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Geology and Ore Deposits of the Sacramento (High Rolls) Mining District, Otero County, New Mexico

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Abstract

In the Sacramento (High Rolls) mining district, Otero County, New Mexico, the Permian Abo Formation unconformably overlies folded and faulted rocks of pre-Permian age; in turn, it is overlain conformably(?) by the Permian Yeso Formation. Structure in the Abo and Yeso is relatively simple, being generally a monocline striking north and dipping gently east and cut by faults of moderate throw. The few intrusives in the district are sills of andesite with no associated mineralization or alteration.

The Abo contains small, irregular deposits of copper and lead minerals occurring separately or associated in discontinuous, light-colored arkose beds sandwiched between red shales. Total production from these deposits through 1962 probably does not exceed 23,000 tons of lead ore varying between 5 and 11 per cent lead and 6500 tons of copper ore varying between 2 and 7 per cent copper. Minor amounts of other metals occur with these principal ore types.

Evidence accumulated as a result of surface and underground mapping, a large number of assays, and extensive testing of favorable-appearing arkose beds with acetic acid and potassium iodide for lead sulfate and lead carbonate strongly suggests that the ores are "semisyngenetic" in origin. Copper and lead sulfides possibly were deposited with the arkose. The source of the metals has not been established. Both copper and lead sulfides later were oxidized and the metals reconcentrated to some extent as carbonates and sulfates by the action of ground water.

Provided such an origin is correct, the overlying Yeso Formation and the underlying rock units, predominantly the Magdalena Group, contain no ore deposits that are genetically related to those in the Abo.

Introduction

In 1948, the New Jersey Zinc Company became interested in scattered lead and copper occurrences in the Abo Formation on the western flank of the Sacramento Mountains, New Mexico (pl. 1). Investigations were designed in 1948 and 1949 to evaluate the known lead and copper ore bodies, to seek additional deposits, and to establish, if possible, whether the ores are hydrothermal in origin. If such could be demonstrated, it was planned to seek replacement ore bodies in limestone beds overlying and underlying the Abo.

Work on this manuscript was initiated some years ago at the request of Eugene Callaghan, former director of the New Mexico Bureau of Mines. It was undertaken with the permission and encouragement of William H. Callahan, manager of exploration for the New Jersey Zinc Company, but because of the press of other assignments, the task was not completed. Its reactivation is due to the following observation made in 1963 by Mr. Callahan to the senior writer: "Now that the genesis of stratiform ore deposits is receiving increasing attention, and syngeneticists and epigeneticists are belaboring each other all over the world, perhaps it is timely to contribute additional concepts to the controversy." Accordingly, this report, an abridgment of one submitted to the Company, describes the geologic setting of the stratiform ore deposits of the Sacramento (High Rolls) mining district and reviews evidence pertinent to their origin.

GEOGRAPHY

The Sacramento (High Rolls) district is on the western slope of the Sacramento Mountains, east of Alamogordo, in the north-central part of Otero County, New Mexico. The district is considered to extend from Red Hill, half a mile north of High Rolls, to Alamo Canyon, seven miles due south of High Rolls. A well-maintained forest road, locally known as the West Side Road, branches from State Highway 83 near High Rolls and provides access to much of the region.

Vegetation includes ponderosa pine, pinion, juniper, scrub cedar, and scrub oak of several types liberally interspersed on the lower sunny slopes with a wide variety of spiny desert plants. Excellent fruit is grown in the vicinity of High Rolls.

Elevations in the district range between 6500 feet and 7500 feet, while those of the Sacramento Mountains as a whole range from 4200 feet at the western mountain front in the Tularosa Basin to 9500 feet at the crest. This relief of 5300 feet makes for considerable variety in the climate. Summers are hot and are characterized by sudden showers; cold and snow or rain can extend over several months during the winter season.

METHODS OF INVESTIGATION

To provide a regional geological background for detailed work, a general reconnaissance was made from Alamo Canyon north to High Rolls, using as mapping bases aerial photographs, a U.S. Forest Service topographic map, and a property map prepared by Company personnel. Results of this reconnaissance are presented on Plate 3. Some of the names on this plate are from abandoned claim locations; they are included to facilitate discussion.

The beginning point of a transit survey designed to provide general engineering control and to locate property was a U.S. Forest Service bench mark labeled W-100 in the Warnock mine area. Co-ordinates 12,000 North and 10,000 East were assigned to W-100 so that all survey calculations would fall in the northeast quadrant. Co-ordinates of all maps included herein are related to this station (pl. 2). Four sets of solar observations were made from this point, averaged, and referenced to distant permanent objects. Traverses were run north and south from the beginning point with side traverses made as needed. Bearings were checked occasionally by solar observations. Ties were made to convenient section corners, using co-ordinates calculated from U.S. Bureau of Land Management plats that show bearings and distances; otherwise, the traverses north and south were not closed. The U.S. Coast and Geodetic Survey adjusted elevation for W-100, based on second order leveling, is 7304.703 feet.

While engineering work was in progress, all workings in the district known to contain either lead or copper minerals were cleaned out for mapping and sampling. Additional exposures were made by open cuts, trenches, shallow shafts, limited drifting, jackhammer holes, and bulldozer cuts.

The two principal areas of mineralization, Warnock and Sacramento Gulch, were mapped by alidade and plane table and studied in particular detail. All open cuts, adits, and likely appearing exposures in these and other areas were mapped and sampled. Attention was concentrated on the Dollins tunnel, Warnock mine, and Ady incline. (The term *tunnel* follows district practice, although the use is not technically correct.)

Fairly coarse sampling techniques were used. Because of the ore type involved, it was not believed necessary to cut precision channels, although at the Warnock mine an attempt was made to do this aided by an air sampling hammer. To ensure reasonable accuracy in assaying results, a limited number of samples was run by two different chemists in separate organizations; comparisons were quite satisfactory.

It was contended by those with mining experience in the district that it is impossible to sample the arkose with any degree of accuracy. To test the validity of this contention, the Warnock and Dollins workings were chosen. Besides attempting to overwhelm the problem with a large number of samples, range of vision was extended by the acetic acid-potassium iodide test (KI) for oxidized lead minerals (Jerome, 1950).

In making this test, a 5 per cent solution of acetic acid is applied by brush, dropper, or spray to a relatively clean surface of the material in question and allowed to stand for 30 seconds to 1 minute. Then a 5 per cent solution of potassium iodide is added. If anglesite or cerussite is present, the canary-yellow lead iodide precipitate appears. This method was used on all sample sites, and locally, areas between samples were tested on a wholesale basis. A critical analysis of the results indicates that samples taken give a satisfactory picture of the distribution and quality of the mineralization.

In the Warnock mine, the KI test, which is essentially qualitative, was calibrated to known lead assays. A crude quantitative scale was established whereby the intensity and speed of appearance of the yellow lead iodide precipitate could be noted quickly and a fairly clear idea gained of the lead carbonate content. After such calibration, the test was used extensively on outcrops, fly sprays and large pressure garden sprays being used with equal satisfaction in applying the solutions.

Sulfidizing cerussite with a 10 per cent solution of Na_2S was done mostly as a curiosity during the latter stages of the investigation. In another problem of this type, sodium sulfide would be useful in helping to reveal the distribution of oxidized lead minerals and in calibrating KI test results.

Nine samples representative of the mineralization in the district were tested spectrographically in the New Jersey Zinc Company's laboratory at Palmerton, Pennsylvania, and checked by Geiger counter for uranium content.

ACKNOWLEDGMENTS

The writers express their appreciation to their former associates, A. Merz, Jr., **H.** C. Summers, and Quentin Drunzer for their enthusiastic and capable assistance in the field and office. M. F. Drunzer was most helpful in supplying information about the district and in conducting certain exploration work for the Company. Beneficial field contacts were had with other geologists, including Lloyd C. Pray, who mapped the Sacramento Mountains, A. L. Bowsher of the Smithsonian Institution, and Jerry Covington of the Humble Oil and Refining Company.

Critical review by William **H.** Callahan, W. P. Johnston, John H. Schilling, Lloyd C. Pray, Frank E. Kottlowski, and George B. Griswold has greatly improved the text and maps; such deficiencies as remain are

solely the responsibility of the writers. Most of the plates and figures which originally illustrated the Company report have been redrafted and color separations made by Roland V. Wilson and Richard R. Paul.

Director Vernon E. Scheid of the Nevada Bureau of Mines generously allowed the senior writer time in 1964 to rework the original Company report for publication.

Finally, appreciation is expressed to officials of the New Jersey Zinc Company and to all property owners (1949) who granted permission to publish the information contained herein.

Geologic Setting

REGIONAL GEOLOGY

STRATIGRAPHY AND STRUCTURE

The rocks underlying the west front of the Sacramento Mountains in the vicinity of Alamogordo represent a sedimentary section ranging in age from Cambrian(?) at the foot of the mountain front to Middle Permian at the crest and on the eastern slopes. The following, generalized from Darton (1928) and Pray (1961), is representative of the gross stratigraphic sequence near the mapped area:

ACE	UNIT	THICKNESS (FEET)
Permian	San Andres Limestone	700
Permian	Yeso Formation	1200-1800
Permian	Abo Formation	100-700
Pennsylvanian	Magdalena Group	2000-2500
Mississippian	Lake Valley Limestone	300-400
Devonian	Onate, Sly Gap, and Percha formations	60-100
Silurian	Fusselman Dolomite	100
Ordovician	Montoya Formation (including Valmont Dolomite)	290-450
Ordovician	El Paso Limestone	430
Ordovician and Cambrian 0	Bliss Sandstone	110
Precambrian	Diabase, sandstone, and shale	--

In general, these formations are but gently tilted or folded, the exceptions being where regional stresses have produced local tight folding and block faulting, particularly along the western mountain front. The more prominent faults and fold axes have predominantly northward trends. However, faults of moderate displacement striking northeast to east have been noted. Dips in the Abo and Yeso generally are moderate and to the east.

