THE DETAILED STRATIGRAPHY OF NORTHERN HANSONBURG MINING DISTRICT, SOCORRO COUNTY, NEW MEXICO

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Master of Science
in Geology

by
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This thesis is dedicated to Jenny,
my Airedale and field companion,
who, in spite of vomiting on my maps,
I still dearly love.

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ABSTRACT

The Hansonburg mining district is located at the northern end of the Oscura Mountains, an easterly dipping fault block that marks the eastern edge of the Rio Grande Rift system in this part of central New Mexico. The faulting here trends north-south, with the main (Oscura) fault accompanied by numerous minor faults that are all of the high angle normal type. Many of these faults acted as conduits for ascending ore solutions that created several small Mississippi Valley Type deposits in Upper Pennsylvanian rocks that rest unconformably on the Precambrian basement rocks.

The Pennsylvanian rocks are primarily carbonates (wackestones and packstones) interspersed with clastic units such as mudstones, shales, and fine to coarse grained sandstones. These lithological units represent shallow water deposition in the nearshore and inner shelf environments.

Most of the carbonate units contain fossils, some sparsely and others composed almost entirely of fossil fragments such as disarticulated crinoid columnals. Fusulinids, the primary index fossil of the Pennsylvanian period, are distributed throughout the strata under study. These fusulinids are almost entirely of the genus *Triticites*, with the specific classification changing frequently

throughout the section. An attempt was made to utilize this quality to facilitate identification of stratigraphic intervals. The result in this specific case was disappointing, but showed that with additional sampling it could be a useful tool.

The clastic sediments were derived from the Precambrian basement rocks of the Pedernal Uplift located to the north and east. Most clastic units are composed of immature arkosic detritus. Pink potash feldspars and iron staining lend a pink to reddish-brown hue to nearly all the clastic units.

With few exceptions, Upper Pennsylvanian units remain laterally continuous throughout the study area. The discontinuity at the Council Springs Limestone / Burrego Formation contact provides one instance where the basal shale unit of the Burrego Formation found on the Blanchard claims to the south thins and nearly disappears when it reaches the southern end of this study area. The bedding of these units ranges from thin to massive, providing the formations with relatively distinct profiles.

The detailed study of the stratigraphy here, and the accompaning map, should prove to be useful tools for future exploration in this area. These will provide the explorationist with the ability to locate himself accurately both on the surface and anywhere throughout the section.

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INTRODUCTION

Location and Access

The Hansonburg mining district is located in eastern Socorro county in central New Mexico, just south of Bingham, New Mexico. Bingham is approximately 30 miles east of San Antonio, New Mexico, on U.S. route 380. A gravel road just east of the post office in Bingham provides access to the mines to the south. The mining district is bounded on the south by the White Sands Missile Range (WSMR)(Fig. 1).

The study area is in sections 25 and 36, T.5S., R.5E., sections 30 and 31, T.5S., R.6E., and section 1, T.6S., R.5E., of the Bingham Quadrangle map (Fig. 2).

Access to the mining district is restricted and permission to enter must be obtained, at this time, from Consolidated Mining Resources, Inc., located in Golden, Colorado.

Geography and Regional Geology

The Hansonburg Mining District lies at the north end of the Oscura Mountains, which are part of the Mexican Highlands Section of the Basin and Range Province (Fenneman, 1931).

The Oscura's represent a northerly plunging anticline that has been displaced by north-south trending normal faults that constitute the eastern edge of the Rio

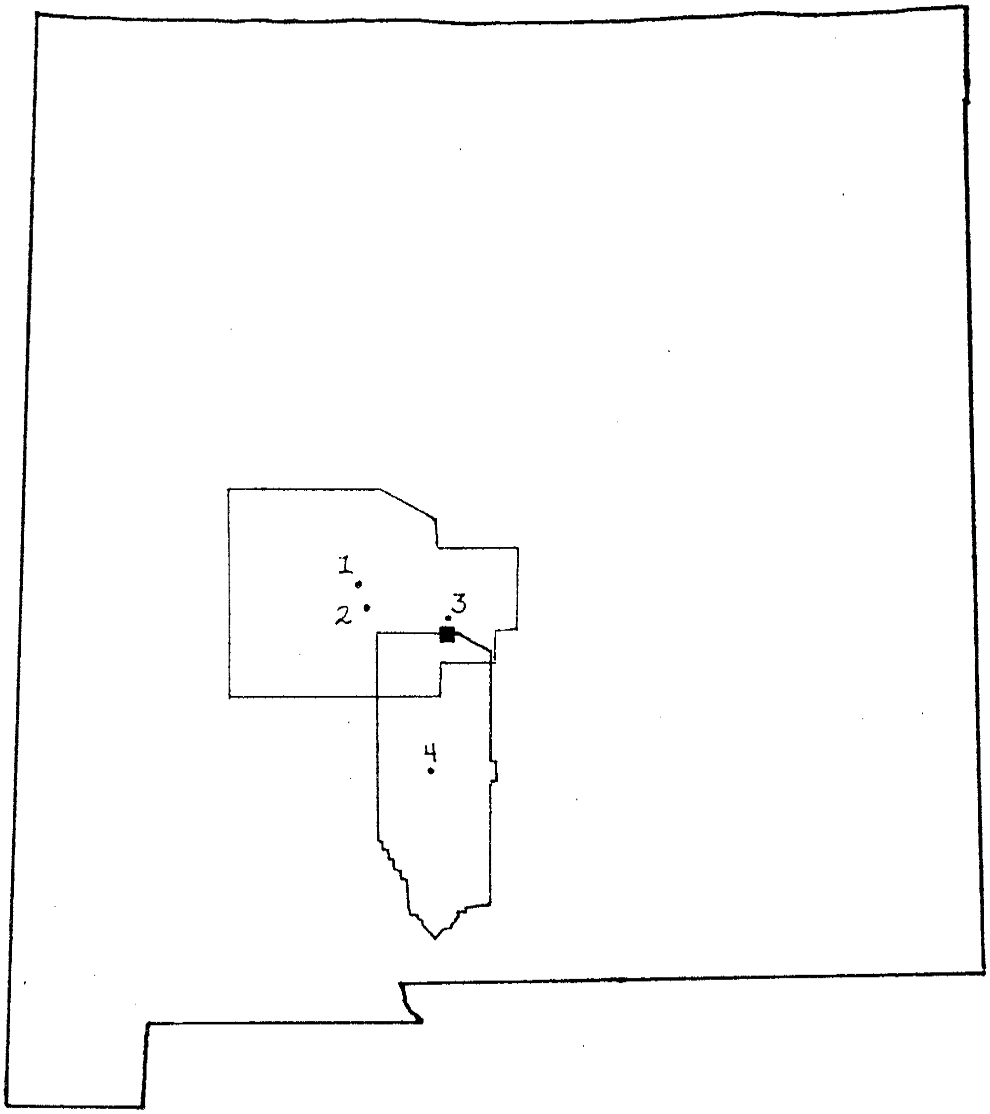


Fig. 1. Index map of New Mexico with Socorro County and 1) Socorro, 2) San Antonio, 3) Bingham, 4) White Sands Missile Range, and ■ Hansonburg mining district.

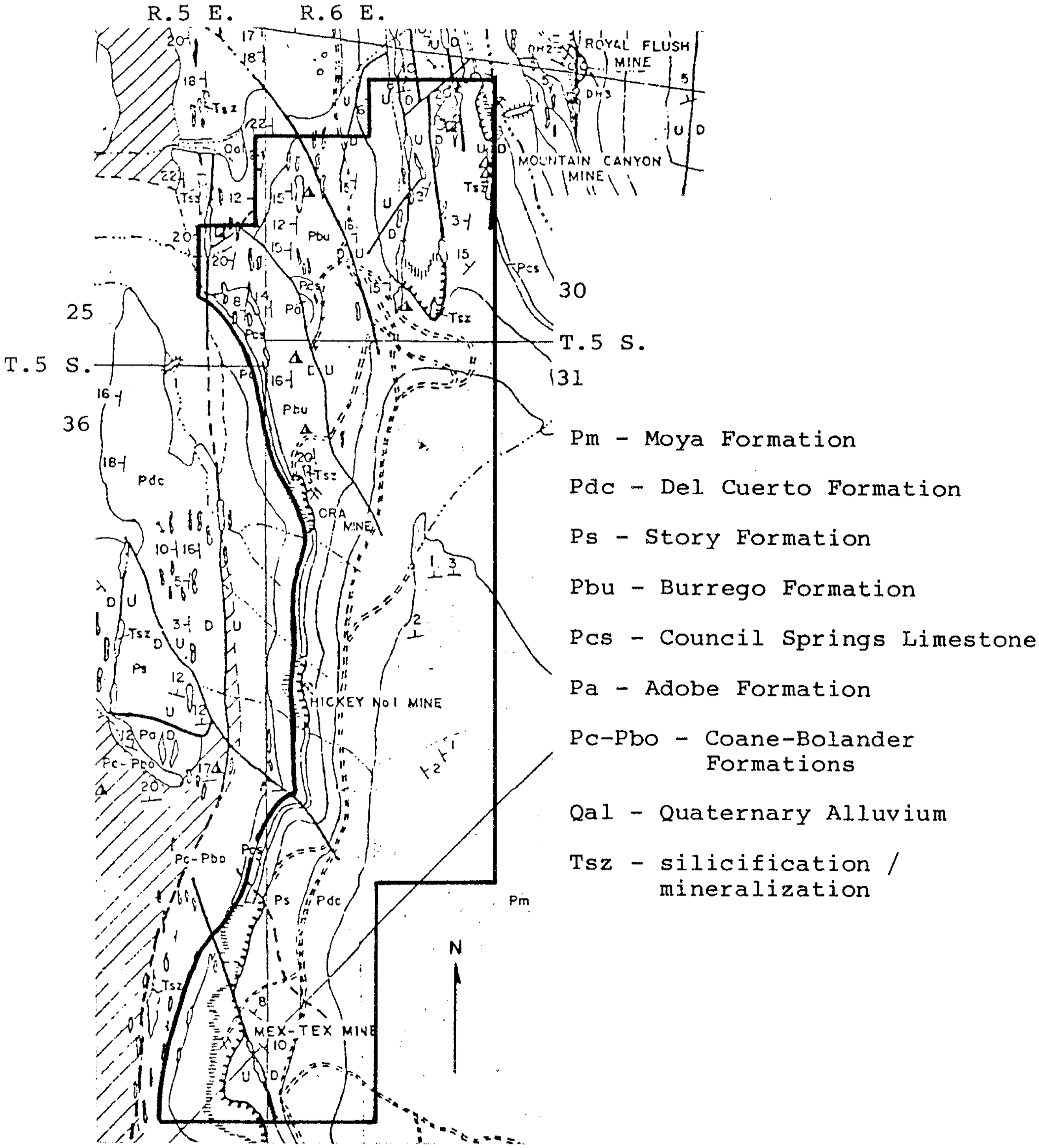


Fig. 2. Index map of field area at Hansonburg mining district. (modified from Lewchalermvong, 1973, Plate 1).

Grande Rift. The rifting was initiated some 32-37 million years before present (mybp), (Chapin,1979). The Oscura uplift terminates to the north at its intersection with the Capitan lineament (Putnam,1980) and to the south at the structurally fascinating Mockingbird Gap, which separates the eastward dipping Oscura Mountains from the westward dipping San Andreas Mountains further south. To the west the Oscura's are bounded by the Jornado del Muerto, a gently sloping intermontane alluvial plain within the Rio Grande Basin, and to the east by Chupadera Mesa and the Tularosa Basin.

The general fault block of the Oscura Mtns. slopes to the east with an average dip of 7 degrees, and the western facing escarpment provides up to 800 feet of relief in the study area and nearly 3000 feet of relief at Oscura Peak (elevation 8732) south of the district on the WSMR.

At the north end of the Hansonburg mining district, Julian Arroyo cuts across the Oscura range draining onto the Jornado del Muerto. Within the area the arroyo generally separates the Pennsylvanian carbonates from the Permian redbeds of the Abo Formation. Drainage in the arroyo is intermittent, with only 11 inches of rain per year, occurring mostly in the summer months.

The slopes in the area are interupted by the more resistant limestone units forming cliffs and ledges, separated by thin bedded limestones and clastic units that weather to smoothly sloping sands and talus. Within the mining district the vegetation includes scattered junipers and pinon on the dip slope with cactii, grasses, and creosote dominating the escarpment and lower elevations.

History and Previous Work

The first mineralization found in the Oscura Mountains was a small, low-grade copper deposit discovered by Pat Higgins in 1872 in the southern portion of the range.

The mining district itself was named for a prospector by the name of Hanson (Jones, 1904) and the Hansonburg ranch lies several miles to the west of the mining district.

In a USGS Professional Paper dated 1910, Lindgren, Graton, and Gordon discuss the copper potential for the area and make the first mention of a lead ore prospect in the Pennsylvanian limestones.

Johnston (1928) examined mines in the Hansonburg area and noted that the ores occurred as fissure and cavity fillings and that there was no evidence of replacement.

The first detailed report on the Hansonburg mining district was by Lasky in 1932, and he reported that the ore was open-space filling along silicified fault zones.

Thompson (1942) provided a detailed classification of the Pennsylvanian system in New Mexico and correlated these with Pennsylvanian sections in Arizona and Texas by comparing their fusulinid content. His type sections for the Veredas and Hansonburg Groups of the Missouri Series and the Keller Group of the Virgil Series are found in the immediate area of the mining district. His classification system, while far too detailed for regional work has been used in all studies of this mining district to date.

Rothrock, et al., (1946) provided a report on fluorspar and delineated the gangue mineralization on the Blanchard claims.

Clippinger (1949) examined the fluorite deposits at the Royal Flush and Mex-Tex mines and reported their occurrence in the interstices of silicified fault breccias. He also noted the use of barite for drilling mud and the development of milling operations designed to separate these two minerals, which, here-to-fore, had been largely regarded as gangue minerals.

Kottlowski (1953) studied the district and reported on the banded nature of the mineralization and proposed that a genetic model similar to Mississippi Valley type deposits could be applied to Hansonburg.

Hambleton (1959) made a paleo-environmental study of the Missourian carbonates in Socorro county and located one of his sections at the Mex-Tex mine area.

Austin and Slawson (1960, 1962) reported on their studies of lead isotopes and noted the leads found at Hansonburg were highly radiogenic (J-type) leads.

Kopicki (1962) studied the general geology and the paragenesis of hypogene and supergene mineralization of the district.

Williams (1964,1966) described the barite and fluorite deposits of Hansonburg.

Roedder, et al., (1968) studied fluid inclusions from the district and established temperature and salinity constraints for the mineralizing fluids.

Lewchalermvong (1973) reviewed the general geology and evaluated ore potential in the central and northern portions of the district.

Beane (1974) re-interpreted the lead data of Slawson and Austin and proposed that the lead was derived from the overlying Permian units and the Precambrian basement.

Silverman (1975) conducted geochemical soil surveys in the northwest part of the district and concluded there must be (or have been) additional mineralization within the confines of the WSMR to the southeast.

Allmendinger (1975) utilized fluid inclusion and stable isotope data and suggested a model for the convection of meteoric waters within the mineralization sequence.

Siemers (1978) studied the Pennsylvanian system in the Socorro region and measured several sections in the Hansonburg district.

Putnam (1980) conducted in-depth geochemical studies and drew correlations between the Hansonburg mining district and the Cave-in-Rock deposits of southern Illinois.

Purpose and Method of Investigation

The Hansonburg mining district has been a long studied area of economic mineralization. Exhaustive research has been done in relation to geochemical analysis of the physical constraints of the deposits, determining a genetic model, the paragenesis, controls of deposition, and providing generally enlightening, yet inadequately detailed geologic maps of the area.

The purpose of this thesis was to map, and stratigraphically study, in great detail the northern portion of this mining district with the explicit purpose of enabling the future explorationist greater control and understanding what strata he is dealing with, and the depth to the probable mineralized zone. The area covered by this study was largely determined by the constraints of funding (in terms of finding and paying field help) and time.

