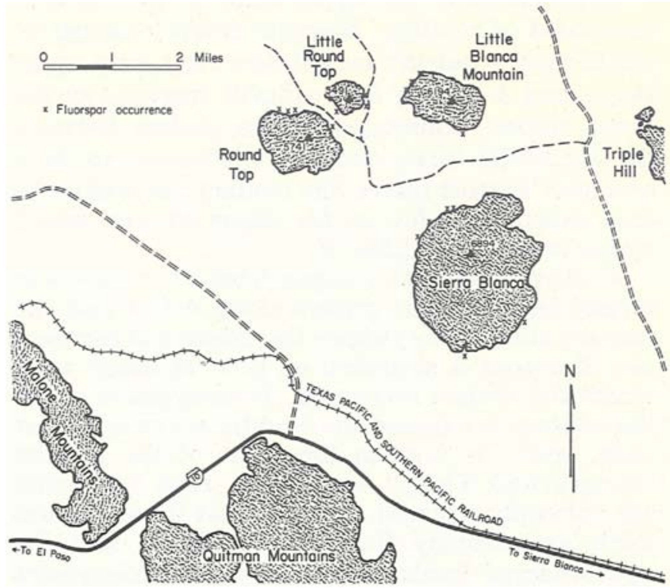

Figure 17. Sierra Blanca peaks district, Hudspeth County.

slopes. Also, sill- and boss-like extensions from the main laccolithic body, at different elevations, are common. There are numerous minor folds and faults of small displacement on the slopes.

All the laccolithic bodies are of fine-grained rhyolite and/or rhyolite porphyry (Albritton and Smith, 1965). Their age is not known exactly; I believe that they were emplaced during mid-Tertiary time (late Oligocene or early Miocene). Sills, dikes, and irregular-shaped bodies of andesite, hornblende andesite porphyry, and latite porphyry, older than the laccolithic intrusions, are abundant in the Cretaceous beds on the slopes of the peaks.

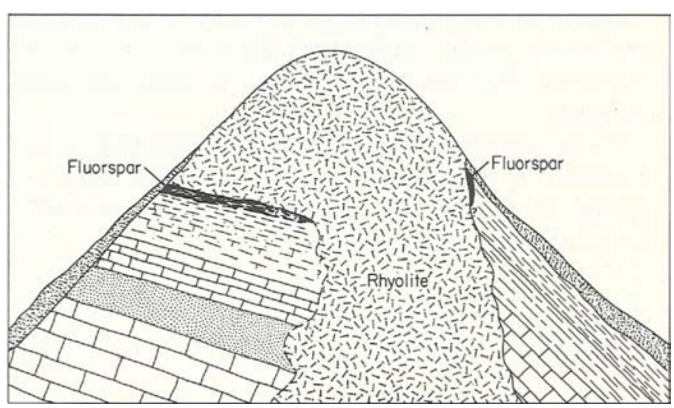

Figure 18. Diagrammatic cross section, Round Top laccolith, Sierra Blanca peaks district, Hudspeth County, showing areas of fluorspar mineralization.

Approximately the upper third of each peak is composed of rhyolite. Rhyolite debris loosened by weathering is quickly moved down the steep upper slopes and deposited as a colluvial mantle over the lower slopes. Consequently, the contact between the laccolithic mass and the Cretaceous rocks is obscured in most places; the contact can seldom be seen except in a few of the larger arroyos, which makes prospecting difficult.

Fluorspar deposits, ranging from a few inches to several feet thick, are present along and/or near the contact almost everywhere the contact is exposed, and fluorspar is abundant as float in many areas where the contact is covered. At most places where the contact is exposed the country rocks are either shale, marl, or nodular limestone of the Washita Group (Duck Creek? equivalent), rock types that are not easily replaced. The fact that the shales and marls are strongly fluoritized indicates that the hydrothermal fluids associated with emplacement of the laccolithic bodies were rich in fluorine. Sill- and dike-like bodies of andesitic rocks cut by rhyolite associated with the laccolithic masses are also strongly fluoritized near contacts.