Pre-Permian deformation is expressed by folding and faulting of the rocks underlying the lower Permian Abo Formation. The Abo lies unconformably on the Pennsylvanian Magdalena Group, although in some places no angular discordance exists between them. In Arcente Canyon, pre-Abo erosion removed the Pennsylvanian section, and the Abo rests directly on Mississippian limestone.

The Abo Formation crops out along the western range front just below the edge of the plateaulike top of the mountains. It ranges from an elevation of more than 8000 feet south of Alamo Canyon to less than 6500 feet at La Luz Canyon, twelve miles to the north. The formation is lenticular, changing in thickness from less than 100 feet to nearly 700 feet. The thick Abo lenses represent pre-Permian structural and topographic lows that were filled in Permian time. The thinner sections represent highs that were veneered.

The contact between the Abo and the overlying Yeso often is exceedingly irregular, but no angular relationships can be observed except in areas of what appear to be deep channel filling. Pray (personal communication, 1949), who has examined a much larger area than covered by this report, suggested to the writers that the irregularities at the base of the Yeso probably are not due to filling of an erosion surface on the Abo but reflect the land sliding of incompetent Yeso rocks across the contact. Although field evidence for or against this belief is often ambiguous, the suggestion is incorporated on Plates 3, 4, and 12. The Yeso limestones, siltstones, and gypsiferous beds are poorly exposed because of their tendency to weather rapidly and produce soils favoring the heavy growth of brush and trees. Often considerable breaking with little displacement is evidenced in the Yeso where exposed in road cuts. Occasionally such zones lie along projected pre-Permian structures and suggest renewed movement along these "basement" breaks, possibly in Laramide time.

Quite recent spring deposits consisting of travertine and calcareous tufa occur in the Abo in Karr Canyon, on the Speckled Bird Nose, and in the east Warnock area. These deposits are believed to correlate with early regional ground-water activity which locally appears to have concentrated commercial lead values and effected the redistribution of certain copper minerals.

INTRUSIVES

The only intrusives found in the district are several hornblende andesite sills that crop out in pre-Abo rocks between Alamo Peak and the Warnock mine and between Alamo Peak and Alamogordo. These sills appear to be laccolithic, thickening from a few feet to a hundred feet in relatively short distances. Borders of the sills commonly show chilling, but these intrusives produce no alteration of the enclosing rock except for rare, narrow bands of bleaching.

Sills and dikes of similar composition are known in Magdalena rocks in Ortega Peak east of the district, in the Abo in a road cut on State Highway 83, and in the Magdalena Group north of High Rolls. Neither significant alteration nor mineralization was observed near any of these intrusives.

THE ABO FORMATION

DISTRIBUTION

From High Rolls to Alamo Canyon, the Abo Formation usually is represented by three distinct members; a coarse basal limestone or quartzite conglomerate, a principal middle member comprising alternating arkose, siltstone, and shale, and an irregular capping of red shales. The conglomerate and red shale members frequently are missing or are obscured by slide rock. The distribution of these members and the outline of the Abo from Alamo Canyon to High Rolls are shown on Plate 3.

The Abo maintains a consistent thickness of about 200 feet along its easternmost exposed edges, but in the Warnock—Speckled Bird area and the Stark Nose—Alamo Canyon area, it extends westward and thickens to about 700 feet, in both instances probably having filled local, pre-Permian basins. The eastern exposures are largely comprised of the arkose member and irregular thicknesses of the red shale member. The basal conglomerate and the red shale attain their greatest thicknesses in the two basins with a corresponding increase in thickness of the arkose member. These variations in thickness do not appear to have affected lead or copper distribution in the arkose, for the Warnock and Speckled Bird deposits are in a basin while the Dollins, Tony, Courtney, and Ady deposits all are in thinner sections of the Abo.

STRATIGRAPHY

Basal conglomerate member. The basal limestone conglomerate is locally distributed in the basins, where it ranges from zero to several hundred feet in thickness. It does not appear between the north Warnock area and Red Hill, although Pray (personal communication, 1948) reports it again north of Red Hill. In the southern area, it is composed of bedded units of about 30 per cent sandy matrix and 70 per cent boulders and pebbles, about 80 per cent of which are limestone and 20 per cent quartzite and quartz. The pebbles range in diameter from one quarter of an inch to four inches, their over-all average diameter being about two inches. In some places, silty layers up to 2 feet thick occur in the conglomerate, but in the southern part of the district the member is fairly uniform. On Red Hill, north of High Rolls, it is predominantly quartzose in character. This basal member usually is flat or dips very slightly.

Arkose member. Though varying in thickness from 50 feet to 200 feet, this member is the most persistent of the three constituting the Abo. Actually, only about 40 per cent of it is arkose; the bulk is composed of red and chocolate shales and siltstones.

Arkose beds ranging from a few feet to 20 feet in thickness and averaging about 6 feet are intercalated with the shales. The thicker sections probably represent main parts of stream channels which crosscut enclosing shales as diastems. One easily gains an erroneous impression as to the amount of arkose in the underlying rock, for locally, where arkose beds are moderately concentrated, an entire area may be covered with arkose float blocks, the shale having been eliminated by erosion.

Differences in composition, grain size, and weathering produce several types of arkose. Where the mineral grains are almost entirely quartz, the arkose is sugary and bleached in appearance. Quartz, feldspar, and carbonate aggregates result in more compact and pink to yellow-brown beds. Modest amounts of limonite occur in small brown spots or blotches in these types, but where limonite is concentrated sufficiently, it colors the arkose a chocolate brown. Occasionally, slightly conglomeratic facies are found, but such coarse beds are minor and discontinuous. All types of arkose grade into shale, this being a general characteristic over the entire region.

For detailed surface mapping, the arkose beds were divided into three color categories; cream, chocolate or purple, and red or light brown. A careful study of specimens would be necessary to determine which of the several varieties is more likely to contain lead values, but observations so far made permit a few general conclusions. Lead, in both sulfide and carbonate forms, is most evident in light gray to pale yellow-brown, medium-grained, compact arkose but also is found in similarly colored, finer or coarser material. Since yellow limonite-spotted rock often carries lead ore, such coloring and spotting at first appeared to be an ore guide. However, much of the district is underlain by such favorable-appearing arkoses that apparently are barren.

Red shale member. The red shale member at the top of the Abo varies from zero to several hundred feet in thickness. This member is thinly layered, brick-red, and varies in composition from shale to silt-stone. Under the influence of gravity, these beds break up and creep extensively so that the actual contact between them and the arkose member beneath is somewhat difficult to fix. This also is true for the YesoAbo contact.

STRUCTURE

Within the area described, the Abo displays considerable irregularity in strike and dip. These irregularities are due partly to sedimentation and partly to deformation. To generalize, the most persistent strike trends are either slightly west or east of north, except in basin areas, with east dips predominating and ranging up to 25 degrees. In detail, gentle strike terraces and synclines, best expressed in arkose beds, often warp the monoclinal structure.

On the various plates, several faults are shown cutting the Abo. No doubt many others have gone unmapped because of poor exposures, but the displacements on them are not great enough to produce significant discrepancies in the relations of the major units. No alteration or mineralization is visible on or near any of the faults observed, except for the Warnock fault where an open cut reveals some bleaching of the red shale.

Near-bedding plane movement is suggested by the occasional kneaded appearance and slickensided surfaces in various shale units of the Abo.

Strong jointing, often noted in the arkose lenses, probably is due to compaction, gentle folding, and sympathetic breaking parallel to or en echelon with larger fault structures. Locally, the joints have had considerable influence on the distribution of mineralization, as subsequently described. Until the acetic acid-potassium iodide method of identifying oxidized lead minerals was employed, the effect of joints in localizing deposition of copper carbonates was more obvious than was their control of lead distribution.

Mineral Deposits

PRODUCTION

Lasky and Wootton (1933) estimate the production of the Sacramento district through 1931 as 1,600,000 pounds of lead and 100,000 pounds of copper. The data from which these figures are derived are fragmentary, but an independent check of *Mineral Resources* volumes from 1900 through 1931 indicates their estimate is so close as to require no further comment.

Since 1931, production has been reported in the *Minerals Yearbooks.* Adding the figures from 1932 through 1962 to Lasky and Wootton's estimate gives an approximate production for the period 1908-1962 of 1,915,500 pounds of lead and 260,570 pounds of copper. Only minor amounts of silver and gold have been produced.

Comparison of the pounds of metal produced with tonnage reported since 1932 shows that the ore has been of two classes and that the grade has varied as follows:

Lead ore	5.0 per cent to 11.0 per cent lead
Copper ore	2.0 per cent to 7.0 per cent copper

Private figures on production before 1932 indicate that much of the lead ore averaged between 12 and 15 per cent lead, a quality possibly due in part to hand-sorting.