The mapping took place over a period from 9/80 through 3/83 with the help of ten different field assistants. The mapping was accomplished with plane table and alidade at a scale of 1 in.= 40 ft.. There was no adequate base map available so a topographic base map with a contour interval of five feet was created simultaneously. These mapping scales were decided upon in order to coordinate with the partially completed mining claim base-line and topographic map of the Blanchard claims to the south of this area.

In conjunction with the map, a detailed stratigraphic study was made of the rock units in the area to reclassify their lithologic type in the more descriptive and commonly used terminology of Folk and Dunham, and to delineate the lateral continuity and consistency of thickness of the rock formations as defined by Thompson (1942).

More than twenty rock thin sections were examined and several stratigraphic sections measured in previous studies and additional sections compiled by this author both on and off the mapped field area were used.

An attempt was made to isolate stratigraphically a possible ore horizon located higher in the section than those recognized here-to-fore on the Blanchard claims to the south. The means of examining this possibility and the conclusions drawn from this endeavor are detailed in the section entitled Fusulinid Stratigraphy.

REGIONAL STRATIGRAPHY

Any discussion involving the Pennsylvanian rock sequences in central New Mexico inevitably becomes confused due to the numerous systems of nomenclature applied to these layers. Siemers (1978) recounts these various systems and makes sound general recommendations for their future use in regional studies (Table 1).

In this study, as in all studies dealing with the Hansonburg mining district, the nomenclature of Thompson (1942) is employed. This is because only his stratigraphic divisions are sufficiently detailed (he divided the Madera Limestone into 13 mappable units) to be of practical use when dealing with such a small section of the Pennsylvanian system; his type sections for much of the Missourian and Virgilian Series in New Mexico are in the immediate area.

In the section on Fusulinid Stratigraphy, reference is made to the nomenclature of Myers (1973). Myers provided the author with identifications of fusulinids from the mapped area and compared them with forms from the Manzano Mountains some forty miles to the north.

In this part of central New Mexico Pennsylvanian rocks rest unconformably on the Precambrian basement. These Precambrian rocks are not exposed in the study area but can be seen to the south of the Blanchard claims. The basement rocks are medium to coarse grained granites and gneisses that include pegmatitic zones and veins composed of distinctive large crystals of pink potash feldspar, quartz, and books of micaceous minerals. Included in these rocks are large xenoliths of amphibolites and veins of "bull" quartz that intrude throughout the Precambrian but not into the overlying Pennsylvanian units (Condie and Budding, 1979).

The thickness of Paleozoic strata resting on the basement increases to the south, the direction from which the shallow sea had transgressed. In southwest Texas a nearly complete Paleozoic section exists. From the San Andres Mountains northward the Pennsylvanian strata thin rapidly; at the south end of the Oscura Mountains these units range from nearly 2000 feet in thickness to only about 600 feet at the north end of the range. Changes also occur in the dominant lithologies from one exposure to another in central New Mexico due to the relative positions these areas had to the Zuni and the Pedernal uplifts and the minor Joyita highlands near Socorro.

The Paleozoic strata in the Bingham area have been intruded locally by abundant dikes and sills of Cenozoic age (Wilpolt and Wanek, 1951).

Table 1. Summary of nomenclature for Pennsylvanian rocks of the Socorro region (from Siemers, 1978).

Gordon (1907)		Loughlin & Koschmann (1942)			Thompson (1942)			Kelley & Wood (1946)			Read & Wood (1947)			Myers (1973)		
Magdalena group	Madera ls	Magdalena group	Madera ls	bluish-black member	Virgil	Fresnal group		Magdalena group	Madera ls	Red Tanks memb	Magdalena group	Madera ls	upper arkosic limestone member	Madera Group	Wild Cow Fm	La Casa Memb
							Bruton fm			Atrasado member						
							Moya fm									Pine Shadow Memb
							Del Cuerto fm									
					Missouri	Hansonberg group	Story fm									Sol Se Mete Member
							Burrego fm									
				bluish-gray member		Veredas group	Council Springs fm									
							Adobe fm									
							Coane fm			Gray Mesa member			lower gray ls member		Los Moyos Ls	
					Des Moines	Bolander group										
						Armendaris group	Garcia fm									
							Whiskey Canyon ls									
							Elephant Butte fm									
	Sandia fm		Sandia fm	upper quartzite	Derry	Mud Springs group	Cuchillo Negro fm		Sandia fm			Sandia fm	clastic member	Sandia fm		
				upper limestone			Hot Springs fm									
				shale												
				middle quartzite		Green Canyon group	Apodaca fm									
				lower limestone			Array fm						limestone memb			
				lower quartzite												

LOCAL STRATIGRAPHY

The stratigraphy described below represents a compilation of several sections measured by this author. Efforts were made to describe as much of this section as possible from within the mapped area, however, the best exposures of certain formations (notably the Del Cuerto and Moya Formations) were found outside the immediate study area.

The author initially examined the Upper Pennsylvanian measured sections of Hambleton (1959) and the type localities of Thompson (1942) for the Hansonburg and Keller Groups. Where these sections were covered, or at best poorly exposed, the author endeavored to fill these intervals with observations from throughout the field area and the immediate vicinity. Lithologic units that change their charactor or appear in only one locality are noted within the text.

In this section, preceding a general lithologic/ stratigraphic description of each formation is a short "introduction" that will acquaint the reader with the "macro" characteristics of each particular formation and the units contained therein that the author considered useful as marker or key beds. This was done with the idea of facilitating any future field work to be done in the area.

A detailed measured section of these formations, complete with detailed descriptions, is provided in Appendix I. In addition the fauna contained in the units under study are identified by their phyla except where a particularly distinctive member may be identified according to suborder or subfamily. Fusulinid faunas that were identified for reasons explained elsewhere are also included in the descriptions below.

COUNCIL SPRINGS LIMESTONE

The Council Springs Limestone is easily distinguished from a distance by its massive cliff-forming nature and the prominent jointing which causes it to break into vertical columns. This enables the new visitor to the area to quickly determine his relative stratigraphic position (Fig. 3).

In areas where mining has exposed the disconformable contact between this unit and the overlying Burrego Formation, 2 to 3 foot deep "pot-holes" are occasionally found in the top of the Council Springs (Fig. 4). These pot-holes have an unclear origin; it has been suggested that these represent paleo-karst activity, submarine furrows, or stream channels. While the Council Springs has been subject to karst-like processes creating many large and small caverns in certain areas, the shape and location

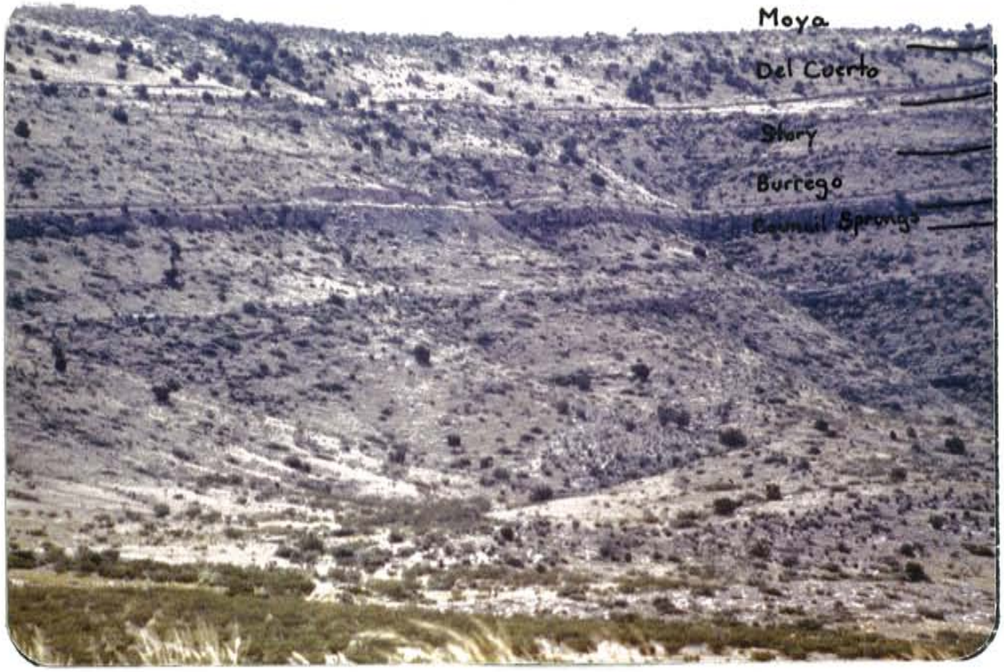


Fig. 3. Section under study. View of escarpment to the southeast. Note Hickey mine on Council Springs Limestone.

Fig. 4. "Pot-hole" in top of Council Springs Limestone, located in the Ora mine. Note pad is 11 inches high.

at the top of the unit of these "pot- holes", and the overlying shale/mudstone that fills these features leads this author to believe channelling created the pot-holes during the time period represented by the disconformity.

The biomicrite/wackestone of the Council Springs Limestone averages 18 feet in thickness.

BURREGO FORMATION

From a distance the Burrego Formation is identified by its stratigraphic position above the massive Council Springs Limestone and the distinctive pair of intraclastic ridges that denote the top of the formation and underlie the thick, reddish, arkosic slope of the basal Story Formation (Fig. 3).

The lithologies present above the disconformable basal contact are varied. The above mentioned "pot-holes" invariably contain a predominantly red laminated shale/ mudstone. At the Ora mine this shale does not extend above the top of the "pot-hole" (top of the Council Springs) and is overlain by the biomicrite referred to in Unit 1 (see Appendix I) of the Burrego Formation. To the south of this field area, on the Blanchard claims, this pot-hole filling shale unit thickens to approximately 8 feet, forming the base of Unit 1.

As described in Appendix I, the biomicrite in Unit 1 is variable in its thickness as well. A good exposure at the northern trench of the Mex-Tex mine (lower Mex-Tex) reveals an erosional contact with Unit 2. Both of the lithologies included in Unit 1 may locally disappear altogether and Unit 2 may rest directly on the Council Springs Limestone.

Useful marker beds within the Burrego Formation include Units 2, 7, 8, and 9 (Appendix I). The crinoidal biosparite/grainstone of Unit 2 is always in evidence overlying the Council Springs. When the Council Springs is buried or offers only a top surface exposure Unit 2 is helpful in determining the position of the basal contact (Fig. 5).

Unit 7 (Fig. 6) lends a distinctive feature to the poorly exposed mid-section of this formation. Its reddish-purple coloration proved particularly useful in the intensely faulted region immediately south and west of the Mountain Canyon mine.

The upper portions of Units 8 and 9 form a pair of ridges denoting the top of the formation. Their sharply contrasting mottled appearance (Figs. 7 and 8) facilitates identification even when their ridge forming qualities are covered.

The predominantly carbonate Burrego Formation has an average total thickness of 58 feet.

Fig. 5. Burrego Formation: Unit 2; biosparite / grainstone. Coin = 1.9 cm.

Fig. 6. Burrego Formation: Unit 7; biosparite / grainstone.

Compass is 7.2 cm. wide.

Both views 500 ft. SSW of Mountain Canyon mine.

Fig. 7. Burrego Formation: Unit 8; intramicrite / grainstone. Julian arroyo. Coin = 2.5 cm.

Fig. 8. Burrego Formation: Unit 9; intrasparite / grainstone. Julian arroyo. Coin = 2.5 cm.

STORY FORMATION

The Story Formation is readily identifiable due to the thick clastic unit that forms reddish slopes overlain by massive carbonates that comprise the upper half of the formation. Within the mapped area, the road to the Mex-Tex mine area rests on top of the Story Formation throughout most of its length.

The Story Formation has a total thickness of 57 feet and 6 inches.

DEL CUERTO FORMATION

The Del Cuerto, from a distance, is the least distinctive formation considered in this study. Composed primarily of ten irregularly bedded limestone units interspersed with three clastic units, the Del Cuerto is a thick slope-forming sequence situated between the underlying massive carbonate units of the Story Formation and those of the overlying basal Moya Formation.

Detailed examination reveals several units that provide the Del Cuerto with its own unique "signature". Unit 3 (Fig. 9), in the basal portion of the formation, is best exposed where the Mex-Tex road first climbs the hill to the south of Julian Arroyo. Unit 3, along with Unit 9, proved critical to the reinterpretation of the geology of the ridge to the northwest of the Mountain Canyon mine.

Probably the best marker bed within the Del Cuerto is Unit 9 (Fig. 10). The distinctive color and biotic composition make this unit unique among strata under consideration in this study. Being resistant and massively bedded, this unit is frequently exposed in the middle of the formation.

The most lithologically distinctive unit in the study area, however, is Unit 11. As described in Appendix I, this orthoconglomerate is rarely visible and has been described from only one location in the district (this author and Thompson, 1942).

The top of the Del Cuerto Formation is marked by the easily recognized Unit 13 (Fig. 11); this unit is well exposed and is found under the massive limestone cliffs of the basal Moya Formation.

The Del Cuerto Formation has a total thickness of approximately 92 feet.

MOYA FORMATION

Within the mapped field area, not all seven units of the Moya Formation are exposed. The lower half of the formation (through Unit 3) caps the Oscura escarpment from the Mex-Tex mine area north to near Station M2 (Plate 1 and Fig. 3).

Within the mapped study area, the Moya Formation seldom exceeds 25 feet in thickness, whereas its complete thickness totals 54 feet.

Fig. 9. Del Cuerto Formation: Unit 3; biosparite / grainstone. NW of Mountain Canyon mine. Coin = 1.8 cm.

Fig. 10. Del Cuerto Formation: Unit 9; biosparite / grainstone. West of Mountain Canyon mine. Lens cap = 7.2 cm.

Fig. 11. Del Cuerto Formation: Unit 13; biomicrite / mudstone. Main escarpment. Scale similar to above.

FUSULINID STRATIGRAPHY

A problem tangentially related to the detailed stratigraphy of this area concerned the stratigraphic position of a possible upper ore body on the Blanchard claims to the south of the area mapped in this study. Samples containing fusulinids from known sections in the study area were compared with fusulinid faunas found above, in, and below the horizon where drilling had indicated an ore body seemingly higher in the section than those ore bodies previously exploited on the Blanchard claims. It was hoped that a correlation of fusulinid types would lend itself to defining the stratigraphic horizon which the drill holes penetrated and hence, where the ore body was situated. These samples were sent to Dr. D.A. Myers of the USGS for preparation and identification. A total of nineteen samples were sent, eleven of them from known sections and eight were from the Blanchard claims, of which two were from units identified in the field by the author.

In the course of this investigation, certain information was developed that has stratigraphic value. With the above limited sampling in mind, a limited biostratigraphic correlation can be drawn between the upper Pennsylvanian section in the northern Oscuras and that described by Dr. Myers in the Manzano Mountains. These correlations based on fusulinid types are presented graphically in Table 2.

Upon examination of Table 2, it becomes apparent that there are discrepancies in the biostratigraphic correlations of time-lines dividing the Missourian and Virgilian Series based on fusulinid types, the primary faunal criterion for time divisions in the Pennsylvanian period. Several fusulinid species found in rocks considered to be Missourian by Thompson (1942) are considered to be representative of Virgilian species by Dr. Myers (pers. comm.). More than anything else, this reflects the inherent difficulty in making chronostratigraphic correlations based on the biostratigraphic relationships of any single form of biota, which may be facies controlled. The correlations will always remain a little vague until more concise faunal assemblage, taxon range, and concurrent range zone studies are compiled using all the available biota.

Specific fusulinid names and accompanying thin section photographs are provided in Appendix II, to facilitate any future paleontologic studies in this area.