Most of the fluorspar is very fine grained and resembles chert. In fact, weathered material on the surface can easily be mistaken for gray chert. However, by careful observation it can be recognized as fluorspar because of its weight and small pink-to-purple areas and streaks. Also, tiny euhedral cubes of fluorite line some fractures and vugs. Along shale-rhyolite and andesite-rhyolite contacts fluoritized zones up to 15 feet thick have been exposed in several bulldozer trenches. Isolated, irregular-shaped pods of fluoritized shale have also been exposed in trenches; such pods are within a few feet of the shale-rhyolite contact. The host shale is not completely replaced in any of the fluoritized zones so far exposed, but the CaF_2 content of the zones ranges from 50 to 75 percent, and much of the unreplaced shaly material can be removed by washing. Silica is the principal impurity.

Four samples taken from fluoritized zones exposed in bulldozer trenches on Round Top and Little Sierra Blanca Mountain contained CaF_2, SiO_2, and $CaCO_3$ as follows:

Sample No.	CaF_2 (Percent)	SiO_2 (Percent)	$CaCO_3$ (Percent)
1	56.35	21.44	5.16
2	73.14	11.28	1.72
3	67.75	10.90	3.44
4	50.93	23.78	11.61

EVALUATION OF THE SIERRA BLANCA PEAKS DISTRICT

The commercial potential for fluorspar in the Sierra Blanca peaks district remains to be determined. Fluoritization is widespread and a few high-grade deposits of minable thicknesses have been exposed in bulldozer trenches. The size, shape, and average grade of these and other deposits in the district will have to be determined by drilling, which will be extremely difficult on the steep, rubble-covered slopes.

As the ore consists principally of cryptocrystalline fluorite, quartz, and clay minerals, it is likely that beneficiation will be difficult. However, if large reserves are found the metallurgical problems will probably be solved and the deposits exploited.

T. E. Mullens, geologist with the U. S. Geological Survey, recently collected several samples from fluorspar deposits exposed in bulldozer cuts on the north side of Little Blanca Mountain and submitted them to the Survey laboratories for spectrographic analysis. All samples analyzed contained trace amounts of beryllium, and all samples containing significant amounts of calcium fluoride contained appreciable beryllium. The beryllium content in fluorite-bearing samples ranged from 1,000 to 10,000 ppm; the beryllium content increases as calcium fluoride content increases. Mullens reported that beryl was observed in thin sections of some of the samples, but additional mineralogic study is needed to determine whether or not beryl is the sole source of the beryllium. Tin in amounts ranging from 100 to 150 ppm was also found in several of the samples analyzed.

Quitman Mountains District

One or two trial lots of metallurgical-grade fluorspar were shipped several years ago from a fluorspar prospect in the northern Quitman Mountains (Evans, 1946). This prospect is in the northeast corner of section 21, block 63-1/2, Public School Lands, Hudspeth County. It is on the east slope of the Quitman Mountains about 3.5 miles southwest of Bug Hill (figs. 2, 19). Coarsely crystalline fluorite occurs in narrow, closely-spaced fissure veins within a sheeted zone about 15 feet wide in lavas of the Square Peak Volcanics (Albritton and Smith, 1965). The zone has been prospected in trenches and shallow test pits over a distance of several hundred feet. Individual veins range from 4 inches to 2 feet in thickness. The