Careful consideration of available figures for pounds produced and grade suggests that total tonnages for the district could not exceed 23,000 tons of lead ore and 6500 tons of copper ore. Although at least ten other mines are mentioned in the history of the district, the bulk of the copper ore has come from the Courtney mine and practically all the lead ore has come from the Alamo mine. By 1948, the latter had come to be known as the Warnock mine, after one of its former operators.

MINERALIZATION

LEAD

Lead mineralization in the Sacramento Mountains apparently is confined to arkose beds within the Abo from Red Hill south to the Ady mine. Although minor lead occasionally is found in several such beds, in a specific area the principal values always are confined to a single light gray to yellowish cream arkose bed. This is well demonstrated by assay results on random samples selected over the entire district from favorable-appearing arkoses and by results of detailed sampling in areas of interesting mineralization. Where concentrated, the lead minerals may make irregular, narrow shoots up to 25,000 tons averaging about 7 per cent lead, although values may range from a trace up to 20 per cent. The thickness of the ore shoots seldom reaches the full thickness of the arkose host beds which average less than 10 feet.

Lead may be represented by galena, cerussite, minor anglesite, or all three; usually the higher values are in cerussite. These minerals, occurring together or separately, are disseminated between feldspar and quartz grains of the arkose, apparently at the expense of cementing material. What probably is cerussite occasionally can be detected in clay galls by the KI method. Rarely, cerussite can be observed on fracture or joint planes.

Though frequently confused underground with fine-grained bluish quartz, galena usually can be recognized easily. Cerussite, however, blends with altered plagioclase feldspars and carbonate cement so well that it is almost impossible to detect. Galena frequently does not show on outcrops, apparently having been leached. Often the leached surfaces are exceedingly porous and have a dull gray appearance due to cerussite and/or anglesite. Lead mineralization occasionally can be detected by careful work with a pick and the use of KI on narrow limonite-stained bands that may or may not show cerussite.

COPPER

Copper mineralization, characterized as the "Red Bed" type and conceded by some to be syngenetic originally but partly redistributed and reconcentrated by ground water in a second, epigenetic stage (Finch, 1933; Lindgren, Graton, and Gordon, 1910, p. 78-79), is widespread, though of minor commercial value, in the Abo Formation of the Sacramento Mountains. Copper concentrations usually are found in the same general area with lead but also are known in a number of places where significant lead has not yet been proved. Copper minerals may predominate in beds above or below those containing lead or may occur in the lead-bearing beds. Only at the Warnock mine, however, were reltively high copper values frequently found in conjunction with high lead values. In no place do the values of the two metals bear any consistent relation to each other. Where an arkose bed occasionally is herein referred to as a *copper bed* or as a *lead bed,* it is intended to imply only that the indicated metal predominates.

In addition to being almost geographically coextensive with lead showings, copper of the "Red Bed" type is known on the Mescalero Indian Reservation north of Red Hill, on the southeast side of Ortega Peak, and from several areas a few miles south of the Ady mine. It is also known in the Tularosa or Bent district, but geologic relationships there are different from those in the High Rolls area, and the Tularosa mineralization may be of other than "Red Bed" origin (Lindgren, Graton, and Gordon, p. 187-190). The copper concentrations usually are narrow, small, and spotty, never more than several thousand tons being extracted from a single locality.

The copper minerals in relative order of abundance are malachite, azurite, chalcocite, and chalcopyrite. The last two minerals often are associated with pyrite or marcasite but rarely with each other. Chalcocite may be present as nodular masses or as replacements of woody material or thin coal seams enclosed in sandy shale or shaly arkose. On Red Hill, north of High Rolls, chalcocite is disseminated in a thin, dense, light gray arkose bed. Chalcopyrite usually is present as fine disseminations in the same general environment as lead but in detail commonly is segregated within the lead-bearing beds and is specifically marked by individual iron-stained bands further colored by minutely disseminated malachite.

Malachite and azurite appear to have been derived from chalcocite and chalcopyrite and probably represent fairly recent oxidation. They either are associated directly with copper sulfides or have migrated away from them, occurring as coatings and disseminations along bedding planes and as fillings of fractures. Usually the occasional high copper values in lead beds are due to these secondary carbonates.

Limited shipments of sorted ore have been made; in general, these averaged slightly under 3 per cent copper. Copper assays of samples collected for this district appraisal occasionally have ranged up to 10 per cent.

OTHER MINERALS

Iron is present in limonite, hematite, pyrite, marcasite, and magnetite. Hematite is represented as staining in the sedimentary rocks. Magnetite occurs as microscopic grains in the arkose. Pyrite and/or marcasite frequently are found with nodular chalcocite, as mentioned above, and are in the lead beds usually as richly disseminated, irregularly circular spots. The former presence of pyrite is suspected in many localities from dark brown limonite spots with peculiar gummy cores. This particular limonite should be differentiated from the light to medium brown spotting or staining that may reflect migration of iron from a number of possible sources. Spots of the former type occasionally appear to be fair guides to concentrations of lead or copper.

In addition to the lead, copper, and iron minerals described, other metals found in the Abo lead beds include zinc in the forms of smithsonite and cobaltiferous smithsonite (no sphalerite has been observed), silver in unidentified minerals, vanadium in vanadinite, and vanadium and copper in combination as rare cupriferous vanadates. Zinc is fairly common in certain lead beds, though it seldom exceeds 0.1 per cent except in areas where its minerals are obvious on joint surfaces. Silver rarely assays as much as 0.1 ounce, but it is quite persistent as a trace metal. A sample taken in the Warnock area gave 0.4 per cent vanadium; the cupriferous vanadates locally displayed were not observed elsewhere in the district.

Nine samples collected from the Tony, Dollins, Courtney, Black Bear, Warnock, and Ady workings were tested spectrographically at the New Jersey Zinc Company's laboratory and a check was made with a Geiger counter for uranium content. Amounts of metals of possible interest, other than lead and copper, ranged as follows:

Zinc, 0.01 to 1 per cent
Silver, 0.001 to 0.01 ounce
Vanadium, 0.0001 to 0.01 per cent
Tungsten, less than 0.001 per cent
Cadmium, less than 0.001 per cent
Manganese, 0.01 to 0.1 per cent
Mercury, less than 0.001 per cent
Nickel, less than 0.001 per cent Tin,
less than 0.001 per cent
Molybdenum, 0.0001 per cent or less
Uranium oxide, less than 0.01 per cent

Because of the limited number of samples, these results are not conclusive but do suggest probable contents of these metals in the arkose beds.

MINES AND PROSPECTS

Since the Warnock mine area has the most extensive showings of lead and consequently the most concentrated development, results obtained there are especially pertinent when considering mineralization in other parts of the district. For this reason, the Warnock appears first in the following descriptions. Thereafter, areas are described geographically beginning with Red Hill at the extreme north end of the district and proceeding southward to the Ady mine. One digression is made from this scheme to discuss mineralization in Karr Canyon.

WARNOCK AREA

In 1949, the Warnock mine area was covered by twelve unpatented Alamo Extension claims owned by Frank J. Holmes of Modesto, California. Development consisted of several thousand feet of drifts, inclines, stopes, raises, open cuts, and short adits and 1550 feet of bulldozer work along the arkose member of the Abo.

Two lead ore bodies containing galena, cerussite, and minor anglesite have been exploited from one general level of lenticular arkose beds.

Oxidized copper minerals, with malachite greatly predominating, are found in shaly arkose above the lead-bearing arkose; these same minerals are found as disseminations and fracture fillings within the lead bed. Chalcocite has not been recognized, and chalcopyrite is of rare occurrence. Other minerals of restricted distribution include pyrite, smithsonite, cobaltiferous smithsonite, vanadinite, and certain cupriferous vanadates.

Geology

The Abo Formation in the Warnock area is shown on Plate 4. The Abo rests in some places conformably and in other places unconformably on the Magdalena. It attains a maximum thickness of more than 400 feet in the basin east of the main workings. The basal limestone conglomerate member is thickest in this basin but thins gradually on the flanks and finally disappears to the east and to the west. The arkose member is persistent and varies from 200 to 300 feet in thickness. The red shale capping member shows an apparent variation of 100 to 200 feet.

The basal conglomerate evidently represents initial erosional products shed from an early Permian land mass. The conglomerate phase was succeeded by the alternate deposition of coarse sediment and fine silt, as might develop at mouths of large rivers during periods of alternating flood and quiescence. Such relationships also are suggestive of fan deposits. Finally, the only material reaching the basin was fine and appears to have been deposited under rather quiet conditions, resulting in the ferruginous, arenaceous capping shales. It is possible that the Warnock—Speckled Bird basin was once coextensive with that in the Alamo Canyon—Stark Nose area. At least, the latter basin resembles the former in its history.

Along the southern slopes, outcrops are numerous and the various parts of the arkose member can be separated. Chocolate- and light chocolate-colored arkoses can be traced by float blocks and outcrops for several hundred feet in some instances, but usually these may gradually fade into cream arkose or become indistinguishable in the float. Shale within the arkose member is obscured by surface debris, but underground workings and bulldozer work indicate a ratio of about 60 per cent shale to 40 per cent arkose. Small but economic concentrations of lead are confined to cream arkose lenses lying from 50 to 100 feet stratigraphically above the basal conglomerate.