The results were disappointing in terms of the original premise. No adequate correlations were possible between fusulinids from the drill hole horizon and those

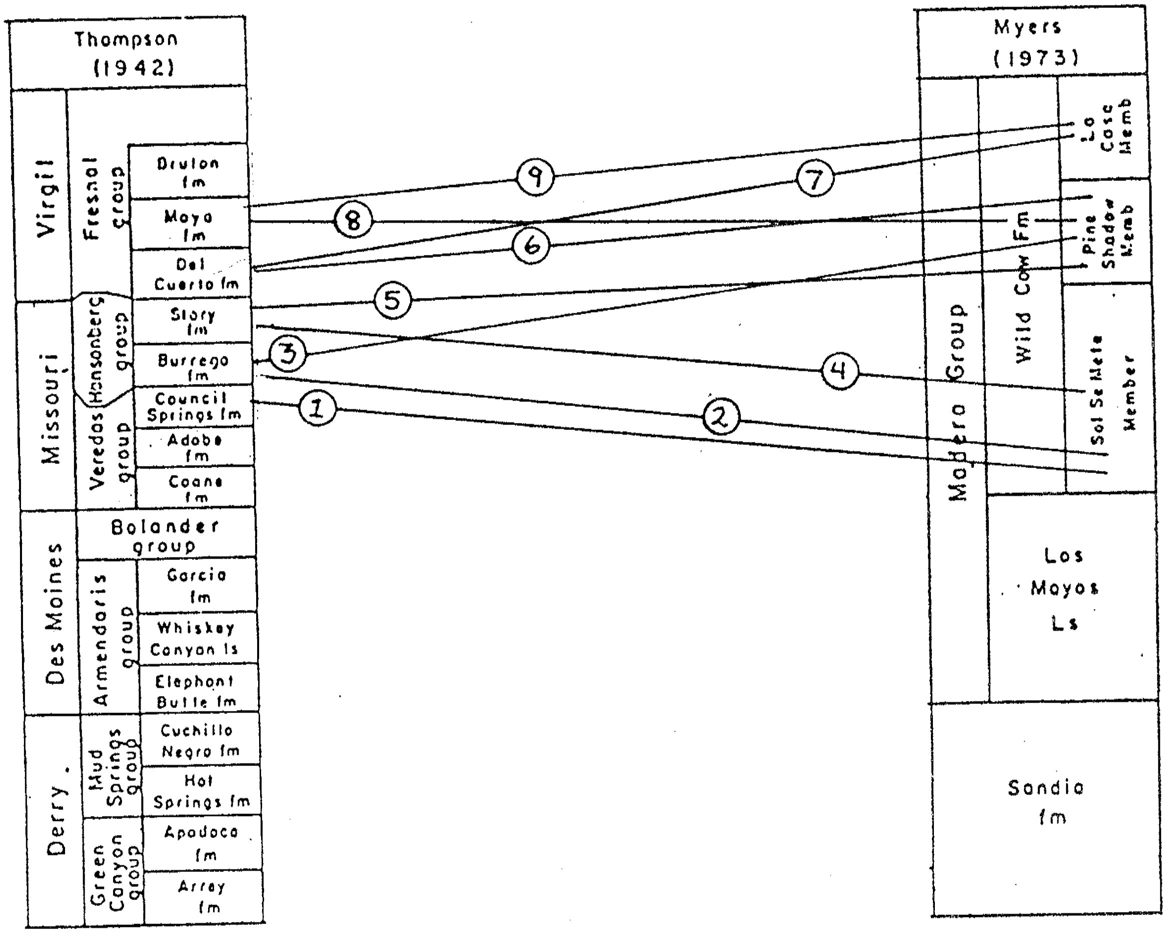


Table 2. Fusulinid stratigraphic correlations, based on collecting localities of Myers (Myers, pers. comm.).

1) Triticites liosepta Stewart; Council Springs Limestone.

2) Triticites cf. T. nebraskensis Thompson; Burrego Formation; Unit 2.

3) Triticites sp. - Burrego Formation; Unit 8.

4) Triticites cf. T. ohioensis Thompson; Story Formation; Unit 3.

5) Triticites sp. - Story Formation; Unit 6.

6) Triticites cf. T. bensonensis Ross and Tyrrell; Del Cuerto Formation; Unit 5.

7) Triticites aff. T. bensonensis Ross and Tyrrell, Triticites aff. T. cameratoides Ross; Del Cuerto Formation; Unit 10.

8) Triticites cf. T. plummeri Dunbar and Condra, Triticites cf. T. beedei Dunbar and Condra, Dunbarinella sp. - Moya Formation; Unit 5.

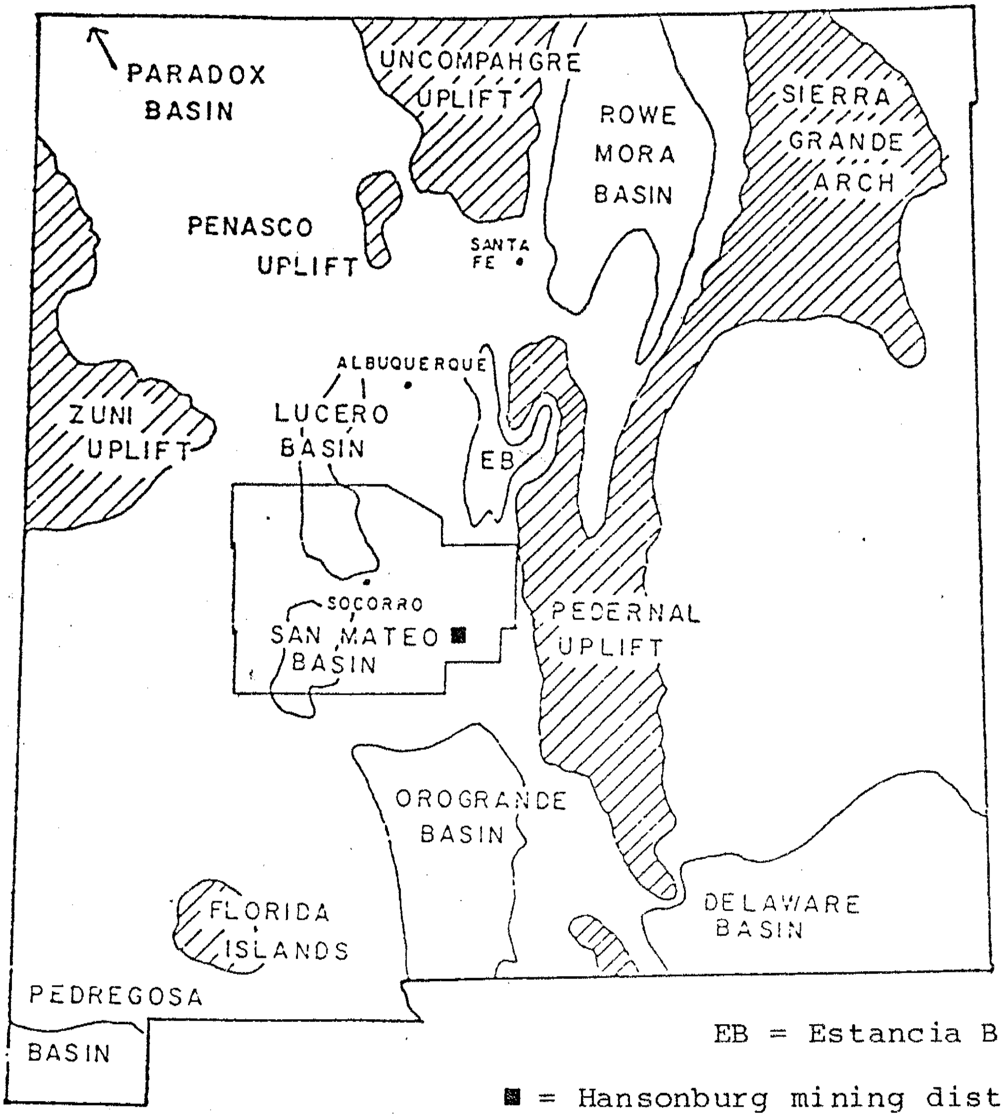
9) Triticites aff. T. whetstonensis Ross and Tyrrell; Moya Formation; Unit 7.

from the known sections. This was largely due to two factors, both of which stem from the limited amount of time the author had to devote to this problem. The first factor involves the inadequate number of samples procured by the author, primarily because of the desire of the author not to impose too greatly on the time and efforts of Dr. Myers. Secondly, the samples taken from above and below the drill hole horizon are suspect as the structural complexity of the southern Blanchard claims does not permit absolute certainty in the stratigraphic position of each sample location. Most of the area is covered with previous mine workings and roads, and where the author was able to make positive identification of units exposed on hillsides or mining stopes their lateral continuity to the area where the drilling occurred remains dubious. Conclusions derived from this investigation are discussed under the section entitled Ore Deposits.

ENVIRONMENT OF DEPOSITION

Central New Mexico remained a structural highland throughout most of the early and middle Paleozoic. Beginning in the Late Mississippian and Early Pennsylvanian, a shallow sea transgressed northward to cover the southwest flank of the North American craton (Thompson, 1942). Within this sea were several long and narrow positive elements that shed detritus into the surrounding basins; the most important of these were the Zuni and Pedernal uplifts (Fig. 12). During the late Paleozoic the area of the Oscura Mountains was under the direct influence of the Pedernal uplift (part of the ancestral Rockies) to the east and north (Kottlowski, 1963).

The lithofacies present in the Hansonburg region are indicative of this area being in the shallow marine carbonate realm, perhaps ranging from the nearshore to the inner shelf environments during deposition. The nearshore environment, as defined by Siemers (1978), represents the area that extends from the strandline to the depth of normal wavebase. Selley (1970) suggests there are three types of nearshore environments, terrigenous, mixed carbonate-terrigenous, and carbonate. The region of the Oscuras and, indeed, most of central New Mexico, falls into the mixed carbonate-terrigenous regime. Lithologically this is represented by thin to medium bedded packstones and



EB = Estancia Basin

■ = Hansonburg mining district

Fig. 12. Pennsylvanian paleogeography. From Bauch (1982, Figure 3).

wackestones and granular terrigenous rocks. These rock types are well represented in the Oscuras where various carbonate lithologies are periodically interrupted with immature arkosic sandstones and shales. Some of the clastic units demonstrate intensive channelization and overbank-type or low energy deposits (Story Formation-Unit 1; see Appendix I and Plate 2) as one might find in interdistributary bays or adjacent to the prograding "fingers" of a nearshore deltaic complex.

The local stratigraphy at Hansonburg has a distinctive cyclical pattern. In the nearshore environment of the mixed type, thick carbonate sequences can accrue wherever the influx of terrigenous material declines due to a low lying landmass, dry climate, or channel abandonment. In this particular case, other factors may have played a role in the periodic pulses of clastic detritus as well.

It has been suggested (Heckel, 1980) that glaciation in Gondwanaland may be responsible for eustatic sea level changes that produced Upper Pennsylvanian cyclothems on the stable craton of Midcontinent North America. Eustatic sea level changes were proposed by Wilson (1967) as being at least partially responsible, along with structural activity associated with the Pedernal uplift, for the cyclic sedimentation in Virgilian units exposed in the Sacramento Mountains southeast of Hansonburg. Wilson believes that more than twenty such sea level fluctuations occurred in the Late

Pennsylvanian, and these were reflected in the shelf deposits he examined.

The Pedernal landmass reached its maximum uplift in Late Pennsylvanian and Early Permian times (Kottlowski, 1960). This was, in all likelihood, a sporadic rather than continual process, and each major period of uplifting may be reflected in the rock record as a period of clastic deposition.

A concept that is often ignored when contemplating lithologic changes representing "transgressive/regressive" sequences is that of local isostatic adjustment (D. Johnson, pers. comm.). As the basin filled with sediments, adjustment was necessary to keep the system in equilibrium. This process, while subordinant to the above mentioned processes, may have aided the tectonic influences responsible for the uplifting of the Pedernal landmass.

The inner shelf environment is defined as being from wavebase to several 10's of metres depth. This is considered to be a generally quiet depositional environment that is occasionally roiled by significant storms. Lithologies representing this environment include carbonate wackestones and mudstones and terrigenous muds, shales, and clays. These rock-types are well represented in the study area, especially where the thicker accumulations of carbonates occur.

These carbonate units are frequently separated by thin shale /mudstone partings, probably representing a cessation in lime mud deposition rather than an influx of terrigenous material as described above (Heckel, 1970).

Even more indicative of the inner shelf environment is the diversity of fauna found in the fossiliferous carbonates in the area. Stenohaline forms such as echinoderms, brachiopods, and cephalopods are common along with mollusks, forams, and algae. In many of the fossiliferous units the fossils are whole and show little sign of abrasion, suggesting a quiet environment.

There are also several intraclastic units and carbonates with rip-up structures that perhaps represent an occasional storm that lowered wavebase so as to rework semiconsolidated sediments on the sea floor.

The lithologic and biotic evidence for this pair of environments is suggestive, not conclusive. It is certain, though, that the evidence points to a shallow marine carbonate environment, perhaps one whose depth does not exceed wavebase but rather depends on a barrier of sorts to lower the energy to a level for the deposition of muds and clays. However, when looking at Pennsylvanian units exposed in the northern Oscura Mountains one does observe a general trend towards shallower environments as one proceeds up through the section. Throughout and above the sequence under study the lithologies become more clastic (and coarser grained) and eventually terrigenous Permian redbeds cap the local strata.

STRUCTURE

Regional Structure

The structural history of this region of central New Mexico begins with Precambrian tectonics. It is thought that a period of structural activity resulted in the formation of rift-like structures similar to the rift we see today. This ancestral feature is not well understood. While there is a general agreement that a rift-like structure exists in the basement rocks, it is not known whether it was formed by tensional tectonics such as the classic continental rift model or by means of a strike-slip movement. It is agreed that this ancestral feature played a significant role in the formation and orientation of todays Rio Grande Rift (Condie and Budding, 1979).

Another feature that may date from as far back as the Precambrian is the Capitan lineament. This feature has been positively dated at 27.9 mybp, but it is considered likely that this lineament, also, has an history that dates back to the basement (Precambrian) rocks. This lineament trends WNW across this portion of New Mexico, from the Riley area NW of Socorro to the Carrizozo region to the SE (Chapin, pers. comm.). There is strong evidence that the ancestral Capitan lineament influenced subsequent structural activities in the region.

One such event was deformation that resulted in the creation of broad folds in this region during the Laramide orogeny. As presently interpreted, the Jornado del Muerto represents a synclinal trough, the Oscura Mountains to the east are part of a northerly plunging anticline and, still farther to the east, the Tularosa basin is another synclinal trough. Both the Oscura anticline and the Tularosa basin seem to terminate at the Capitan lineament (Putnam,1980). In a general way this lineament could possibly be considered the structural border between the broad basin of the Jornado del Muerto to the south and the narrow "pinched" section of the Rio Grande rift in the vicinity of the city of Socorro.

About 32-37 mybp (Chapin,1979) the next major structural event took place, initiation of the present rift system. The Oscura Mountains mark the eastern edge of the rift in this area. Northerly trending normal faults cut the Oscura anticline and dropped a block to the west creating a graben in the area of the Jornado del Muerto, the "uplifted" block of this anticline gently dips to the east. To the south of the Oscuras this eastern edge of the rift undergoes a most interesting change at Mockingbird Gap.

Here the easterly dipping Oscuras terminate and disappear into the colluvium, several fault blocks crop out, and then, just south of Mockingbird Gap the San Andreas Mountains rise from the colluvium with the steep escarpment to the east and the fault block dipping to the west. Unfortunately, this fascinating exhibit of torsional tectonics remains unavailable for detailed study as it is situated deep within the restricted area of WSMR.

Local Structure

In the Hansonburg Mining District the faults are all high angle normal faults, found in an en echelon pattern usually with the downdropped block to the west towards the graben. All of these faults trend within a few degrees of north. Within the district are three major faults, i.e., those with displacement measured in hundreds of feet.

Approximately one mile west of the Oscura escarpment is the Oscura fault(s). This fault is regarded as the primary fault of the eastern edge of the rift in this area. Although the fault is largely concealed by alluvium its displacement is certain to be in hundreds of feet. The throw of the fault decreases to the north and dies out in the Oscura anticline, quite possibly at its intersection with the Capitan lineament. Its trend is mostly north-south along the escarpment, but to the north of the area it changes direction to the east, giving it an overall trend of N15E (Kottlowski,1953).

The next major fault to the east was referred to as the Axis fault by Kopicki (1962). It lies at the base of the escarpment and has a trend very much like that of the Oscura fault, dying out in the southwest 1/4 of section 30. Kottlowski (1953) reports a displacement value of 550 feet below the Julian-Malachite (Mex-Tex) mine, with the Permian Bursum Formation found adjacent to the Lower Pennsylvanian Bolander Formation.