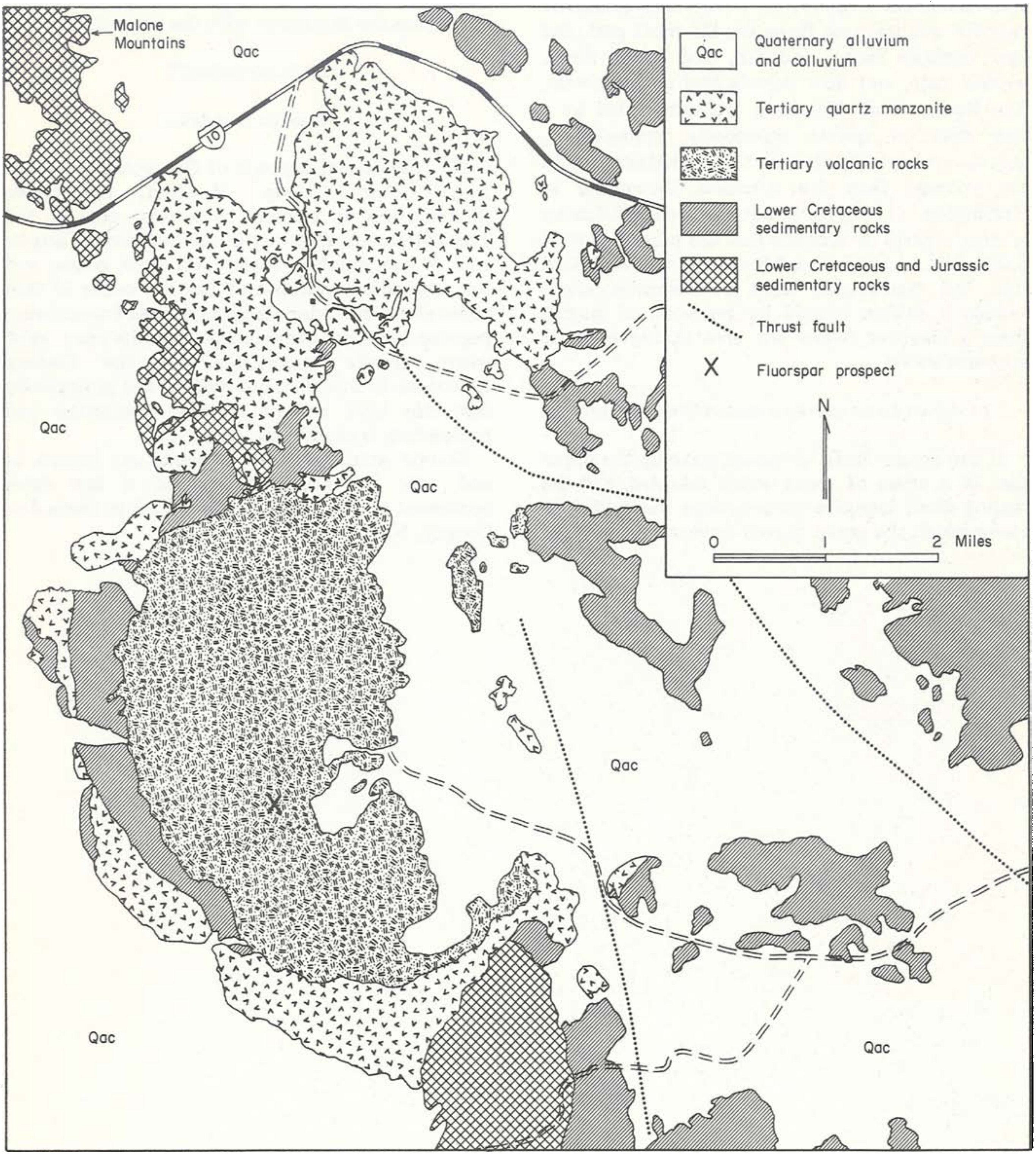

Figure 19. Geologic map, northern Quitman Mountains.

sheeted zone strikes N. 65° E.; dips range from 55° SE. to vertical.

The Square Peaks Volcanics were studied and named by Huffington (1943). The sequence has a total thickness of about 3,500 feet and comprises rhyolite and trachyte flows for the most part, but also contains latite, andesite, and basalt flows, welded tuff, and flow breccia and conglomerate. The Square Peak Volcanics are surrounded by a ring dike of quartz monzonite, granodiorite, granite, and syenite. The encircling intrusive rocks are younger than the volcanics. According to Huffington (1943) the Square Peak Volcanics occupy a basin or syncline that has subsided about 3,000 feet. Albritton and Smith (1965) suggested that the oval-shaped mass of volcanics might occupy a caldera caused by recession of magma from a chamber below the area during episodic intrusive action.

EVALUATION OF QUITMAN MOUNTAINS DISTRICT

If the Square Peak Volcanics make up the upper part of a prism of rocks which subsided, and the ringing silicic intrusive rocks occupy the fault zone along which the prism moved downward, then the geologic picture is similar to that for Aguachile in northern Coahuila, Mexico (McAnulty et al., 1963), and the inside contact zone around the ring dike is favorable for accumulation of fluorspar deposits, especially at depth where Cretaceous limestones are in contact with the ring dike.

EL PASO COUNTY

Franklin Mountains

No commercial deposits of fluorspar are known in El Paso County. However, appreciable fluoritization is evident in a road cut on the Trans-Mountain Highway in the Fusselman Canyon area of the Franklin Mountains. Both coarse and fine crystalline varieties of fluorite occur in thin zones along the outer margins of small Precambrian pegmatite dikes. Commercial deposits may exist where granite pegmatites cut the Castner Limestone in this area, but most of the geologically favorable land is in a military reservation and prospecting is prohibited.

Several small fluorspar deposits are known in and near the Organ Mountains, a few miles northwest of the Franklin Mountains in Dona Ana County, New Mexico.

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