The Warnock lead bed disappears under float to the northwest and pinches out in shale to the east. Direct correlation with the east Warnock bed is prevented by the fault which has dropped the Warnock block about 200 feet (down to the west), but the east Warnock bed is at the same general level in the arkose member as that in the main Warnock mine and probably is its equivalent. The east Warnock bed strikes east, dips from 5 to 15 degrees north and varies from 4 to 8 feet in thickness. It is strongly jointed with north- and east-trending sets predominating. The bed lenses into shale east of the portal below point 1 on Plate 4. It was bulldozer-stripped westward to point 4 where the great number and large sizes of arkose blocks and the steep hillside made further stripping impractical. From points 1 to 2, this bed has a consistent thickness of about 6 feet, then it thins at 2 and interleaves with shale for about 40 feet westward to the gulch. Southwestward from the gulch, it averages about 8 feet thick for 200 feet to point 3 where it becomes thin-bedded, shaly, and chocolate-colored. Between points 3 and 4, it is poorly exposed and shaly, but at point 4, it is about 5 feet thick and cream in color. It gradually lenses out westward toward the Warnock fault.

Since strike and dip observations in the Abo and in the Magdalena are rather well distributed on Plate 4, a detailed description of their considerable variation is not necessary. Apparently the variations are due to basin topography, sedimentation, and deformation. Slight folding has in many instances produced northeast and northwest joint sets which seem to have effected localization of lead and copper minerals.

The largest fault involving the Abo cuts through the Warnock area about parallel to the Alamo Peak fault to the west (not shown). The Warnock fault apparently has had a slight scissor or couple movement with the greatest displacement of about 200 feet to the south. It is detectable mainly through discrepancies in positions of the red shale-arkose and arkose-conglomerate contacts. Also, the sharp change in dips of the Magdalena limestones plus the abrupt disappearance of a distinctive crinoidal limestone in the Magdalena as the fault is crossed suggest its presence. A bulldozer cut on the fault at point 5 (pl. 4) discloses a yellow zone, 6 feet wide, of shattered shales flanked on the west by red shales and on the east by chocolate shales typical of those in the arkose member. No mineralization shows in or near this zone, and the only alteration is slight bleaching and hardening of the red shales. The bleaching may be due either to surface waters which have used the fault as a channel or to hydrothermal action; however, the Magdalena limestones are neither altered nor mineralized on or near this fault.

West of point 2, just above the lead bed, is an old spring deposit of gray travertine and calcareous tufa, suggesting that there has been considerable movement of ground water in the arkose member. Similar deposits occur in arkose on the northeast side of the Speckled Bird Nose.

On the western edge of the map area, an andesite sill with laccolithic tendencies is present in the Magdalena limestone. It shows variation in grain size due to chilling along its borders. No alteration occurs in the sill or in adjacent rocks. In the general area of the sill, a silty arkose bed between Magdalena limestones and the basal conglomerate of the Abo reflects the change in late Pennsylvanian from marine to continental conditions of sedimentation.

Southeast of the sill is a pre-Abo normal fault with 50 to 100 feet of displacement, down to the east.

Sampling Results

All arkose outcrops were tested with KI and the results recorded on Plate 5. The only areas showing favorable response were those outcrops near the main Warnock mine portal and those at the east Warnock workings. Most of the cuts and likely outcrops were sampled and assayed with results comparable to those of the KI test, the only appreciable values being found in the two areas just mentioned.

The strip of arkose exposed by the bulldozer in the east Warnock area was sampled and tested with KI; the results are shown on Plate 6. KI tests suggest two possible concentrations of lead. One extends from the Alamo No. 1 adit, point 1, westward about 200 feet. The second extends from the gulch, at the break in the section, southwestward for 300 feet where the bed begins to finger out into shale. Lead assays show interesting variations within short distances. In the first concentration, two high-grade samples containing 14.70 and 17.10 per cent lead were obtained from 2 feet of the bed. Assay of an adjacent sample, HR-404, showed 0.55 per cent lead, and values dropped to a trace of lead in sample HR-405 at the lower Warnock No. 2 portal. In the second "concentration," lead values do not exceed 0.15 per cent, being no better or worse than those in supposedly barren parts of the bed.

In all samples from the bulldozer cut, other metals followed their usual patterns. Silver ranged from a trace to 0.26 ounce (higher values were with higher lead assays), copper from 0.06 to 0.66 per cent, and zinc from a trace to 0.15 per cent.

Warnock Mine

Three plates are included to illustrate the geology of the Warnock mine. Plate 7 is a plan of the mine with certain selected sections to which the generalized results of sampling and KI work have been added. All underground workings were sampled at about 20-foot intervals or less; results are recorded on Plate 8. The sample points then were treated with KI and any adjacent areas of interest also were tested. The red coloring on the plan (pl. 7) represents appreciable KI results, while red on the cross sections represents tentative ore shoots as outlined by assay results and defined more precisely by KI work. Plate 9 is a block diagram showing underground workings, geology, and distribution of galena within the arkose bed.

The lensing into shale and the swelling of the arkose bed are clearly shown in the plan, sections, and block diagram. The bed grades into shale in almost every direction but west and possibly a narrow strip to the northeast. The long axes of its thicker sections show slight orientation parallel to the dip, but such sections commonly are featureless as far as sedimentary structures are concerned. Where the bed begins to thin out into shale, bedding planes break up its massive appearance. In the vicinity of points 1 and 2 on Plate 7, the arkose is strongly cross-bedded in a manner suggesting swift scouring currents of changing paths. It is noteworthy that at these two locations, the lead carbonate ore shoots, as outlined on section **D-D',** seem to truncate in horizontal ends that are parallel to the foreset limbs of the cross-bedding as if the mineralizing agent were traveling down dip and became diverted to the hanging wall by the horizontal laminations. These near-horizontal shoots in a bed dipping 15 degrees suggest a series of level bubbles. This effect also is illustrated by section C-C'.

Jointing and fracturing in the Warnock bed are represented by two main trends; northwest, parallel to the strike of the bedding, and northeast, parallel to its dip. The ore shoots are aligned subparallel to the dip set of joints, although the strike set is the more prominent. The joints usually do not penetrate the shales above or below the arkose. Almost all of them are open and smooth-surfaced. Both sets of joints may have been produced by settling and flexing of the arkose with the adjacent incompetent beds adjusting to the forces by flow and bedding plane slippage.

In the over-all picture, individual joints do not seem to have controlled lead distribution, although a possible relation is suggested by the fact that mineralization is coincident with zones of concentrated jointing. In detail, however, the joints have definitely effected concentration of lead carbonate, but they exert no apparent effect on galena distribution. Galena commonly is in discontinuous ribbons which range, without obvious reason, from top to bottom of the arkose bed, but concentrations of this sulfide occasionally do show relation to the details of cross-bedding.

Three graphic examples of the influence of joints on lead carbonate distribution, as revealed by **KI** work, are shown in large scale on Plate 7. These are from parts of stope walls that were sprayed with **KI.** In some instances, however, the distribution of values has not been controlled by joints at all. In only a few instances in the mine are joint faces coated with lead carbonate, even when adjacent wall rock is heavily impregnated with it. This suggests that the fractures acted more as dams to the mineralizer than as channels for it. The concentration of lead carbonate on the up-dip side of the joints wherever noted suggests a possibility that the lead-bearing solution traveled down dip, was backed up at joints whose surfaces are smooth and much less permeable than normal arkose, and deposited its load behind these faces.

East Warnock Workings

Galena is visibly disseminated in small shoots underground in the East Warnock arkose bed. Limited KI tests indicate the presence of cerussite. Possibly 2000 tons of ore averaging about 6 per cent lead have been mined from the several hundred feet of workings. Geology and assay results are presented on Plate 10.

RED HILL

That area designated as Red Hill is less than a mile north of High Rolls on the eastern half of property owned in 1949 by Allan Walker of Alamogordo, New Mexico (pl. 3).

Red Hill has a cap of Yeso limestone, is comprised almost entirely of the relatively flat-lying Abo arkose member, and is underlain by Magdalena limestone. The basal conglomerate member of the Abo is unlike that to the south, being composed almost entirely of well-rounded quartzite and chert pebbles up to 6 inches in diameter in both calcareous and quartzose matrices. The arkose member is similar to that farther south except that purplish arkose beds are more abundant. These occasionally range up to 15 feet in thickness and alternate with red or purple arenaceous shale bands. An arkose bed near the base of the member changes in color laterally from cream to purple and, though averaging about 6 feet thick, occasionally ranges up to 12 feet. The main purple beds occasionally show mottled bleaching, an effect which probably results from the action of ground waters moving in porous beds and along joint planes. All arkose beds are characterized by abrupt lensing. Other than local north- and east-trending joint sets, limited to arkose, no structure is evident.

The best known mineralization is low-grade copper carbonates in a thin, gray, arkosic shale seam in the lower part of the Abo arkose member near the base of Red Hill. The carbonates replace organic material like twigs and leaves and coat intergranular spaces, joints, and bedding planes. This mineralization is developed by a few short open cuts on the east and west sides of Red Hill.

In addition to the copper carbonates, fine blebs and erratic stringers of chalcocite occur in a thin, dense, cream arkose bed high in the arkose member on the northeast side of Red Hill. Sparse malachite also is present, but because of the dense character of the rock, oxidation has been inhibited.

"Red bed" type of copper showings are known both east and north of Red Hill but were not examined by us.