Another mile to the east is the Hansonburg fault. This fault differs from the others as its displacement decreases to the south (Kopicki,1962). It splits into several faults and eventually terminates at the southern end of the district near its border with WSMR.

The Axis and Hansonburg faults lie to the west and east of this study area respectively. Within the mapped field area are numerous minor faults. These faults remain parallel to subparallel with the major faults, and, like the major faults, all are considered to be high angle normal faults. Displacement ranges from negligible to nearly 200 feet at one location where the Council Spings Limestone has been found adjacent to the Del Cuerto Formation, northwest of the Mountain Canyon mine. Displacement in these minor faults generally increases to the north, which is contrary to the displacement of other faults in the district; occasionally there may be considerable drag on such faults (Fig. 13). The length of these faults is limited, usually to less than a mile, then they may terminate at a junction with another fault, simply die out as a single fault, or splay into several relatively short faults. The minor faults may be discreet individual faults or a narrow zone or swarm of closely spaced faults whose surface expression is seen as essentially linear with a small degree of sinuosity. These faults and fault zones may or may not show brecciation.

The joint system on the exposed dip slopes in the field area is composed of two sets of nearly vertical joints, one oriented to the NW and the other set to the NE. The joint sets range from nearly N45W to N45E, but clearly show a prominent N-S trend (Fig. 14). These sets may be found together at any given locality or may be mutually exclusive. When found together, field evidence is contradictory as to whether one set preceeded the other so it is perhaps best to consider them as contemporaneous.

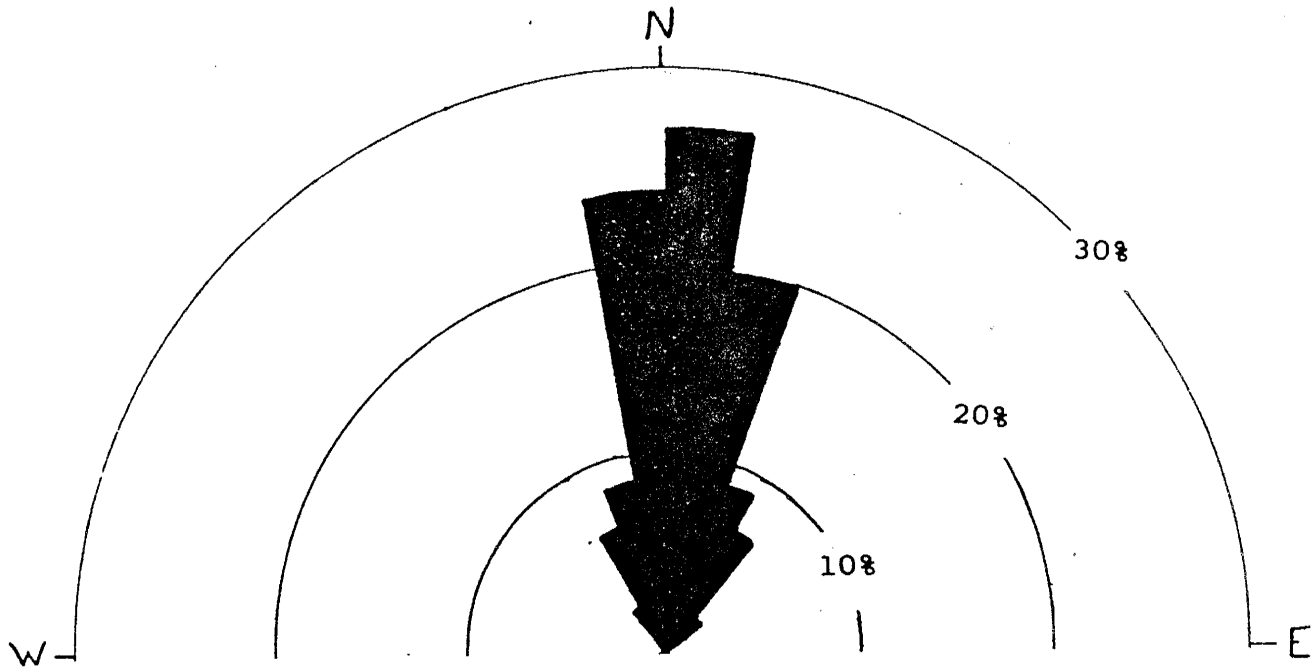
The joints within each set may be closely spaced or separated by several feet. Typically, the individual joint has a width of less than 1/4 inch but varies up to 4 inches, and the length varies from inches to 10's of feet.

Kopicki (1962) reports that the frequency of joints in evidence decreases as one goes east away from the Oscura fault. This, and the subparallel orientation of the joint system to the fault system is indicative of these sharing a common stress field. Field observations suggest that these joints are basically of the oblique shear-type with a relatively little component of shear involved, as only occasionally does one set visibly offset the other, and, as mentioned above, which set offsets the other is not consistent.

The joints may or may not be mineralized with calcite or siderite, the principal joint fillers. Those joints that are mineralized (Kopicki refers to them as partings) appear to have dilational veins within them as no evidence for replacement was detected by this author.

Another set of joints which have no clear relationship to the previously discussed sets are found within mineralized fault zones and ore bodies. While these joints also generally trend to the north, their orientation may not coincide with joints immediately adjacent to them in the country rock. This may primarily be the result of one or two factors. The first being that the mineralized area is a different medium whose tendency for strain would be different from that of the surrounding carbonate rock even if under the same stresses. More likely, however, is that these joints are a result of continued adjustment within the structural setting and the brittle nature of the ore fractured where the host lithologies were able to absorb these minor stresses without significant deformation. Further evidence for the latter explanation can be seen where mineralized fault zones have fractures that show slickensides that are coated with crystallized silica, suggestive of an ongoing process of structural adjustment during the waning stages of mineralization and probably beyond.

Fig. 13. Drag along fault, Mex-Tex mine. View of escarpment to the southeast.



n = 45

Fig. 14. Rose diagram demonstrating frequency and trend of joint sets in 10 degree intervals.

ORE DEPOSITS

There have been over two hundred minerals reported from the Hansonburg mining district. The vast majority of these are supergene minerals derived from the surrounding sedimentary pile and alterations of the original hypogene mineralization. It is the hypogene minerals, galena, barite, and fluorite, that have been the focus of "industrial" economic interest, and it is these minerals that constitute what is referred to below as ore bodies, deposits, and mineralization in general, although they are always accompanied by a varying suite of supergene minerals and gangue minerals such as quartz, calcite, and siderite. The following sections deal with the fundamental aspects of the genesis and deposition of these ore bodies and in no way should be considered a complete statement of these problems.

Genetic Model

The mineral deposits of the Hansonburg mining district have long been noted to be similar to the Mississippi Valley Type lead deposits in Missouri, Illinois, and Indiana (Kottlowski, 1953). These deposits occur in the telethermal zone of deposition, a shallow realm of low temperatures and pressures (Park and MacDiarmid, 1975). Like other such deposits, geochemical evidence indicates the ore solutions were derived from formational waters deep within the adjacent sedimentary basin via the dewatering of permeable units by compaction. Faulting associated with the activation (reactivation ?) of the Rio Grande Rift system provided channelways for the ascending ore fluids. Being associated with an active rift system may also account for the anomalously high temperatures of formation for this deposit (135-210 degrees centigrade) where most such deposits are less than 145 degrees centigrade. Thermodynamic calculations based on fluid inclusion data indicate the composition of the ore solutions did not change appreciably during deposition; this, along with other evidence, suggests decreases in temperature and pressure being the main criteria for precipitation of the minerals here (Putnam, 1980).

Depositional Controls

The mineralization found at Hansonburg is vein-like with tabular to lenticular ore bodies, with their long axes parallel to the essentially north-south trending minor faults in the district. These features form the two general categories the mineralization falls into: 1), those restricted to the fault zones, and 2), those which have considerable lateral extension away from the fault zone. Basically, only those ore bodies that fall in the second category have been of economic interest in the past.

All the hypogene mineralization occurred as open-space fillings (Kottlowski, 1953). Much open space was provided within the brecciated fault zones themselves. Along the traces of those faults that acted as conduits for the ore solutions one can observe extensive silicification and occasionally a linear or narrow podiform ore body (these account for the numerous prospect pits throughout the area). These faults are all high-angle normal faults with the down-dropped block usually to the west. They are sometimes found as single faults that "cleave" the rock rather cleanly or, more commonly where mineralization is found, as a swarm of faults that more or less parallel each other, such as is found immediately southwest of the Mountain Canyon mine (Plate 1). Mineralization within these faults is seemingly not restricted to any one horizon, although it has not been observed by this author any higher in the section than the Story Formation, perhaps for reasons no more complex than erosion.

Ore bodies of the second type, i.e., those with appreciable lateral extent, occur exclusively in the Council Springs Limestone and the lowermost Burrego Formation. Again, these ore bodies are located adjacent to faults that acted as conduits for the mineralizing fluids. The reasons for the tight stratigraphic control of ore zone location revolve around the relative availability of open space for the occurrence of mineralization.

Lewchalermvong (1973) sites several structural reasons for the confinement of mineralization to these units. The massive nature of the dense, fine grained Council Springs Limestone promotes intensive shattering as a result of tectonic forces acting on it, such as along the faults in the district. The overlying basal Burrego unit (the biomicrite/wackestone), while not massive, has a rather closely spaced system of perpendicular joints that would tend to open up and provide space for mineralization as well. Most of the normal faulting in the district involves a considerable component of rotational movement along the fault plane. Where the displacement is minimal at the hinge of the fault, the units would undergo tremendous torsional stress that would result in even greater shattering of a unit such as the Council Springs Limestone. This situation can be seen easily at the Mex-Tex mine.

The secondary porosity generated by tectonic shattering of the rock clearly plays a major role in providing a suitable environment for ore deposition, however, within the Council Springs Limestone itself there are locally layered zones with considerable primary porosity as well. These are the rip-up structures referred to in the section entitled Local Stratigraphy. The angular carbonate clasts in these zones appear to be considerably more porous than the surrounding micritic limestone. These layers were then acted upon by the initial influx of formational waters and/or by the formation of paleo-karst, generating yet more available space for subsequent mineralization. This process is reflected in the "coon-tail" or banded structure of the ore bodies.

The other source of available space for mineralization is the solution channels and caverns referred to above. Karst activity was prevalent in the Council Springs Limestone immediately to the south of the mapped field area on the Blanchard claims. This is probably due to the fact that here the basal Burrego Formation consists of up to eight feet of shale, providing essentially an impermeable cap for the ascending waters. The dissolution began with the porous layers just discussed, and eventually opened up caverns (Putnam, 1980). This was a long term process as some of the caverns are mineralized and others are not. The basal Burrego shale unit on the Blanchard claims restricts the mineralization to the Council Springs Limestone exclusively, whereas to the north where the shales' thickness is negligible to nonexistent, mineralization extends into the basal Burrego Formation and little evidence of karst activity can be found.

As stated in the section entitled Fusulinid Stratigraphy, an attempt was made to discern the location of a horizon where several drill holes suggested a possible ore body well above the Council Springs Limestone on the Blanchard claims. As also stated above, the results of this endeavor were inconclusive. Field evidence suggests that the drill hole horizon is probably the top of the Story Formation. Fusulinids taken from this unit were altered but identified as definitely Virgilian (Myers, pers. comm.) which lend some support to this being the Upper Story Formation or younger.

The drill holes in question form a linear pattern nearly 400 feet long and up to 100 feet wide with the mineralization being located at various depths from the surface to several 10's of feet at different holes. The trend of this drill hole pattern and exposed mineralization is closely aligned to the probable trend of a significant, and mineralized, fault that can be traced farther to the north until it is covered by a road and mine dump. It is the judgment of this author that the mineralization found here represents this first type of ore deposit referred to, i.e., restricted to a fault zone. In this case, however, the mineralization does have considerable width to it and may very well be of potential economic interest, this area probably represents a feathering out of a mineralized fault zone rather than a discrete ore body.

For more detailed information regarding the geochemistry, paragenesis, and genetic models of this mining district, please refer to the History and Previous Work section and the Bibliography.

FUTURE EXPLORATION

A fine overview of geologic features to be used in defining a target area for exploration is presented by Chettavat Lewchalermvong in his thesis (1973, pages 60-61). A synopsis of his targeting factors includes:

1.) The favorable bedrock units (Council Springs Limestone and the lower Burrego Formation) should underlie the drilling area.
2.) The drilling area should be adjacent to minor faults that may have acted as conduits for ascending ore solutions. Criteria for this are discussed under Ore Deposits.
3.) The potential ore horizon should be overlain by an impermeable shale unit.
4.) Silicified zones appearing along faults and fractures may be an indication of an ore deposit below.

As most surface mineralization has already been explored by prospect pits and shallow shafts and adits, future exploration will consist of drilling exploratory holes in areas of potential. Core drilling would give the most informative results, allowing the explorationist to examine the strata he is penetrating and perhaps lending greater understanding to the local structure. Much of what was undertaken in this thesis was to facilitate such endeavors, and should be considered tools to be used in exploration.

The Map

The map included in this study (Plate 1) was prepared for this express purpose. Besides allowing the explorationist to determine what units are exposed on the surface of any given locality, the map was constructed in sufficient detail (1 inch = 40 feet) to make extrapolating the depth to any given horizon both easy and accurate. The scale chosen also provides considerable detail to such features as the trend of faults, joint systems, and any associated mineralization. Included on this map are landmarks that may be used as points of reference such as claimposts (identified where possible) section corner markers, prospect pits, roads, and fences, to aid precisely in determining ones location in the field. Unfortunately, expenses prohibited the construction of permanent station markers, but small rock piles still mark each station, and at the bottom of each pile there should be a rock marked with the station symbol.

Stratigraphy

The detailed study of the local stratigraphy also provides an essential tool for exploration. Under the section entitled Local Stratigraphy, one will find descriptions of the formations taken as a whole, and then a general lithologic overview of each formation. The unit descriptions in Appendix I provide many morphological features useful for determining stratigraphic location. These include detailed lithologic descriptions, thicknesses, faunal assemblages, and the designation of particularly distinctive units as key or marker beds. Not only should this facilitate the identification of surface outcrops but should be very useful when examining drill cores, chips, or decently prepared drill logs, in terms of ascertaining the position in the drill hole. In conjunction with the above descriptions, a stratigraphic column (Plate 2) was prepared.

The section of this thesis dealing with fusulinid identification could be of possible use in the same manner as just discussed, particularly if a more complete fusulinid assemblage is compiled.

To this authors knowledge, none of the various geophysical methods of exploration have been employed at the Hansonburg mining district. Such methods as electro-conductivity surveys, or even seismic surveys (cost permitting-which is doubtful) could perhaps be very illuminating in terms of hidden ore deposits.

As just suggested, cost will determine the method of exploration to be used, whatever the financial parameters are, hopefully this study will prove to be an asset for future exploration.

APPENDIX (I)

COUNCIL SPRINGS LIMESTONE

C.S.Ls. 18 ft., Massive bed, with lower 4 ft. locally divided into two 2 ft. beds of light gray/buff biomicrite/wackestone. Weathers to a rough, solution-pitted surface of same color. Unit contains minor chert, blebs of re-crystallized calcite, occasional angular carbonate lithoclasts that are locally abundant enough to show well defined, laminated, rip-up structures. Although not very fossiliferous, this unit does contain brachiopod fragments, crinoids, bryzoa, and fusulinids identified as *Triticites liosepta* Stewart. This cliff-forming unit has a well developed vertical jointing system.

BURREGO FORMATION

UNIT 1 0-8 ft. of predominantly red, laminated, silty, shale. Thickens to the south. May be overlain by 0-3 ft. of irregularly bedded (2-5 in.) gray/buff colored biomicrite/wackestone. Weathers to buff color. Distinctive vertical joint sets nearly perpendicular to each other with orange Fe-staining disseminating away from the joints. Unit contains some pelecypods, brachiopods, and fusulinids mixed with fragmented shelly material. This unit pinches out locally and when in good exposure shows an irregular contact with the overlying unit.

UNIT 2 4 ft. of irregularly bedded (6-14 in.) gray/buff colored biosparite/grainstone. Weathers buff. Contains abundant disarticulated crinoid columnals, re-crystalized to spar, shell fragments, pelecypods, and fusulinids identified as *Triticites* cf. *T nebraskensis* Thompson. Grain size to 2 mm. Ridge former. Key bed.

UNIT 3 5 ft. 4 in. of irregularly bedded, nodular, light gray biosparite/grainstone containing crinoid columnals, fusulinids, algal matter, and various skeletal fragments. Nodules frequently in a white clay matrix when weathered. Poorly exposed slope former.

UNIT 4 8 ft. of massively bedded gray biomicrite/wackestone that fines upward to a miclutite. Large secondary calcite crystals in lower portion of unit. Contains fragments of both pelecypods and brachiopods, crinoid columnals, and phylloidal algae. Ridge former.

UNIT 5 6 ft. 5 in. of fissile, gray, moderately sorted,clayey, arkosic, fine grained sandstone. Fines upward to a dark gray to green laminated shale. Upper contact of unit highly altered to poorly indurated white clays with dark gray shale nodules incorporated within and fusulinids, presumably weathered from unit above. Poorly exposed slope former.

UNIT 6 6 ft. of irregularly bedded, nodular, dark gray biomicrite/wackestone interbedded with thin partings of clays and muds in lower portion. Abundant fusulinids (*Triticites* sp.) becoming extremely abundant toward the top of unit.

UNIT 7 3 ft. of highly distinctive, irregularly bedded, red/ purple biosparite/grainstone. Composed largely of recrystallized crinoid columnals and skeletal fragments. Weathers like sand. Key bed.

UNIT 8 10 ft.. Irregularly bedded, locally cherty, gray/green biomicrite/packstone that weathers to a grayish brown in lower portion. Unit becomes a more massively bedded intramicrite/packstone that shows a very distinctive mottled pattern of dark gray sparry limestone clasts, usually well rounded, incorporated in a matrix of light gray, fossiliferous micrite. This unit contains brachiopods (notably including large specimens of the suborder Productacea), pelecypods, crinoid columnals, fusulinids (Triticites sp.) and locally contains abundant algae. Ridge former.

UNIT 9 10 ft. 5 in.. Basal 2 ft.6 in. is irregularly bedded, nodular, gray sparite that is seldom exposed but separates the massive beds above from the unit below. This unit becomes massively bedded (two 4 ft. beds) gray intrasparite/grainstone with an appearance very similar to that of Unit 8. Unit 9 contains brachiopods and some skeletal material with algae more abundant towards the top.

UNIT 10 1 ft.6 in. of a single bed of dark gray/green biomicrite/packstone. Algae abundant; laminated with surface showings of what appears to be carbonitized plant fragments. One large (7 in. diameter) convoluted cephalopod found in cross section on surface, with occasional bellerophon-type gastropods.

The Burrego Formation has an average total thickness of 58 feet.

STORY FORMATION

UNIT 1 21 ft. Basal 5 ft. of this unit is a maroon/reddish brown mudstone that becomes interbedded with thin beds of friable, mottled, gray-green/red, well sorted, clayey, medium grained, arkosic sandstone. This sandstone predominates for the next 6 ft. as a thin to medium bedded unit showing considerable crossbedding, becoming increasingly micaceous and fining upwards until in the last 5 ft. it grades into red/brown micaceous silty shale. The top contact of this unit is intensely weathered to a poorly indurated, white clay that contains clasts of the above mentioned shale. Key bed.

It should be noted that the lithologies present in this unit are highly variable throughout the area, primarily in terms of grain size. To the east of the field area, in Julian Arroyo, this unit is exposed primarily as a medium to coarse grained, intensely cross bedded, arkosic sandstone, representing a channel complex oriented in a west-southwest direction. Throughout the Hansonburg district, however, the unit remains easily identifiable due to its color, abundant phyllosilicate content, and nearly constant thickness (although it appears to thin south of the field area on the Blanchard claims).

UNIT 2 2 ft. of irregularly bedded, nodular, light gray micrite/mudstone interbedded with partings of a weathered, white clayey material.

UNIT 3 10 ft. of massively bedded, gray/buff biomicrite/wackestone. Unit contains brachiopods, pelecypods, bryzoans, fusulinids identified as *Triticites* cf. *T. ohioensis* Thompson, and locally abundant phylloidal algae. The unit becomes more thinly bedded (1-2 ft.) in the upper portion and the appearance of dark gray, angular, micritic intraclasts lends it a mottled pattern on its rough weathered surface. Ridge former.

UNIT 4 9 ft. of medium to massively bedded gray/buff fine grained biosparite/grainstone. This unit contains some brachiopods, pelecypods, skeletal fragments and fusulinids identified as a Virgilian _Triticites_ sp. The unit becomes more fossiliferous towards the top. Ridge former.

UNIT 5 1 ft. 6 in. in a single bed of buff colored biosparite/grainstone composed largely of disarticulated crinoid columnals and shelly fragments. Poorly exposed and weathers in a granular fashion.

UNIT 6 8 ft. of massively bedded gray biosparite/grainstone containing abundant fusulinids (_Triticites_ sp), algal debris, and shelly fragments. Unit also has many re-crystallized calcite blebs.

UNIT 7 6 ft. of medium to massively bedded gray biomicrite/ packstone. Weathers to a rough, solution pitted surface, or a very smooth surface depending on the amount of exposure the rock has had. Unit contains a distinctively large proportion of phylloidal algae evident on all surfaces, and in local areas may show thick accumulations of rip-up structures coincident with the algal remains. This top unit also has numerous re-crystallized calcite blebs.

The Story Formation has a total thickness of 57 feet 6 inches.

DEL CUERTO FORMATION

UNIT 1 9 ft. of poorly exposed silty shale, reddish/brown in the lower portions becoming green/ dark gray in the upper portion of the unit. At the top this unit is intensely weathered to a white clayey matrix containing clasts of the dark gray, fissile shale.

UNIT 2 2 ft.6 in. of irregularly bedded, nodular, dark gray sparite.

UNIT 3 3 ft., A massive bed of gray to maroon biosparite/grainstone, friable, weathering to a reddish brown. Unit 3 contains abundant crinoid columnals and shelly debris, which are thoroughly recrystallized into coarse calcite grains. As with most of this formation, this unit is exposed only locally, but when it is it makes a fine basal marker bed.

UNIT 3a 4 ft. of discontinuous, thin bedded (< 3 in.), red, moderately sorted, medium to coarse grained, arkosic sandstone. This arkose contains a greater percentage of quartz and less micaceous constituents than those found in the Story Formation, and is finer grained (< 1.5 mm) than the sandstone/conglomerate (Unit 11) found above.

It should be noted that there is some confusion on the part of this author as to the stratigraphic relationship between this unit and Unit 3 as they seem to occupy nearly the same position in the Del Cuerto Formation at different locations in the area. It may be that the influx of arkosic detritus remained local in its distribution but lent its color diagenetically to the surrounding carbonate lithologies. Again, the covered nature of the lower half of the Del Cuerto Formation prohibited any concise explanation.

UNIT 4 8 ft. of irregularly bedded, medium to light gray micrite/mudstone. Very few bryozoans and skeletal material found in this unit.

UNIT 5 4 ft. of thin to medium bedded, gray, biomicrite/wackestone. Contains fusulinids identified as *Triticites* cf. *T. bensonensis* Ross and Tyrrell, brachiopods, and some pelecypods.

UNIT 6 6 ft. of red/brown, moderately sorted, medium grained, arkosic sandstone. Similar to Unit 3a. Poorly exposed.

UNIT 7 6 ft. of irregularly bedded, nodular, gray micrite/mudstone interbedded with gray/green silty shales. Unit contains curious tear shaped blebs of secondary calcite that are white in color and have an outer "rind" of orange/brown siderite.

UNIT 8 2 ft. of nodular, dark gray biomicrite/packstone that has a resinous appearance on fresh surfaces. Contains abundant brachiopods and pelecypods in the upper portion.

UNIT 9 8 ft. of medium to massively bedded, purple to bluish gray biosparite/grainstone. Surface weathers to a solution pitted blue/gray. Abundant rugose corals in lower portion of unit and extremely abundant pelecypods and brachiopods above. Ridge former and key bed.

UNIT 10 9 ft. of irregularly bedded, nodular, light gray (becoming more purple in hue in upper portion) biomicrite/wackestone. Unit contains brachiopods, pelecypods, fusulinids identified as *Triticites* aff. *T. bensonensis* Ross and Tyrrell, and *Triticites* aff. *T. cameratoides* Ross. Generally a poorly exposed slope former.

UNIT 11 9 ft.. Basal 4 ft. is a thin to medium bedded, oligomictic pebble orthoconglomerate. This distinctive unit is composed of rounded limestone clasts of varying lithologies averaging 15mm across in a poorly sorted arkose composed of angular red potash feldspars and quartz crystals (measuring from .5 to 8mm) in a fine grained, green, chloritized matrix. This grades into 5 ft. of thin to medium bedded, poorly sorted, coarse grained, arkosic sandstone. This sandstone is more coarsely grained and has a much higher quartz content (nearly 50%) than those previously described in this section. Unfortunately, this unit is usually covered with blocks and finer talus from the massive limestones overlying it.

UNIT 12 12 ft. of irregularly bedded, light gray biomicrite wackestone becoming massive in the upper 8 feet. Unit contains some crinoid columnals, brachiopods, shelly fragments, and has abundant algae (phylloidal) in the upper portion. Ridge former.

UNIT 13 10 ft. of thin irregular beds of very dark olive/gray biomicrite/mudstone with scattered, diffuse zones of gray sparite. Unit contains skeletal fragments and many small crinoid columnals. This unit is intensely jointed with vertical, perpendicular joint sets that cause the unit to break into flat blocks. Grading away from these joints is a distinctive orange/buff weathering pattern that makes this unit of the Del Cuerto Formation an easily recognizable key bed.

The Del Cuerto Formation has a total thickness of approximately 90 feet.

MOYA FORMATION

UNIT 1 3 ft. composed of two beds of buff/gray biosparite/grainstone. This unit contains abundant small (<10 mm) bellerophon gastropods that weather cleanly out of the rock. Unit 1 is seldom exposed due to the massive nature of the overlying unit.

UNIT 2 21 ft. of very massive, dense, light gray biomicrite/packstone. Unit weathers to a rough, solution pitted, uniform gray surface. Lower half of the unit contains occasional crinoidal and brachiopod fragments and becomes more algal (locally very abundant) in upper third of the unit. The top of this cliff forming unit becomes a darker purple/gray color and contains abundant large bellerophon gastropods (2.5 to 6cm), turreted gastropods, a diversity of crinoid columnals, and phylloid algae, making this a key bed.

UNIT 3 3 ft. of evenly bedded, gray biosparite/grainstone containing sparse pelecypods and gastropods.

UNIT 4 3 ft. of irregularly bedded, dark gray/purple to green biosparite/grainstone. Weathers to a rough green/brown surface. This unit contains abundant algal matter that stands out on a weathered surface in addition to brachiopods, gastropods, and crinoid columnals. This poorly exposed slope forming unit seems to grade laterally into a greenish micritic/mudstone.

UNIT 5 17 ft. of thin to medium bedded, light gray/buff biomicrite/packstone. This unit contains crinoid columnals, shelly fragments, fusulinids identified as *Triticites* cf.*T. plummeri* Dunbar and Condra, *Triticites* cf.*T. beedei* Dunbar and Condra, and *Dunbarinella* sp. (found mid-way through this unit), and locally abundant phylloidal algae sections. This unit forms a step-like ridge.

UNIT 6 4 ft. of massive dark gray biomicrite/wackestone with a lighter gray mottled pattern probably due to burrowing organisms. Abundant crinoid columnals throughout.

UNIT 7 3 ft. made up of two beds of gray biomicrite/wackestone containing abundant bellerophon gastropods, locally abundant algal debris, and fusulinids identified as *Triticites* aff. *T. whetstonensis* Ross and Tyrrell. Top of formation.

The Moya Formation has a total thickness of 54 feet.

APPENDIX (II)

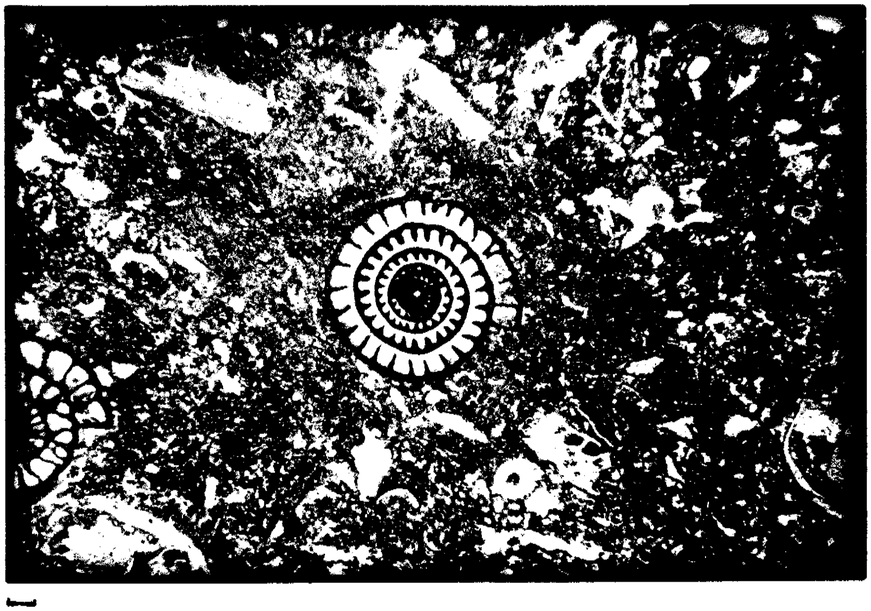


Fig.15. *Triticites liosepta* Stewart. Transverse view. Council Springs Limestone. Bar = 0.5 mm.

Fig.16. *Triticites liosepta* Stewart. Longitudinal view. Council Springs Limestone. Bar = 0.5 mm.

Fig.17. Triticites cf.T. nebraskensis Thompson. Longitudinal view. Burrego Formation; Unit 2. Bar = 0.5 mm. Crossed nichols.

Fig.18. Triticites cf.T. nebraskensis Thompson. Transverse views with oblique longitudinal. Burrego Formation; Unit 2. Bar = 0.5 mm.

Fig.19. Triticites sp. Transverse and oblique longitudinal view. Burrego Formation; Unit 8. Bar = 0.5 mm.

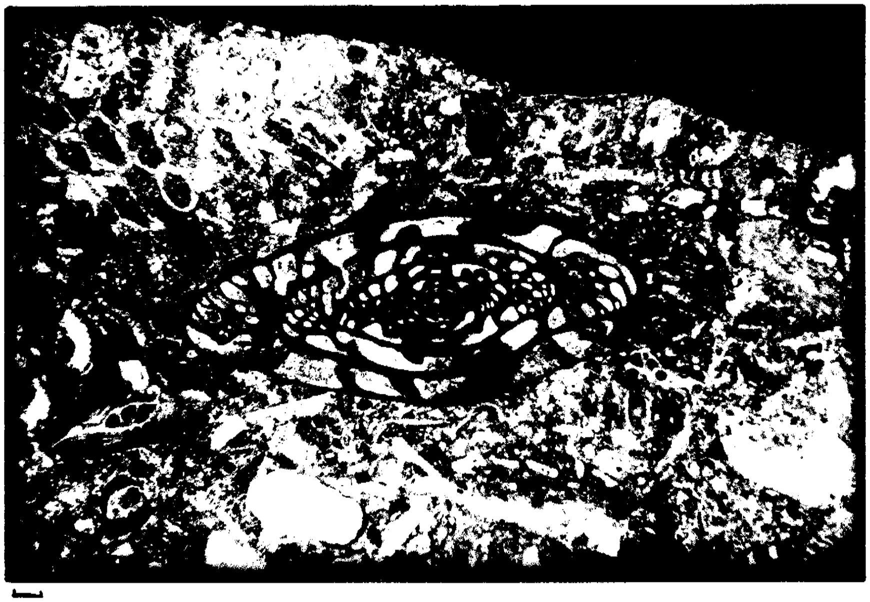


Fig.20.Triticites sp. Longitudinal view. Burrego Formation; Unit 8. Crossed nichols. Bar = 0.5 mm.