A cream-colored bed near the base of the Abo arkose member on the west side of Red Hill contains one restricted area of zinc-lead mineralization. Visible galena, slightly oxidized to cerussite, is disseminated over a width of 2 to 6 inches and appears as fine blebs in other parts of the rock. Mineralization in the bed responded poorly to the KI test. The arkose is cut by joints that do not persist beyond its 6-foot thickness. The sample results are presented on Plate 11. The higher zinc values are in botryoidal smithsonite on or near joint planes, while several samples of compact, unfractured rock uniformly assayed 0.10 per cent zinc. These relationships suggest that zinc may have been leached from a considerable area and concentrated in the joint channels by ground waters.

SACRAMENTO GULCH AREA

Showings of lead and copper in the vicinity of Sacramento Gulch, about one mile southeast of High Rolls, in 1949 were covered largely by twelve unpatented claims. These were owned by M. F. Drunzer of High Rolls and R. S. Casner of El Paso, Texas. Some of the better mineralization is on the Dollins homestead directly east of the unpatented property (pl. 3).

Surface and subsurface geology and assay results are illustrated on Plates 12 and 13.

The sub-Abo Magdalena Group is in angular unconformity with the Abo. The Magdalena beds strike northwest and dip from 5° to 40° NE. The overlying Yeso appears to be disconformable, but this appearance probably is created by float blocks spilling across the contact. Neither the Magdalena nor the Yeso shows evidence of mineralization.

Nearly half this area is covered by Yeso float; consequently, only about 200 feet of Abo are exposed at any locality. Except for two places in Sacramento Gulch, neither basal conglomerate nor red shale is exposed, the main rock type being arkose. Thick surface cover made it impossible to separate the arkose member into units for correlation, but an attempt was made to trace arkose beds that cropped out and obtain some idea of the structure. This work indicated that the arkose unit bearing lead in Sacramento Gulch is in the same relative stratigraphic position as the bed developed by the Tony tunnels about 50 to 75 feet above the base of the Abo. This stratigraphic position of productive arkoses is comparable to that in the Warnock area.

The combination of surface and underground mapping proves the arkose beds are lenticular. Diastems plus general lensing result in thickness ranges of from 0 to 15 feet. Diastems are well developed in the vicinity of the Dollins tunnel, Sacramento open cut, East Sacramento No. 2 tunnel, and Tony tunnels; exposures in the East Sacramento No. 2 tunnel suggest that all channels are separate entities and may have preferred orientations of about N. 45° E. In nearly all instances here and occasionally elsewhere, galena, chalcopyrite, copper carbonates, and jointing are almost coextensive with thicker parts of the channels.

Practically all the main workings show more or less galena disseminated in a cream arkose bed. Cerussite usually occurs with galena at the outcrop but gradually or rapidly fades with increasing distance from the surface. Occasional clay galls which show no galena but which respond very well to the application of **KI** suggest absorption of lead carbonate.

Copper is represented principally by malachite, commonly disseminated with lead values in the arkose; it occasionally appears in beds other than those bearing lead. Chalcopyrite occurs in the arkose at the Dollins tunnel but also is in a narrow limonite- and malachite-stained band exclusive of lead minerals. Pyrite is visible in the East Sacramento No. 2 tunnel.

Development in this area comprises about 500 feet. The Dollins workings investigate lead mineralization in a 10-foot-thick section of arkose. The headings expose two main joint sets; the predominant set strikes northeast, the other, northwest. Most of these joints are filled with rubble and dirt from the surface which is about 15 feet above the back. The arkose is cream, coarse, and contains several small, gray shale pods. A 1-inch shale seam and other bedding features indicate a dip of about 10° NW. At the end of the east drift, chocolate-colored shale in the floor presumably represents the footwall of the arkose bed.

The east drift shows a large amount of easily visible but scattered galena and rare chalcopyrite, particularly in the upper half, but the response to KI was slight. The galena imparts a high-grade appearance to the arkose, but most of the assay values are low because of the paucity of lead carbonate. Some relatively high assays, however, were obtained along several feet of the east wall near the back. Galena, although apparently concentrated in strongly jointed or fractured areas, is unrelated to such areas in its detailed distribution; sedimentary features such as deeper parts of channels, porosity, and cross-bedding provide the detailed control. The probability is that a joint plane will have no more disseminated galena on its face than will arkose inches or feet from such a plane. As demonstrated at the Warnock, this is not true of lead reconcentrated as lead carbonate; the joints may serve as dams but only rarely as channels. At the Dollins workings, lead carbonate is scarce except in outcrop.

The North Sacramento adit is driven in red shale, the lead-bearing arkose horizon being the back. The base of the arkose is marked by a scab of disseminated galena and cerussite which ranges up to 3 inches in thickness. A sample selected from this band and including some arkose above it assayed 0.03 per cent copper, 3.38 per cent lead, and 0.42 per cent zinc. The Sacramento open cut, adjacent to the tunnel, exposes the full width of the lead bed; the sample cut over the 7 feet of width assayed 0.04 per cent copper and 0.75 per cent lead. **KI** results were uniformly poor.

The cut reveals spots of fine-grained galena erratically and sparsely distributed over the face. The lower 6 inches of bed, corresponding to that in the back of the North Sacramento adit, show a concentration of galena and a favorable reaction to KI.

LOWER KARR CANYON

The geological environment in lower Karr Canyon (pl. 3) is merely the southeasterly extension of that in the Sacramento Gulch area (pl. 12) except that more Abo red shale is found in Karr Canyon. Valley fill obscures the lower part of the Abo arkose member and the underlying Magdalena Group. The Yeso Formation shows its usual irregular relations with Abo red shale; Yeso float occasionally obscures the shale completely and is in contact with the arkose member. Cover is so thick that continuity of beds and structure are difficult to establish. However, the arkose member seems to be persistent and its individual arkose beds relatively flat-lying and characteristically lenticular.

Two undeveloped spots of mineralization occur in jointed cream arkose beds on the southwest side of Karr Canyon. One showing of slightly disseminated malachite is of little more than passing interest: the other is slightly oxidized galena, finely disseminated in thin, irregular, limonite-stained bands. Samples of the best showing of lead assayed poorly. A limited KI test over the exposed parts of the bed indicated no reconcentration of lead as cerussite.

Arkose beds prominently exposed along the east side of Karr Canyon have been visually examined and KI-tested in part. They appear to be totally lacking in metal values of any kind. The beds are predominantly purple in color but are believed to be equivalent in part to favorable-appearing but mostly barren cream-colored beds on the west side of the canyon. Extensive deposits of calcareous tufa are concentrated at the mouths of several small gulches.

SACRAMENTO GULCH TO COURTNEY MINE

Between Sacramento Gulch and the Courtney mine, only minor showings of base metals are to be found in the Valley, Stream, Coachman, and Cactus cuts, approximately located on Plate 3. The two small Valley cuts expose slightly oxidized galena associated with limonite and malachite disseminated in a thin, cream arkose bed above that usually bearing lead.

The Stream adit develops a cream arkose below the bed exposed by the Valley cuts; the "Stream arkose" also is higher in the section than the arkose bearing lead in Sacramento Gulch. Although no lead can be seen underground, some galena ore is piled on the dump. Samples from the tunnel assayed no copper and only sparse lead.

Lead was faintly indicated by **KI** tests in the Coachman and Valley cuts.

COURTNEY MINE

Three unpatented claims, the Grandview, Courtney No. 1, and Courtney No. 2, control all showings of copper and lead in and near the Courtney mine. In 1949, F. E. Calkins of High Rolls owned these claims (pl. 3).

To date, only copper ore has been produced from a surface open cut and from inaccessible underground workings. Mining has been limited to a contorted, much fractured, shaly arkose stratum containing nodules of chalcocite and copper carbonates. During the early history of the property, the mineralized arkose was mined and allowed to disintegrate on the surface; the chalcocite and copper carbonate nodules then were screened out and shipped. In later years, some production has come from lower grade copper carbonate which impregnated shaly arkose and replaced fossil twigs and leaves within it.

An inaccessible 90-foot shaft in the open cut reputedly encountered an arkose stratum about 50 feet from the surface. A limited exploration of the bed disclosed thin streaks of fairly high-grade galena. What probably is the same bed crops out about 200 feet west of the shaft. This cream arkose has been investigated by trenching, jackhammer holes, and shallow shafts, but only minutely and sparsely disseminated galena and cerussite have been found. Assay results are reported on Plate 14.

COURTNEY MINE TO ARCENTE CANYON

This section of ground shows more structural complexity than any other in the district (pl. 3). As a consequence, there is exposed in Arcente Canyon, with varying degrees of conformity, sediments ranging from the Ordovician El Paso Limestone to the Permian Yeso Formation. Because of irregularities in sedimentation, the Abo is represented by varying thicknesses of its arkose and red shale members. On the south side of Arcente Canyon, the Abo Formation rests directly on Mississippian crinoidal limestones.

Several of the fault structures shown are pre-Abo in origin and possibly are related to the evolution of the ancestral Rockies; others involving the entire exposed section possibly are of Laramide age. Some early faults may have been reopened by later stresses. Because of the combined effects of at least two orogenic periods, strikes and dips of beds in all formations are quite irregular.

The few mine workings expose galena and its oxidized products slightly disseminated in a cream-colored arkose bed. These showings are in the Black Bear and Andy open cuts on the north side of Arcente

Canyon and in the Bisbee adits located on a tributary gulch on the south side of the canyon. In 1949, the Black Bear unpatented claim was owned by F. E. Calkins. Assay results for the Black Bear are on Plate 15; those relating to the several Bisbee workings are on Plate 16.