Fig.21.*Triticites* cf.*T. ohioensis* Thompson. Transverse and altered longitudinal views. Story Formation; Unit 3. Bar = 0.5 mm.

Fig.22.*Triticites* cf.*T. ohioensis* Thompson. Longitudinal view. Story Formation; Unit 3. Bar = 0.5 mm.

Fig.23.*Triticites* sp. Longitudinal view. Story Formation; Unit 6. Bar = 0.5 mm.

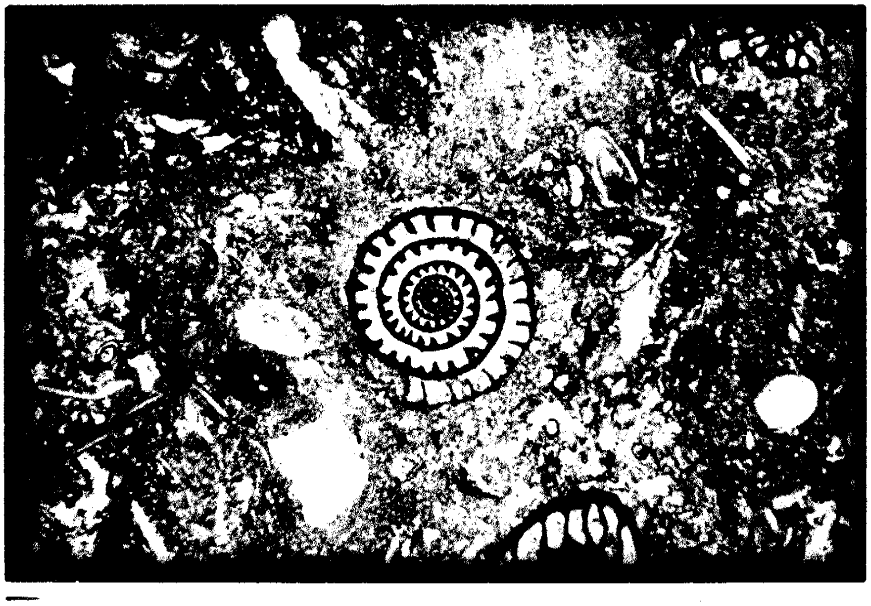


Fig.24.*Triticites* sp. Transverse view. Story Formation; Unit 6. Bar = 0.5 mm.

Fig.25.*Triticites* cf.*T. bensonensis* Ross and Tyrrell.
Longitudinal view. Del Cuerto Formation; Unit 5.
Bar = 0.5 mm.

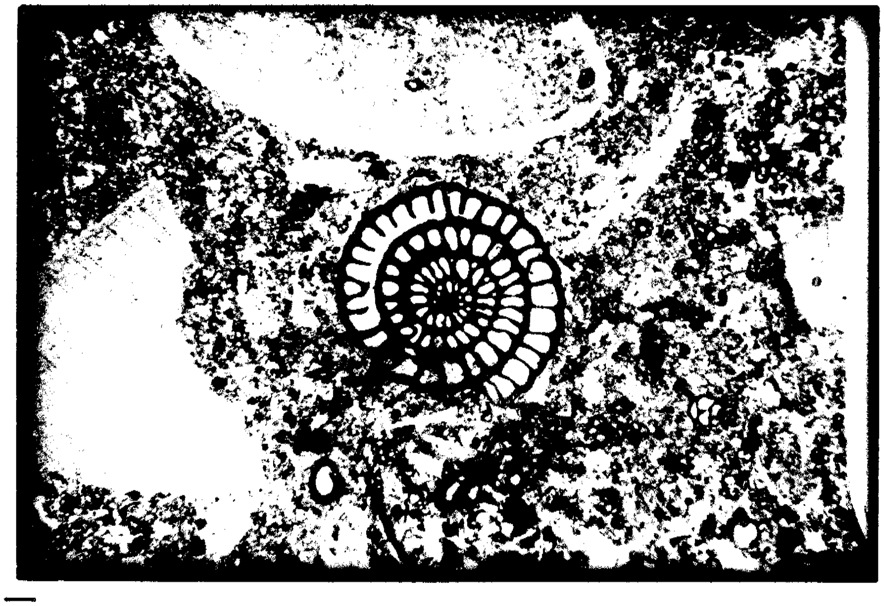


Fig.26.*Triticites* cf.*T. bensonensis* Ross and Tyrrell.
Transverse view. Del Cuerto Formation; Unit 5. Bar =
0.5 mm.

Fig.27.*Triticites* aff.*T. bensonensis* Ross and Tyrrell. Transverse view. Del Cuerto Formation; Unit 10. Bar = 0.5 mm.

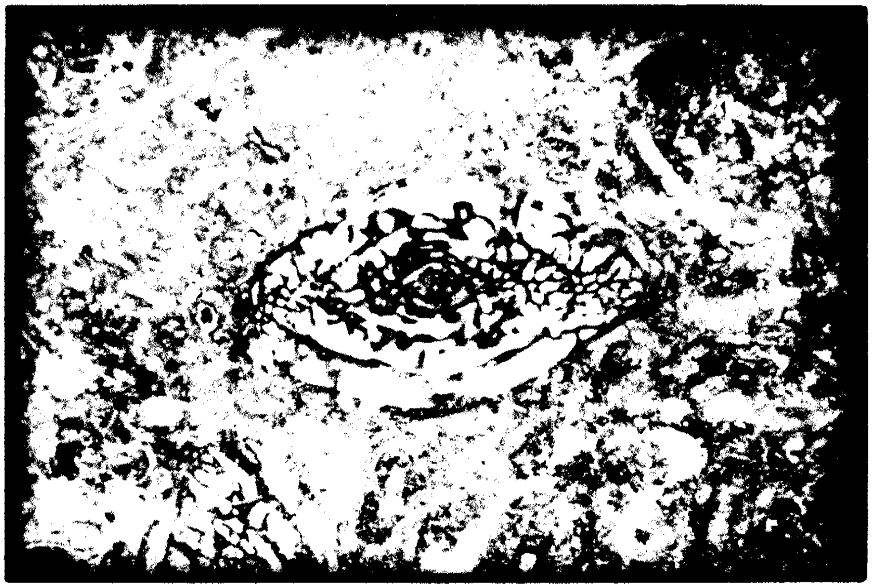


Fig.28.*Triticites* aff. *T. bensonensis* Ross and Tyrrell. Longitudinal view. Del Cuerto Formation; Unit 10. Bar = 0.5 mm.

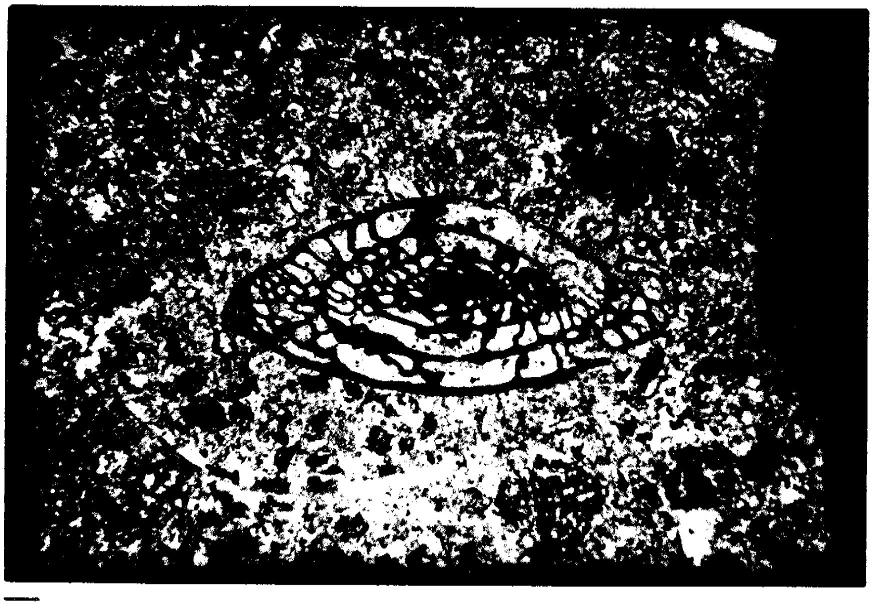


Fig.29.Triticites aff.T. cameratoides Ross. Longitudinal view. Del Cuerto Formation; Unit 10. Crossed nichols. Bar = 0.5 mm.

Fig.30.Triticites aff. T. cameratoides Ross. Oblique transverse view. Del Cuerto Formation; Unit 10. Bar = 0.5 mm.

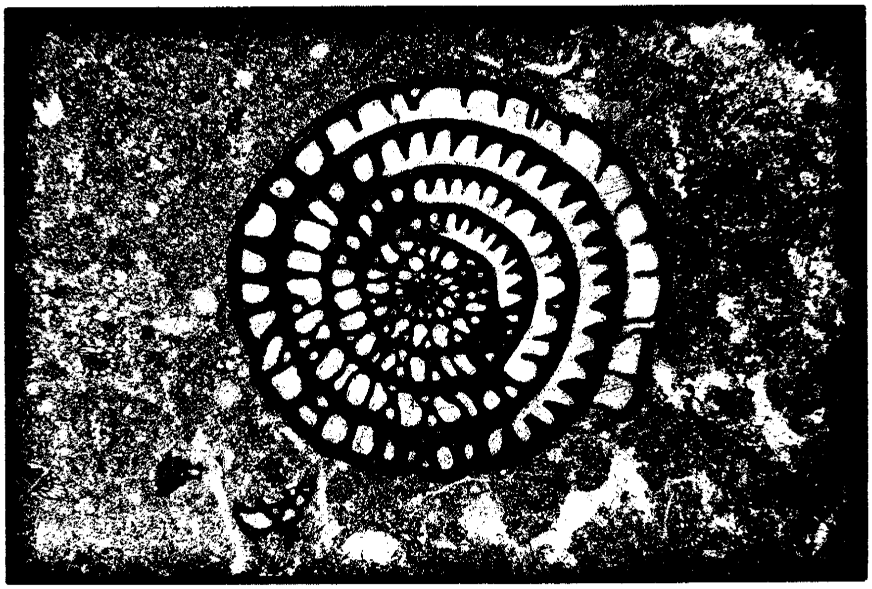


Fig.31.Triticites cf.T. beedei Dunbar and Condra. Transverse view. Moya Formation; Unit 5. Bar = 0.5 mm.

Fig.32.Triticites cf.T. beedei Dunbar and Condra. Longitudinal view. Note juvenile Triticites cf.T. plummeri in lower center. Moya Formation; Unit 5. Bar = 0.5 mm.

Fig.33.*Triticites* cf.*T. plummeri* Dunbar and Condra. Longitudinal view. Moya Formation; Unit 5. Bar = 0.5 mm.

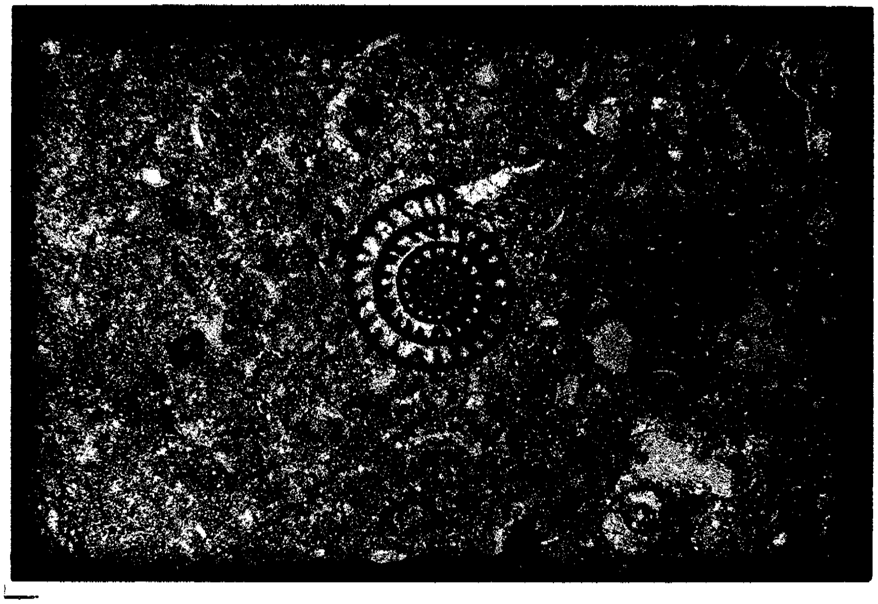


Fig.34.*Triticites* cf. *T. plummeri* Dunbar and Condra. Transverse view. Moya Formation; Unit 5. Bar = 0.5 mm.

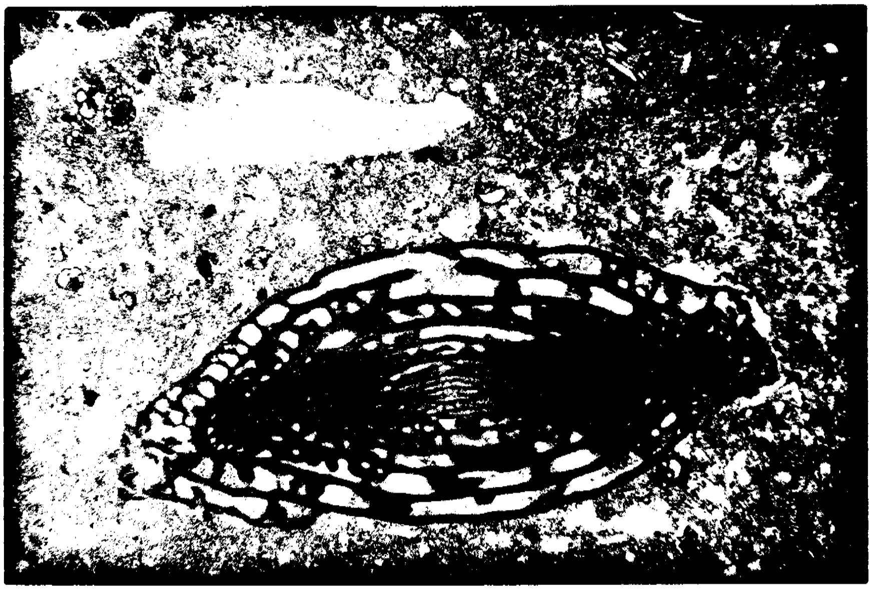


Fig.35. Dunbarinella sp. Longitudinal view. Moya Formation; Unit 5. Bar = 0.5 mm.

Fig.36. Dunbarinella sp. Oblique view. Note the foram Bradyina sp. in lower right hand corner. Moya Formation; Unit 5. Bar = 0.5 mm.

Fig.37.*Triticites* aff.*T. whetstonensis* Ross and Tyrrell. Longitudinal view. Moya Formation; Unit 7. Bar = 0.5 mm.

APPENDIX (III)

ESTIMATED PRESENT VALUE OF THE ORE RESERVES AND POTENTIAL GEOLOGIC TONNAGES

The values for ore tonnage (proven, probable, and potential) used in this appendix are those of Chettavat Lewchalermvong (1973). The only exception to this are the figures for Area 8 (Fig. 38) which were generated by this author. The only changes in the figures used by Lewchalermvong concern the present price quotations for lead, barite, and fluorite (fluorspar) as derived from the December, 1983 issue of Engineering and Mining Journal. The estimations of ore tonnage for Areas 1-7 are Lewchalermvong 's alone, as this author would not presume to challenge them. The reader is encouraged to examine pages 63-70 and Appendix II (pages 93-98) of the Lewchalermvong thesis for a greater understanding of the location of Areas 1-7 and the means of his estimations.

The following amended table is from page 69 of his thesis. Besides the addition of Area 8 the only other adjustment was the updating of prices as follows:

(original price in parenthesis)

Barite ($40/ short ton)...$97.50/st

Fluorspar ($80/st)........$180/st

Lead ($0.166/lb.).........$0.251/lb.

Present value of proven ore (1700 tons) is estimated to be $ 98,283

Present value of proven and probable ore (total 4750 tons) is estimated to be $ 286,378

Present value of proven ore, probable ore, and potential geologic tonnage at Area 1 (total 8350 tons) is estimated to be $ 403,008

Present value of proven ore, probable ore, and potential geologic tonnage at Area 1, and Areas 2, 3, and 4 (total 19,150 tons) is estimated to be $ 844,010

Present value of proven ore, probable ore, and potential geologic tonnage at Area 1, Areas 2, 3, and 4, and Areas 5 and 6 (total 52,150 tons) is estimated to be $ 1,625,489

Present value of proven ore, probable ore, and potential geologic tonnage at Area 1, Areas 2, 3, and 4, Areas 5 and 6, and Area 7 (total 98,750 tons) is estimated to be $ 2,059,885

Present values of proven ore, probable ore, and potential geologic tonnage at Area 1, Areas 2, 3, and 4, Areas 5 and 6, Area 7, and Area 8 (total 190,470 tons) is estimated to be $ 2,305,907

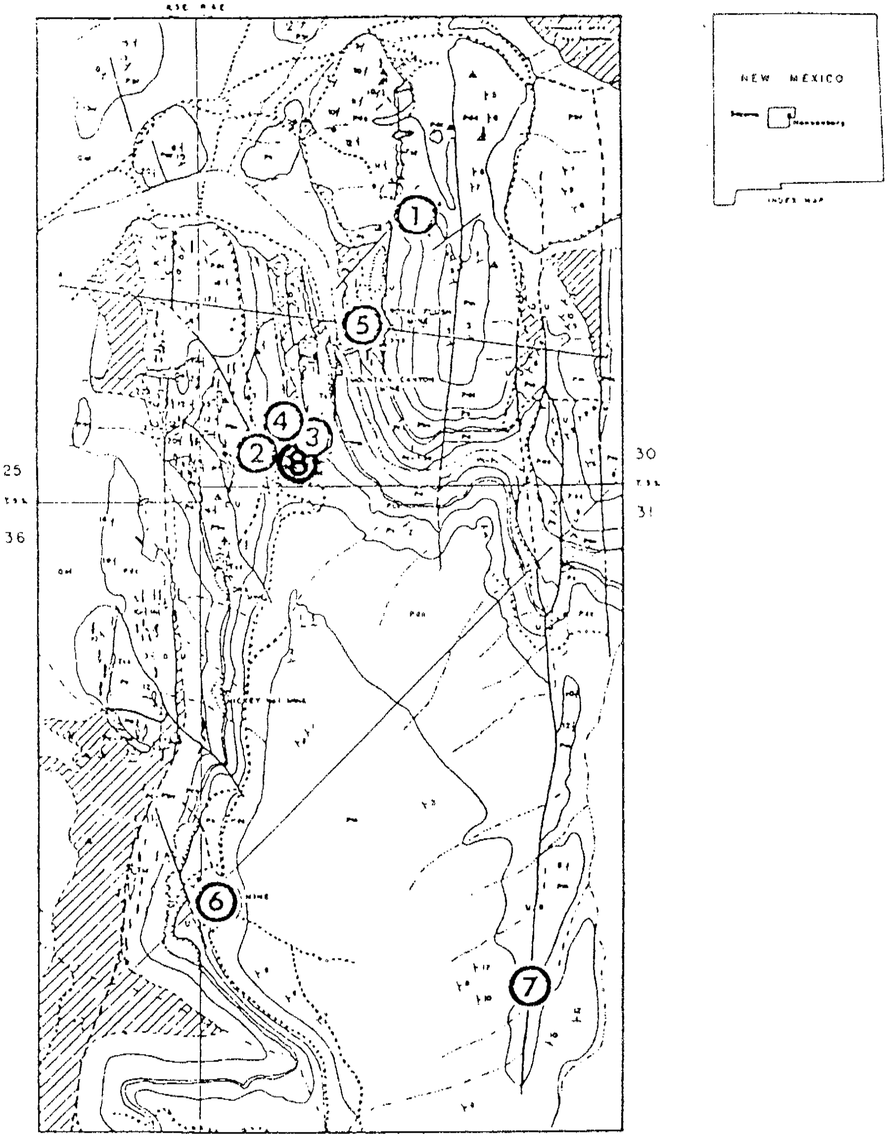


Fig. 38. Map of geologically favorable areas.Areas 1-7 from Lewchalermvong. After Lewchalermvong (1973, Figure 11).

APPENDIX IV

ESTIMATED POTENTIAL GEOLOGIC TONNAGE FROM A GEOLOGICALLY FAVORABLE AREA

Area 8. Area 8 is located about 1000 feet SSW of the Mountain Canyon mine, just north of the big curve on the road leading to the Mex-Tex mine to the south (Fig. 41). This area is situated between Stations Z2, B3, C3, and D3 (Plate 1,and Fig. 41). The author regards this area as geologically favorable for mineralization because: (1) there is a considerable amount of surface mineralization exposed by prior bulldozing, (2) the area is marked by the confluence of several mineralized and/or silicified fault zones whose displacement decreases to the south and at this area becomes negligible, i.e., this is the hinge area for these faults, (3) the Council Springs limestone exposed downslope (immediately to the north) contains abundant silicified joints (Fig. 42) and, (4) the area is effectively surrounded on three sides by an "upthrown" block.

The surface mineralization here is situated on the top of the Burrego Formation, therefore, the top of the stratigraphic horizon where one would expect to find an ore body would be located approximately 62 feet below the

Fig. 39. Area 8., showing two mineralized zones, Station B3, and taken from Station C3 looking south (see Plate 1).

Fig. 40. Silicified joints in Council Springs Limestone, directly overlain by Burrego Formation; Unit 2. North of Station G3 (Plate 1).

surface (Plate 3). The faults that converge on this area may have shattered this potential ore horizon to a suitable degree for the developement of an extensive ore body. The trend of these faults, as depicted on Plate 1, is at best an estimation, as this area was extensively bulldozed and the surface mineralization also tends to obscure their exact location. It is entirely possible that these faults may feather out to a degree greater than shown, and this would indicate an even more intensely shattered host horizon.

As interpreted by this author, mineralization is possible between the eastern-most and western-most faults in this area as delineated above. Mineralization may extend into the surrounding "stable" block as well, however this is not considered in the following estimates.

The tonnage factor used (10.00 cubic feet per ton) is the average for ores in the northern portion of the Hansonburg mining district. The assay values used are the average values for the Mountain Canyon mine as used by Lewchalermvong (1973).

It should be noted that some overlap may exist between these estimates and those of Lewchalermvong's Areas 2, 3, and 4, as the exact location of these areas is somewhat questionable.

The following estimates were compiled to compliment Appendix II of Lewchalermvong's thesis in form and substance (hence the name Area 8).

Proven Ore + Probable Ore + Area 1 + Areas 2, 3, and 4, + Areas 5 and 6, + Area 7 + Area 8

Area 8

The potential geologic tonnage at Area 8 (50.7% $BaSO_4$, 14.7% CaF_2, 2.5% PbS, 27.2% SiO_2, and 4.6% $CaCO_3$)		91,702 tons
Mining loss 20%, obtained ore		73,376 tons
Milling loss 20%, recovered ore		58,701 tons
Contained in recovered ore		
Barite		29,761 tons
Fluorite	8,629 tons	
Galena		1,468 tons
or Lead (PbS = 86.8% Pb)	1,274 tons	
Total mineral concentrates from Area 8		
Barite concentrate (88% $BaSO_4$)*		33,819 tons
Fluorite concentrate (97% CaF_2)		8,896 tons
Lead concentrate (60% Pb)		2,123 tons
Estimated value of potential geologic tonnage at Area 8		
Barite ($97.50 per ton)		$ 3,297,353
Fluorite ($180 per ton)		$ 1,601,280
Lead ($301 per ton)**		$ 639,448
Total estimated value		$ 5,538,081
Estimated value of total proven ore, probable ore, Area 1, Areas 2,3,and 4,Areas 5 and 6, Area 7 and Area 8 (total 190,470 tons) is		$ 7,597,966
This 190,470 tons could be mined in 10 years (100 tons per day); at 25% interest and 5% redemption; the present value factor is 0.30349.		
The present value for all ore reserves and potential geologic tonnage is estimated to be		$ 2,305,907

* The 29,761 tons of barite derived from assay value would yield 33,819 ton of 88% barite concentrate, i.e., (29,761 x 12%) + 29,761 = 33,819

** The price for lead is based on 60% concentrate.

APPENDIX (V)

COMMODITY SUMMARIES
FOR
LEAD, BARITE, FLUORSPAR

LEAD

Uses and Consumption

In the U.S., by far the greatest amount of lead (63%) is used in the production of batteries, and when considered with other uses in the general realm of tranportation, such as gasoline, it comprises a full 75% of its consumption in 1982. Lead use in construction, pigments, ammunition, electrical components was about 20% with the balance for ceramics, glass, type metal and other small uses.

Domestic consumption has dropped 24% over the last five years. Clearly the hard times in the automotive industry plays a great part in this decline. The recession and its impact on the construction industry together with health and environmental constraints have added to the problem.

Over the same period of time, world consumption has dropped 7% for, with the exception of environmental constraints, largely the same reason, i.e. recession. On a world basis, the U.S. consumes 27%, Europe 41%, and Japan 10% of the lead used.

Domestic Production

Mine production in the U.S. centers on the activity of twelve mines that account for 99% of the output. Eight of these mines are in Missouri and provide 93% of the domestic production. Mine production was up 15% in 1982 over 1981 figures but this is primarily the result of 1981 statistics being depressed by a three month labor strike in SE Missouri. The past three years represent a general increase in mine production due to a decrease in secondary production of lead over the same period, as a result of a scarcity of scrap lead which was being exported overseas. Imports comprise only 1% of apparent consumption in the U.S. over the last three years, down from 12% in 1978.

The Buick Mine, jointly owned by AMAX Lead Co. and Homestake Lead Co., is the single largest producing unit, producing over 205,000 tons of concentrates annually. St. Joe Lead Co. produced 213,777 tons of concentrates and is the overall leading producer with six mines and four mills.

World Production

World mine production of lead decreased in 1981 by 5% from 1980 as a response to worldwide recession. Since 1981 the statistics have risen only slightly. Exceptions to this general trend have been, most notably, Australia and Canada, with increases since 1980 of 12 and 18% respectively. In the past year world mine production was 3.4 million metric tons. The U.S. is the leading lead producer followed by Australia, Canada, Mexico, and Peru.

U.S. imports of foreign lead, for the period 1978-1981, break down as follows:

Ore, Concentrates, and Bullion ;
  Peru 32%, Honduras 27%, Canada 19%, and Australia 9%
Pigs and Bars ;
  Canada 39%, Mexico 37%, Peru and Australia 8%

Reserves and Stocks

In the last few years, major and marginally economic resources of lead have been located in the U.S., Canada, Australia, and So. Africa. As much as 1.4 billion tons of subeconomic reserves have been identified and await developments in recovery technology. Prospects for discovering new major economic deposits at a rate exceeding consumption are regarded as very favorable.

World reserves are estimated at 146 million tons. The U.S., Australia, and Canada have the greatest reserves with approximately 25 million tons each.

The government (GSA) stockpile of lead as of 11-30-82 was 545,000 metric tons, a little over half the GSA goal of 998,000 m. tons. There have been no sales of lead by the GSA since 1975.

Stocks by producers and consumers have dropped 21% since 1981 to 155,000 m. tons, probably the result of the scarcity of secondary production material.

Prices

The price of lead has continued to decline since an average high of $.52/lb. in 1979. The average price in 1983 was $.251/lb., after hitting a low of $.21/lb. in the first quarter. The continuing decline in price is due chiefly to the lingering world recession, hence lower demand, and the large inventory of the LME (London Metals Exchange).

The worldwide price for lead is established by the LME. The U.S. producers price usually lags behind the LME price but follows it closely. Asarco is frequently the producer price leader in the U.S. and its price is usually considered the official U.S. Producer Price.

Governmental Regulations

The U.S. imposes a tariff on various lead imports with the present levels extending to 1987 when certain tariffs will be reduced, especially those relating to secondary lead production such as lead scrap. In as much as the U.S. is nearly a net exporter of lead, the reduction in tariffs should have no real impact on the industry.

The Depletion Allowance for domestic producers is 22% and for foreign enterprises 14%.

The greatest impact the government has made on the industry has been the regulations of the EPA and OSHA. Several years ago lead was greatly restricted in it's use in pigments for paints. Since then the EPA has also reduced the lead content in gasolines, ultimately to phase it out altogether, and enforced strict ambient air and water quality standards on the lead and related industries.

OSHA, for it's part, has imposed regulations regarding occupational exposure to lead (primarily airborne) throughout the industry.

Planned Capital Investments for 1983 (Zinc included)

Planned projects requiring considerable capital investments include new mine and mill facilities, smelters, feasibility studies, and various plant modifications.

Worldwide, there are 25 projects planned for this year totalling 2.5 billion dollars. Nearly half that amount will be invested in North America (1.1 billion) and the lion's share will be in Canada, where 770 million will be spent. Cominco alone is to invest 410 million at its facilities at Trail, British Columbia.

Within the U.S., Cominco American will invest 150 million at its operation at the Red Dog deposit in Alaska. Asarco will spend nearly 72 million on above and below ground facilities at West Fork, MO.. Noranda and St. Joe Minerals both have plans requiring millions of dollars each.

There are five projects planned in Europe, four in Asia, and another four in Australia, with investments of 466, 550, and 298 million dollars respectively.

Outlook

It is estimated that U.S. mine production and apparent consumption will increase 3% each in 1983. Using 1978 as a base, demand for lead in the primary and secondary sectors is expected to increase 2.5% annually through 1990.

These estimates, however, are based on some very uncertain assumptions. These largely revolve around the future of the automotive industry. Highest on the wish-list for the lead industry is the development of cost-competitive and reliable electric vehicles, with their great banks of batteries. A more realistic potential lay in the diesel car, which by 1985 could make up 10-20% of the market. These cars require larger batteries or dual battery systems for ignition and lighting. Any rebound in the automotive industry would be a boon for the domestic lead industry.

Other factors that could bring the supply/demand ratio for lead into closer balance, and hence, favorably effect prices include: supply disruptions due to labor difficulties, continued scrap lead shortages, and changes in the net import/export ratio.

BARITE

Uses and Consumption

Over 90% of the barite produced is used as a weighting agent in oil and gas well drilling fluids. While there are alternatives to barite as drilling mud, such as celestite, ilmenite, and some iron ores, the low cost and technical advantages of barite insure its remaining the principal mud used in the petroleum industry. Other uses for barite include use in paints, glasses, some rubber products, and as a source for barium chemicals.

Domestic consumption was down 12% in 1982 after reaching an all-time high in 1981 of 4.7 million tons. This, of course, reflects the downtrend in drilling activity due to the present oil glut and economic doldrums.

Of the amount consumed in the U.S. in 1982, 52% of it was imported. Over the past five years China has been the main exporter to the U.S. with 24% of the market, followed by Peru with 21%, Chile (13%), Morroco (11%), and a host of other nations providing the remaining 31%.

Domestic Production

Nevada produces 90% of domestic barite, with Missouri and Arkansas accounting for most of the rest. Mine production in 1982 was 2 million short tons, down 30% from the record high in 1981. Of this a mere 3% was exported.

In spite of this decline in 1982, the U.S. remained far and away the largest producer in the world, producing nearly three times as much as the next leading producer.

During the record year of 1981 domestic producers had high hopes for the future and numerous developments were planned to open new sources of barite and to increase facilities for grinding the mineral. While no information is available, it it safe to assume these plans were scaled back for this year or put on indefinite hold.

World Production

As stated above, the U.S. is the world production leader, producing 27% of all barite mined. China is the next largest with a level of 800,000 short tons in 1982. Numerous other countries produce barite at amounts half that of China.

As in the U.S. production around the world was down in 1982 with a decrease of 14%.

Reserves and Stocks

Barite resources around the world may be as much as 2 billion tons, but only 390 million tons have been positively identified. The U.S. has the largest known reserves estimated at 100 million tons and hypothetical reserves that could add as much as an additional 150 million tons.

No information is available on private stocks in the U.S. and the GSA has no stockpile program.