SPECKLED BIRD NOSE

Sediments on the Speckled Bird Nose, the north continuation and thicker part of the basin of Abo sediments which contain the Warnock mine, have been described under the Warnock. One easterly trending fault, subparallel to one in Arcente Canyon and to one directly south of the Courtney mine, was mapped (pl. 3).

Thick Abo in the basin is connected by a thin veneer of arkose and red shale to the same members in Arcente Canyon. No mineralization is known in this thin strip, although several arkose fragments with poor copper showings were found near the forest road.

On the west side of the main nose, minor showings of malachite, azurite, and chalcocite in a fractured, massive, lenticular, cream arkose bed have been developed by several short adits. Travertine locally is abundant on joint surfaces. Limited KI work on various parts of the explored bed failed to indicate lead carbonate, and no galena was recognized. Similar results were obtained from a lower arkose bed.

Two miles due west of the Speckled Bird Nose on the southwest side of Ortega Peak, scanty disseminations of malachite and azurite were reported by A. L. Bowsher (personal communication, 1948).

WARNOCK EXTENSION TO ADY MINE

Adjoining the Alamo Extension claims (Warnock) on the east and covering the outcrop of Abo arkose beds to Caballero Canyon were the three unpatented claims, Warnock Extension Nos. 1 and 2 and Caballero Extension No. 1 (pl. 3), owned in 1949 by M. F. Drunzer of High Rolls.

Excellent exposures in Caballero Canyon show structure in the Magdalena Group to include anticlines, synclines, and block faults, all of which predate deposition of the Abo. Partly because of the irregularities on the eroded Magdalena surface and partly because of sliding of the incompetent Yeso rocks across the contact, the Abo appears to vary greatly in thickness. The three members of the Abo are presented, but the basal conglomerate and the red shale show surface discontinuity because of conditions just described. The arkose member is persistent though occasionally obscured by slide blocks of the red shale member.

Structure in the Abo is reasonably simple. The northwest-striking monocline is very gently warped by both strike and dip anticlines, synclines, and terraces. Northeast and northwest joints or fractures often appear to be localized by these gentle folds. Geology and assay results of workings in this area are shown on Plate 17. Malachite and galena are found separately and together in cream-colored arkose beds of marked lenticularity. Because of good exposures, all signs of mineralization have been given some attention in the past. Although rumors exist of numerous burro loads of high-grade copper ore having been packed out from the Bueno mine (never positively located by us), it is believed that production from this area could not exceed a few hundred tons of low-grade ore.

West of the road, several float blocks of cream arkose containing spots of malachite and heavily disseminated, somewhat oxidized, galena are found. Specimens from this locality are interesting in that cubic casts suggest that galena can be leached from arkose in a limited way without residual cerussite or anglesite forming. Such casts also might result from the leaching of pyrite without the formation of residual limonite.

On the dump of a caved cut at the northeast corner of Warnock Extension No. 2 are blocks of arkose with richly disseminated galena, but no ore has been proved in place. These blocks possibly represent material selected from the float by prospectors.

Except for one small cluster of pyrite crystals, no sulfide has been found in the Magdalena limestones.

ADY MINE AREA

The Abo rests with marked angular relationship on the Magdalena Group and may be partly disconformable with the Yeso Formation. The Abo, about 200 feet thick, is represented by nearly equal amounts of the arkose and red shale members. Strikes of beds within the Abo are about N. 30° W.; dips vary up to 25° NE. No faults were found (pl. 3). One hundred feet of open cut and several hundred feet of irregular inclined workings investigate showings of malachite, azurite, and chalcocite *(see* pl. 18). These minerals have replaced carbonaceous material and have been deposited in joints and bedding planes in a somewhat shaly bed of arkose 10 feet thick, about 50 feet above the Abo—Magdalena contact. The general environment of the copper resembles that at the Courtney mine and that on the Speckled Bird Nose. Fifty feet above the copper-bearing bed, four short irregular inclines are driven on a cream arkose stratum about 7 feet thick. In general these workings showed poor assays, but in one incline lead carbonate ore, with no visible galena, assayed up to 11 per cent lead over a width of 5 feet, and copper values up to about 3 per cent also were indicated.

The most extensive working in the Ady area is a 15-degree incline reported to be 1800 feet in length but now badly caved and partly inaccessible. Though predominantly in red shale of the arkose member, this incline cuts several arkose strata, including one bearing lead. Lensing of the arkose beds shows well in the incline, but no galena or cerussite is evident.

About 500 feet down the incline from the portal, malachite occurs in a coaly seam interbedded with red shale and ranging up to 6 inches in thickness. In a southeast crosscut, a few hundred feet farther down the dip, a 4-inch band of nodular chalcocite and pyrite, often mutually intergrown and brilliantly coated with malachite, can be seen in what probably is the same thin coal band.

South of the Ady mine only slight copper mineralization has been revealed in the Juniper cuts. No mineralization is known on Stark Nose southwest of the Juniper showings.

ORE GENESIS

Information on the Sacramento district pertinent to a discussion of genesis of the several ore types is summarized below:

1. No clear evidence of hydrothermal action is known in any of the formational units either above or below the Abo Formation from north of High Rolls south to Alamo Canyon. Structures either crosscutting the entire sedimentary series or confined to a limited stratigraphic section show no mineralization or alteration.

2. Andesite sills and dikes occur in or near the district. No significant alteration is found adjacent to them. No intermediate intrusive rock types, such as quartz-monzonite, are known.

3. Lead occurs in galena and cerussite and rarely in anglesite. In detail, the first two minerals may occur together as cerussite coating galena or as independent but often closely associated disseminations. Anglesite, when present, always coats galena. Occasionally galena may be bunched into patches and discontinuous stringers. These minerals often are associated with copper carbonates, chalcopyrite, pyrite, silver in unidentified minerals, and zinc, probably derived from sphalerite and reconcentrated as smithsonite. Cobalt and vanadium are of rare occurrence.

Copper in chalcocite, chalcopyrite, malachite, and azurite is found in several arkose and shale beds entirely within the Abo and may be associated with or independent of obvious lead mineralization. Chalcocite commonly replaces carbonaceous materials and rarely appears as disseminations. The reverse is true of chalcopyrite. The copper carbonates apparently have been derived from the sulfides and may appear as independent replacements of carbonaceous material, as disseminations, and as coatings on bedding and joint planes.

Pyrite or marcasite may be found in the same situations as the copper sulfides.

4. The principal lead mineralization is at a fairly constant level in the Abo arkose member in beds sandwiched between relatively impervious shales.

5. Minor lead values in the form of partly oxidized galena are rather evenly distributed in the outcrop of the lead horizon over the entire district, but occasionally the metal appears in minor quantities in arkose beds at other levels.

6. Possible arkose host beds represent parts of ancient stream channels. These are highly lenticular, tending to grade rapidly into shale in almost every direction. Often the arkose remnants are isolated, disklike masses, not visibly tapped by faults.

7. No alteration or mineralization is evident in red shales or possible feeding structures adjacent to the lead ore bodies, although both lead and copper minerals show a tendency to occur in light-colored arkose beds.

8. Galena concentrations, though frequently appearing in strongly jointed arkose, bear no relation in detail to joint, fracture, or main bedding planes. Galena seems more controlled by thicker channel positions and sedimentary features such as cross-bedding within these channels.

9. The long-exposed surfaces of certain specimens show cubic casts suggesting complete leaching of galena with no formation of residual lead carbonate or sulfate.

10. Spring deposits of several types reflect the activity of ground waters.

11. Cerussite or cerussite-rich calcium carbonate rarely is found on open joints. Smithsonite is not uncommon as a filling, but zinc sulfide has not been recognized.

12. Lead-carbonate concentrations commonly are found in coarser parts of the arkose beds. These concentrations may terminate abruptly down dip against joint surfaces or foreset beds of the cross-bedding and gradually fade out on the up-dip side of such surfaces. This produces what might be termed the "level bubble" effect at the Warnock mine where lead-carbonate shoots have a near-horizontal attitude within an arkose bed dipping 15 degrees. These shoots are arranged at six different recognizable levels (pl. 7, section C-C').

13. Clay galls and seams within lead-bearing arkose occasionally respond well to the KI test and contain no visible galena.

DISCUSSION AND CONCLUSIONS

Disregarding the great number of geological factors involved at various times, the problem in genesis, as suggested by the evidence, can be separated into two parts: first, the means by which the metals were introduced into the sediment and, second, the means by which they were subsequently concentrated.

As to the first, when we entered the district, we favored the view that the structural history, presence of igneous rocks, and assemblage of metals implied a hydrothermal origin for the ore deposits. As evidence accumulated, we gradually began to favor a hypothesis of "semisyngenetic" origin.

Though the chemical factors involved may be somewhat different, the general histories of the copper and lead mineralizations probably are almost identical. Because of their frequent direct association with copper and lead, iron (subsequently deposited as pyrite), zinc, silver, vanadium, and cobalt must have been deposited by the same processes suggested for copper and lead.

Our use of the term *semisyngenetic* (**H.** A. Schmitt, 1948, has coined the term *syngenoid* for this type) implies that the sulfides, originally epigenetic and hydrothermal in origin, or accessory minerals in igneous rocks, were leached and carried as salts by surface and ground waters and to a lesser degree as fine metalliferous detritus from sites of original emplacement into basins of accumulating sediments. The metal salts may in part have been sulfidized by 1-1$_2$S, possibly generated from decaying vegetable matter, and trapped in porous unconsolidated arkoses and shaly arkoses in the basin. Copper sulfides probably were deposited in shales by reduction of the soluble copper sulfate by organic material.

The first eight items summarized above, though indirect, tend to support this possibility for initial emplacement of the sulfides in the arkose. In addition, the continuous, lateral, far travel required for low-temperature hydrothermal solutions moving through discontinuous beds, with limited channels available, makes a hydrothermal origin questionable.

As to the second part, there can be little doubt that most of the copper carbonate in the district has resulted from fairly recent oxidation of original copper sulfide. That organic material was influential as a precipitant is indicated by the common association of copper carbonate with coal and well-preserved woody material.

The last five items summarized above strongly suggest that lead was taken into solution by ground water, migrated to some extent, and was redeposited as cerussite. During this ground-water phase and the later period of oxidation, some cerussite and anglesite actually were fixed as surface coatings on galena. An immediate natural argument, because of the usual nonmigration of lead under oxidizing conditions, is that the lead-carbonate concentrations have been derived from galena in place. In counterargument, it can be pointed out that the KI work spectacularly demonstrates, and the sodium sulfide test confirms, that slightly oxidized galena and cerussite with no sulfide cores whatsoever often have mutual boundaries. In such situations, galena commonly is disseminated, while cerussite often occurs in irregular forms apparently developed at the expense of cementing material and controlled by the shape of feldspar and quartz grain boundaries. The presence of lead carbonate in clay galls to the exclusion of galena suggests absorption of lead salts from migrating ground water.

The fact that lead and copper minerals tend to occur in light-colored arkose beds suggests that the beds either were light-colored to begin with or have been leached to some extent by circulating ground waters. However, the same effect would be expected from circulating hydrothermal solutions.

All this has led us to the conclusion that the ores in the Sacramento district are "semisyngenetic" in origin and are confined to the Abo. It is a conclusion that stimulates interesting speculation as to the original source of the sulfide minerals, but this involves a regional geological problem broader than could be covered during this project.

`references

Darton, N. H. (1928) *"Red Beds" and associated formations* in *New Mexico,* U.S. Geol. Surv., Bull. 794, p. 198-220.

Finch, J. W. (1933) *Sedimentary copper deposits of the western states,* in Ore deposits of the western United States, Am. Inst. Min. Eng., Lindgren vol., p. 481 - 487.

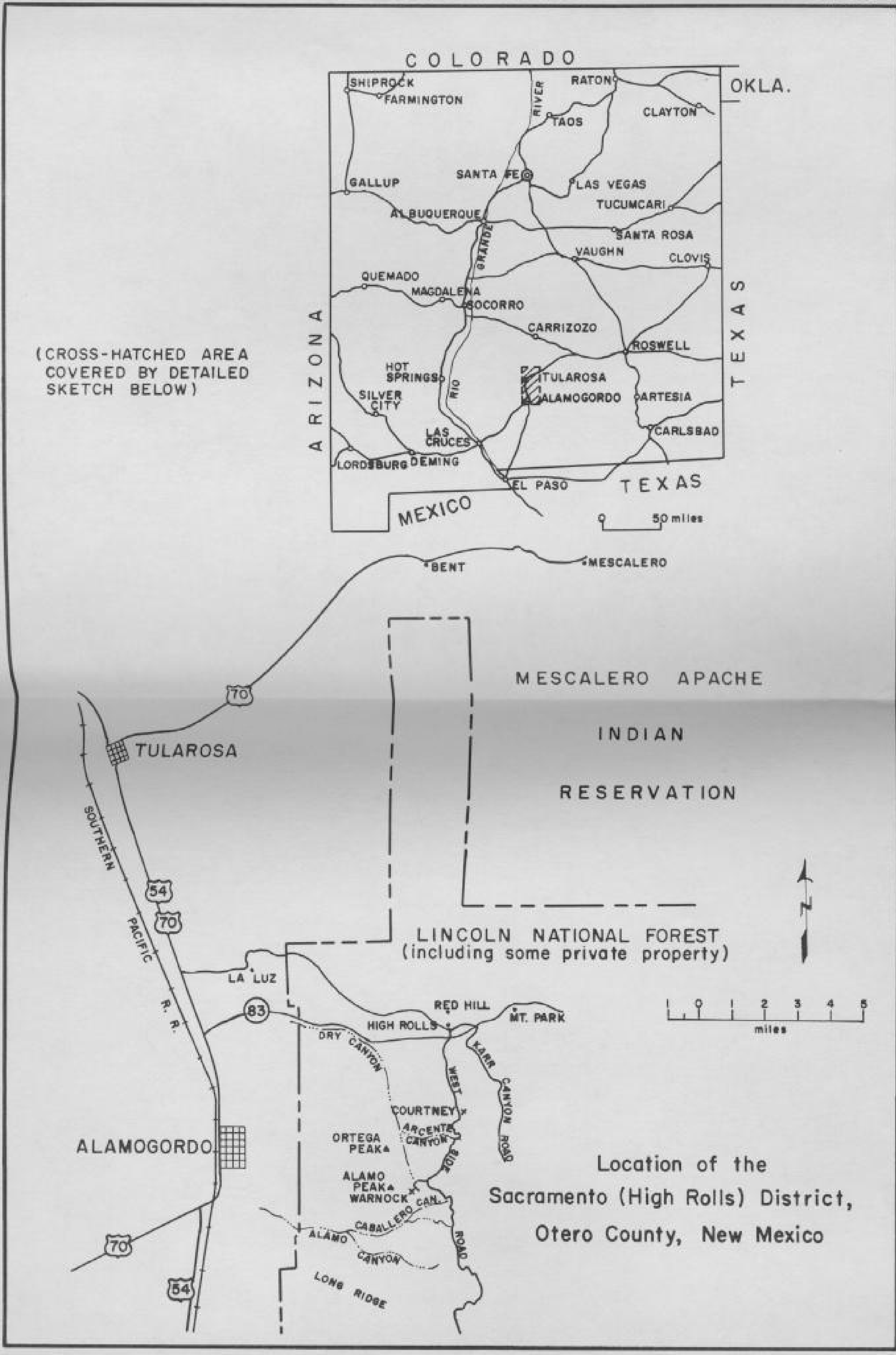
Jerome, S. E. (1950) *Special field applications of a confirmatory test for lead,* Econ. Geol., v. 45, p. 358-362.

Lasky, S. G., and Wootton, T. P. (1933) *The metal resources of New Mexico and their economic features,* N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 7, p. 85-87.

Lindgren, Waldemar, Graton, L. C., and Gordon, C. H. (1910) *The ore deposits of New Mexico, U.S.* Geol. Surv., Prof. Paper 68, p. 78-79,187-190.

Pray, **L.** C. (1961) *Geology of the Sacramento Mountains escarpment, Otero County, New Mexico,* N. Mex. Inst. Min. and Tech., State Bur. Mines and Mineral Res., Bull. 35,144 p.

Schmitt, H. A. (1948) *Proposed field classification of the mineral concentrations of economic interest,* unpub. ms., 11 p.



Location of the Sacramento (High Rolls) District, Otero County, New Mexico

INDEX MAP TO PLATES

PLATE NO.