Prices

The price of barite was making very strong gains over the past five years until, again, 1982. Even so, the price is up a full 35% since 1978, to $32/ton (average mine price), down from $35.96/ton in 1981. This compared to a 26% increase in the Producer Price Index for non-metallic minerals over the same time period is very impressive.

Governmental Regulations

The U.S. imposes a tariff of $1.27/ton on crude barite imported from MFN counrties and $4.00/ton for others. For ground barite the MFN tariff is $3.25/ton and

$7.50/ton for non-MFN countries.

A Depletion Allowance of 14% has been established for both domestic and foreign ventures.

As yet, the only offensive thing the EPA has found with barite is the manner in which it is mined, usually open-pit, so such operations must conform to the appropriate reclamation standards.

Outlook

Obviously, the future of the barite industry is directly linked to the amount of drilling by the petroleum companies. It is expected that the demand for barite will remain sluggish through 1985, increasing at a rate less than 4%. After that the demand should be greater and barite should regain it's previous robust character.

FLUORSPAR

Uses and Consumption

Industrial fluorspar is sold in three different grades, depending on its CaF_2 content. Acid-grade fluorspar contains greater than 97% CaF_2, and is used in manufacturing hydrofluoric acid, an essential ingredient in the aluminium, fluorchemical, and uranium industries. Ceramic-grade fluorspar has between 85 and 95% CaF_2. It is used in the production of ceramics, glass, and enamels. Metallurgical-grade (met-spar) contains 60 to more than 85% CaF_2 and is used in the iron and steel industries as a neutral flux.

Acid-grade fluorspar accounts for 58% of the fluorspar consumption in the U.S. and met-spar 36% with ceramic-grade accounting for the remainder.

Domestic demand for fluorspar decreased 35% in 1982 and apparent consumption has dropped a full 40% in the last five years. Beyond the effect of the world-wide recession, these figures reflect the poor state of domestic steel production and technological advances in both the recycling of fluorspar ingredients and the use of substitutes.

The U.S. has always relied heavily on the use of imported fluorspar. Although it consumes 20% of world production, in 1982 fully 87% of apparent consumption was imported. Of this, 60% comes from Mexico and 30% from South Africa. China has been vastly increasing production and working it's way into the U.S. import market with very low prices.

Domestic Production

Three producers in So. Illinois (Ozark-Mahoning Co., Inverness Mining Co., and Hastie Trucking and Mining Co.) account for 90% of domestic production. Small firms in Texas and Nevada make up the remainder. Domestic production is down 43% over the past five years. Western production has become increasingly uneconomic due to high freight rates to the Midwestern and Gulf state markets.

World Production

While over 25 countries produce fluorspar, Mexico, the world leader, produces 23% of the world's production. Eight counries (Mexico, USSR, So. Africa, Mongolia, China, Thailand, France and Spain) are responsible for 80% of the production.

Last year overall production fell 6%, from 5.6 million short tons to 5.3 million. This is largely due to the present world recession. Over the past five years, however, production is up 5%.

Mexico has over 140 operating mines but the Cia. Minera Las Cuervas facility at San Luis Potosi produced almost 85% of that country's fluorspar. Poor transportation and the near collapse of the Mexican economy will cause problems for their status as world leader.

Reserves and Stocks

The world reserve base is estimated at 620 million tons, or approximately 100 million tons of contained fluorine. So. Africa has the greatest reserves with 170 million tons followed by the U.S. with 117 million tons and Mexico with 68 million tons.

World resources of fluorine from phosphate rock are estimated at 1 billion tons, the U.S. at 30 million tons.

Domestic producers generally don't stockpile much material, in 1982 only about 10,000 tons, or roughly 5% as much as the consumers. Consumer stocks have remained at about 200,000 tons over the past five years.

The GSA stockpile has a goal of 1.4 million tons of acid-grade and 1.7 million tons of met-spar. As of 11-82, the inventory stands at 896,000 and 412,000 tons respectively.

Prices

World prices for Fluorspar decreased in 1982, with acid-grade dropping slightly to $135/ton, but met-spar and ceramic-grade plummeting 20% to $107/ton. The prices had remained stable for several years until 1980 when they jumped on both the domestic and world markets. The present depressed prices will probably remain steady for the next year.

Mexico, as the chief producer, has been the price leader on the world market. It's price has been affected by the general economic slump and by pressures brought to bear by the Planned Economy producers, especially China who, in 1981, undercut the delivered Mexican price by over $25/ton.

Domestic fluorspar values actually increased by 5% in 1983, bringing the price to $180/ton for acid-grade and $110/ton for met-spar.

On the average, prices for fluorspar have remained stable for the past two years while the Producer Price Index for non-metallic minerals has increased 8%.

Governmental Regulations

In 1979, the EPA banned the manufacture and interstate shipments of aerosols containing chlorofluorocarbons. This had a considerable negative impact on the fluorchemical industry.

The government imposes a tariff of $2.10/ton on acid-grade fluorspar and 13.5% ad valorem on met-spar for countries with Most Favored Nation status, for other nations the tariff is $5.60/ton for acid-grade and no difference in rates for met-spar.

The Depletion Allowance has been established at 22% for domestic producers and 14% for foreign enterprises.

Outlook

In the freeworld countries, who produce 65% of the fluorspar, the future is tied to a general recovery from world recession. Increased demand for aluminium, steel, and fluorchemicals is necessary before the fluorspar market will look good again.

South Africa has the brightest future in fluorspar production. It already has the largest production facility in the world (General Mining's Buffalo mine) and two other mines that are nearly comparable. Later this year or early in 1984 Armco Inc. will complete yet another large capacity facility. Considering So. Africa has twice the reserves of Mexico it should overtake the production leaders position in the near future.

China, while it has made great strides, will continue to have trade difficulties due to political problems with the U.S..

Domestically, the long term lowering of demand for fluorspar and its related chemicals will continue as steelmakers make greater use of olivine and dolomitic limestones in flux and new technology increases the aluminium industry's capacity for recycling the fluorine it uses in its smelters.

In spite of this, the USBM exspects a short term increase in domestic production and consumption of 18 and 20% respectively during 1984. This is predicated on an economic recovery and expanded uses for fluorchemicals.

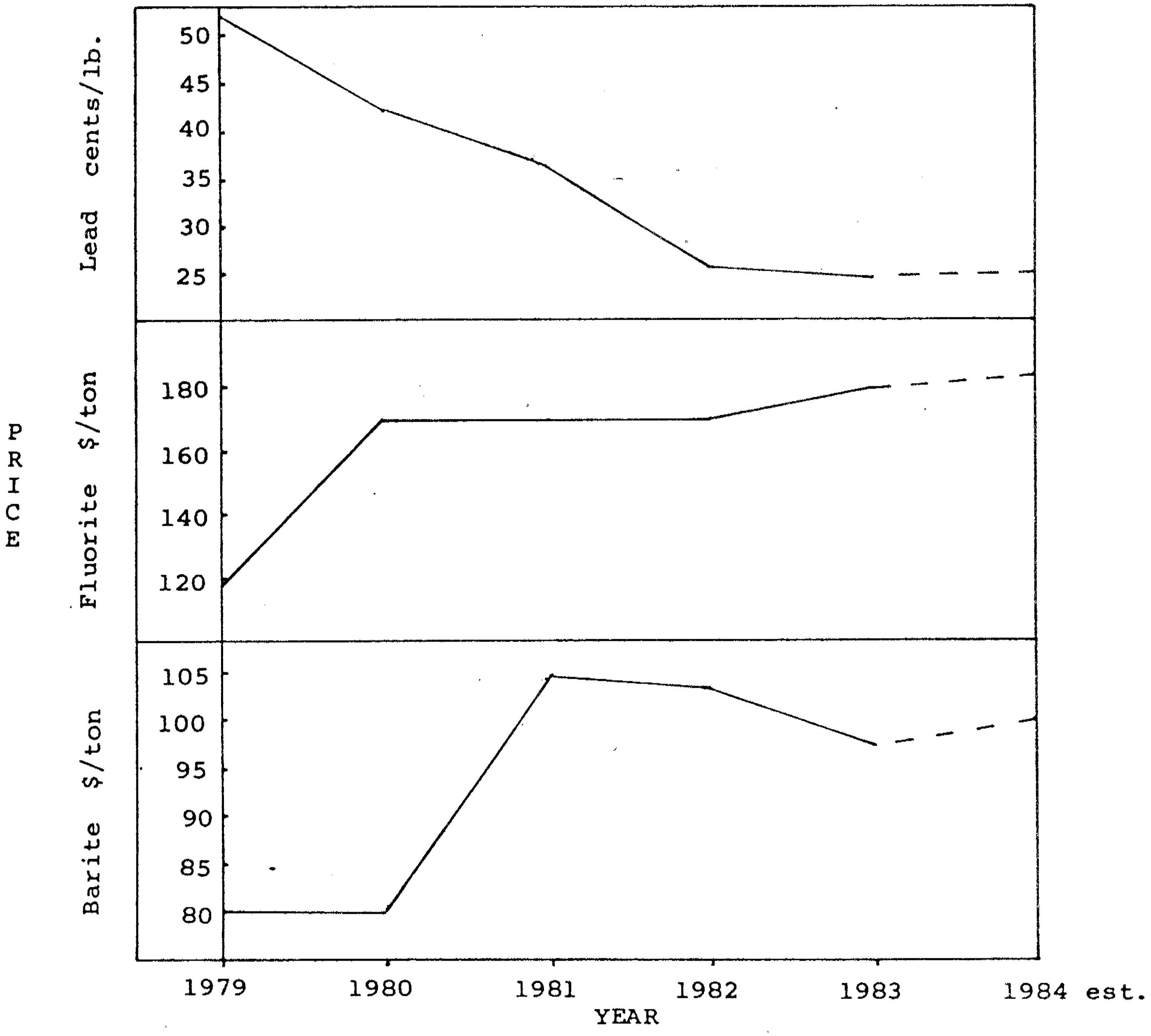


Fig. 41. Price trends for the past five years and estimates for 1984.

BIBLIOGRAPHY

Allmendinger, R. J., 1975, A model for ore genesis in the Hansonburg mining district, New Mexico: M.S. Thesis, New Mexico Institute of Mining and Technology, 190 p.

Anonymous, 1983, Markets: Eng. Mining Jour., v. 184, no. 12

Austin, C. F., and Slawson, W. F., 1960, Anomalous leads from a selected geological environment in west-central New Mexico: Nature, v.137. p.400-401.

________, 1962, A lead isotope study defines a geologic structure: Econ. Geol., v.57, p.21-29.

Bauch, J. H. A., 1982, Geology of the central area of the Loma de Las Canas quadrangle, Socorro County, New Mexico: M.S. Thesis, New Mex. Inst. of Mining and Tech., 116p.

Beane, R. E., 1974, Barite-fluorite-galena deposits in south-south central New Mexico: A product of shallow intrusions, groundwater, and epicontinental sediments abs: Geol. Soc. Am., abstracts with programs, v.6, no.7, p. 646-647.

Chapin, C. E., 1979, Evolution of the Rio Grande Rift-A summary in Rieker,R.E. ed., Rio Grande Rift: Tectonics and Magmatism: Wash. D.C., Amer. Geoph. Union, pl.5.

Clippinger, D. M., 1949, Barite of New Mexico: New Mex. Bur. of Mines and Min. Res., Cir. 21, 28p.

Condie, K. C., and Budding, A. J., 1979, Geology and geochemistry of Precambrian rocks, central and south-central New Mexico: New Mex. Bur. of Mines and Min. Res., Memoir 35, 58p.

Fenneman, N. M., 1931, Physiography of the western United States: McGraw Hill Book Co., N.Y., 534p.

Hambleton, A. W., 1959, Interpretation of the paleoenvironment of several Missourian carbonate sections in Socorro County, New Mexico, by carbonate facies: M.S. Thesis New Mex. Inst. of Mining and Tech., 87p.

Heckel, P. H., 1970, Recognition of ancient marine environments: in Recognition of Ancient Sedimentary Environments, Rigby,J.K. and Hamblin,W.K., eds.. Soc. Econ. Paleont. and Mineral., Spec. Publ. no.16, p.226-287.

________, 1980, Paleogeography of eustatic model for deposition of Midcontinent Upper Pennsylvanian cyclothems: in Paleozoic paleogeography of west-central United States, West-central United States paleogeography symposium 1, Fouch, T. D., and Magathan, E. R., eds., Rocky Mtn. Sec., Soc. Econ. Paleont. and Mineral., p.197-215.

Johnston, W. D., 1928, Fluorspar in New Mexico: New Mex. Sch. of Mines, State Bur. of Mines and Min. Res., Bull. 4, 128p.

Jones, F. A., 1904, New Mexico Mines and Minerals: The New Mexican Printing Co., Santa Fe, 349p.

Kopicki, R. J., 1962, Geology and ore deposits of the northern part of the Hansonburg mining district, Bingham, New Mexico: M.S. Thesis, New Mex. Inst. of Mining and Tech., 103p.

Kottlowski, F. E., 1950, Geology and ore deposits of a part of the Hansonburg mining district, Socorro County, New Mexico: New Mex. Bur. of Mines and Min. Res., Cir. 23, 9p.

________, 1960, Summary of Pennsylvanian sectionsin southwestern New Mexico and southeastern Arizona: New Mex. Bur. of Mines and Min. Res., Bull. 66, 187p.

________, 1963, Paleozoic and Mesozoic strata of southwestern and south central New Mexico: New Mex. Bur. of Mines and Min. Res., Bull. 79, 100p.

Lasky, S. G., 1932, The ore deposits of Socorro County, New Mexico: New Mex. Sch. of Mines, State Bur. of Mines and Min. Res., Bull. 8, 139p.

Lewchalermvong, C., 1973, Investigation and evaluation of the Royal Flush and Mex-Tex mines, and adjacent area, Hansonburg mining district, Socorro County, New Mexico: M.S. Thesis, New Mex. Inst. of Mining and Tech., 102p.

Lindgren, W., Graton, L. C., and Gordon, C. H., 1910, The ore deposits of New Mexico: U.S.G.S., Prof. Paper 68, 361p.

Myers, D. A., 1973, The upper Paleozoic Madera Group in the Manzano Mountains, New Mexico: U.S.G.S., Bull. 1372-F, pF1-F13.

Park, C. F., and MacDiramid, R. A., 1975, Ore Deposits: W.H. Freeman and Co., San Fran.

Putnam, B. R., 1980, Fluid inclusion and microchemical analysis of the Hansonburg Mississippi Valley-Type ore deposits in central New Mexico., M.S. Thesis, New Mex. Inst. of Mining and Tech., 120p.

Roedder, E., Heyl, A. V., and Creel, J. P., 1968, Environment of ore deposition at the Mex-Tex deposits, Hansonburg district, New Mexico, from studies of fluid inclusions: Econ. Geol., v. 63, no. 4, p.336-348.

Selley, R. C., 1970, Ancient Sedimentary Environments: Cornell Univ. Press, Ithaca, N.Y., 237p.

Siemers, W. T., 1978, The stratigraphy, petrology, and paleoenvironment of the Pennsylvanian system of the Socorro region, west-central New Mexico: Ph.d. Thesis, New Mex. Inst. of Mining and Tech. 259p.

Silverman, A. N., 1975, Geochemical and biochemical studies in the Hansonburg mining district, New Mexico: M.S. Thesis, Univ. of Missouri-Rolla, 70p.

Thompson, M. L., 1942, Pennsylvanian system in New Mexico: New Mex. Sch. of Mines, State Bur. of Mines and Min. Res., Bull. 17, 85p.

Williams, F. E., 1964, Barite deposits of New Mexico: New Mex. Bur. of Mines and Min. Res., Cir. 76, p.34-43.

________, 1966, Fluorite deposits of New Mexico: U.S.B.M. Info. Cir. 8307. p.120-126.

Wilpolt, R. H., and Wanek, A. A., 1951, Geology of the region from Socorro and San Antonio to Chupadera Mesa, Socorro County, New Mexico: U.S.G.S. Oil and Gas Preliminary Map, Map OM 121.

Wilson, J. L., 1967, Cyclic and reciprocal sedimentation in Virgilian strata of southern New Mexico: Geol. Soc. Am., Bull. 78, p.805-818.

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