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2. INDEX MAP TO PLATES
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5. RESULTS OF KI TESTING - WARNOCK SURFACE AREA
6. RESULTS OF SAMPLING AND KI TESTING - EAST WARNOCK BULLDOZER CUT
7. PLAN AND SECTIONS OF THE WARNOCK MINE (SHOWING GEOLOGY AND GENERALIZED RESULTS OF SAMPLING AND TESTING WITH KI)
8. ASSAY MAP - WARNOCK MINE
9. BLOCK DIAGRAM OF THE WARNOCK MINE (SHOWING GEOLOGICAL RELATIONSHIPS AND DISTRIBUTION OF USABLE GALENA)
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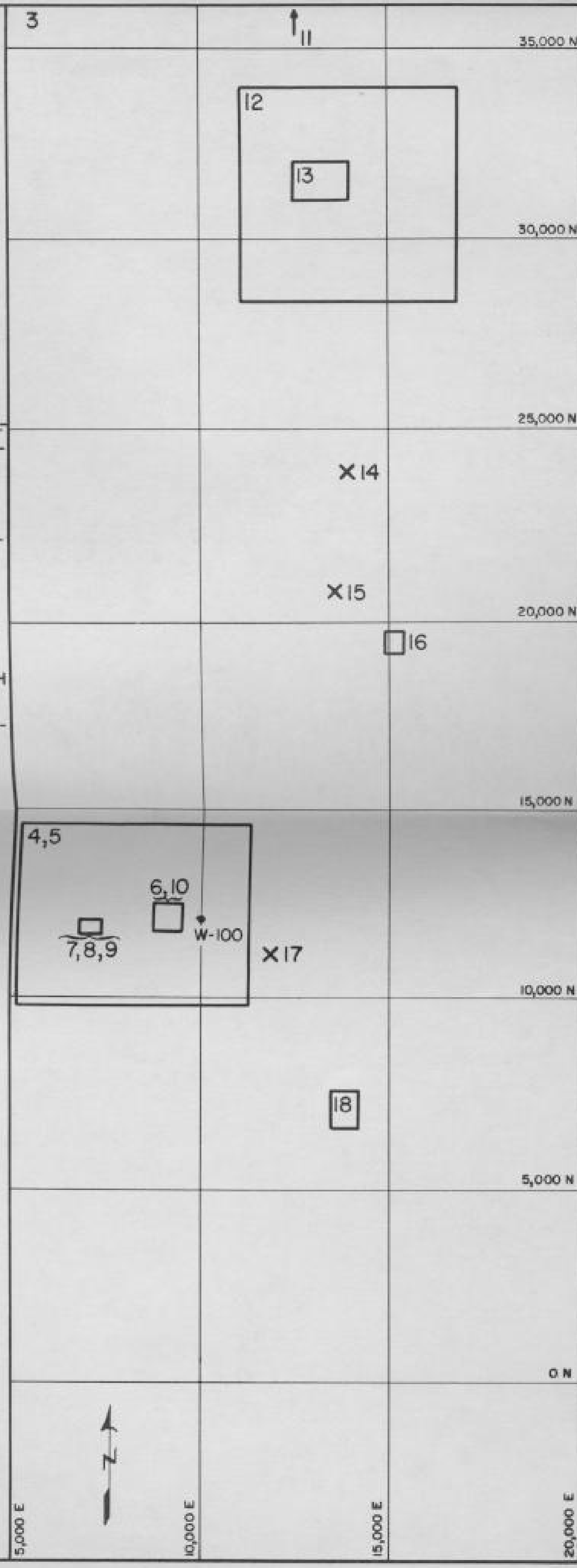
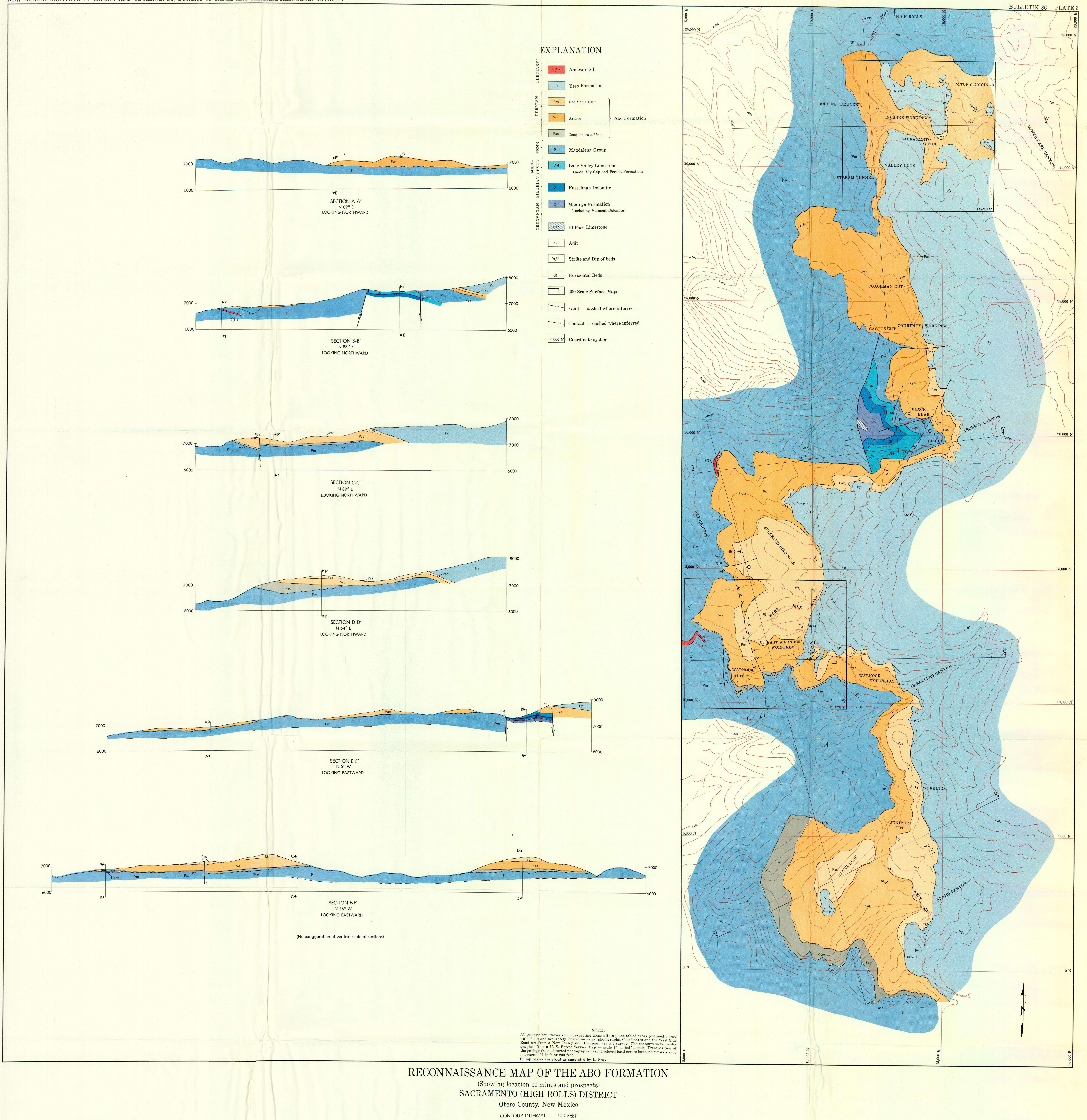
18. GEOLOGY AND ASSAY MAP - ADY AREA





RECONNAISSANCE MAP OF THE ABO FORMATION

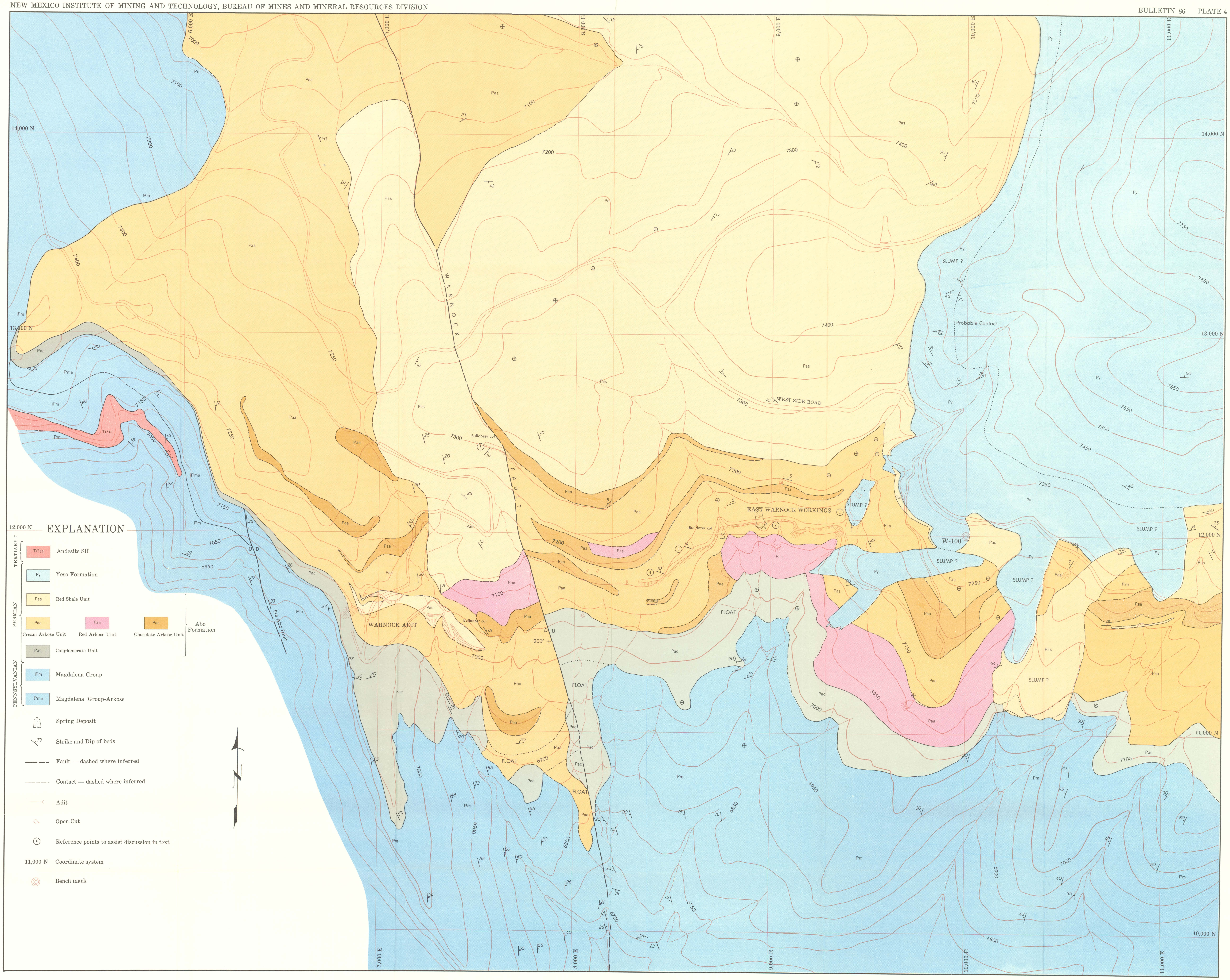
(Showing location of mines and prospects)

SACRAMENTO (HIGH ROLLS) DISTRICT

Otero County, New Mexico

CONTOUR INTERVAL 100 FEET

1200 0 1200 2400 3600 4800 Feet



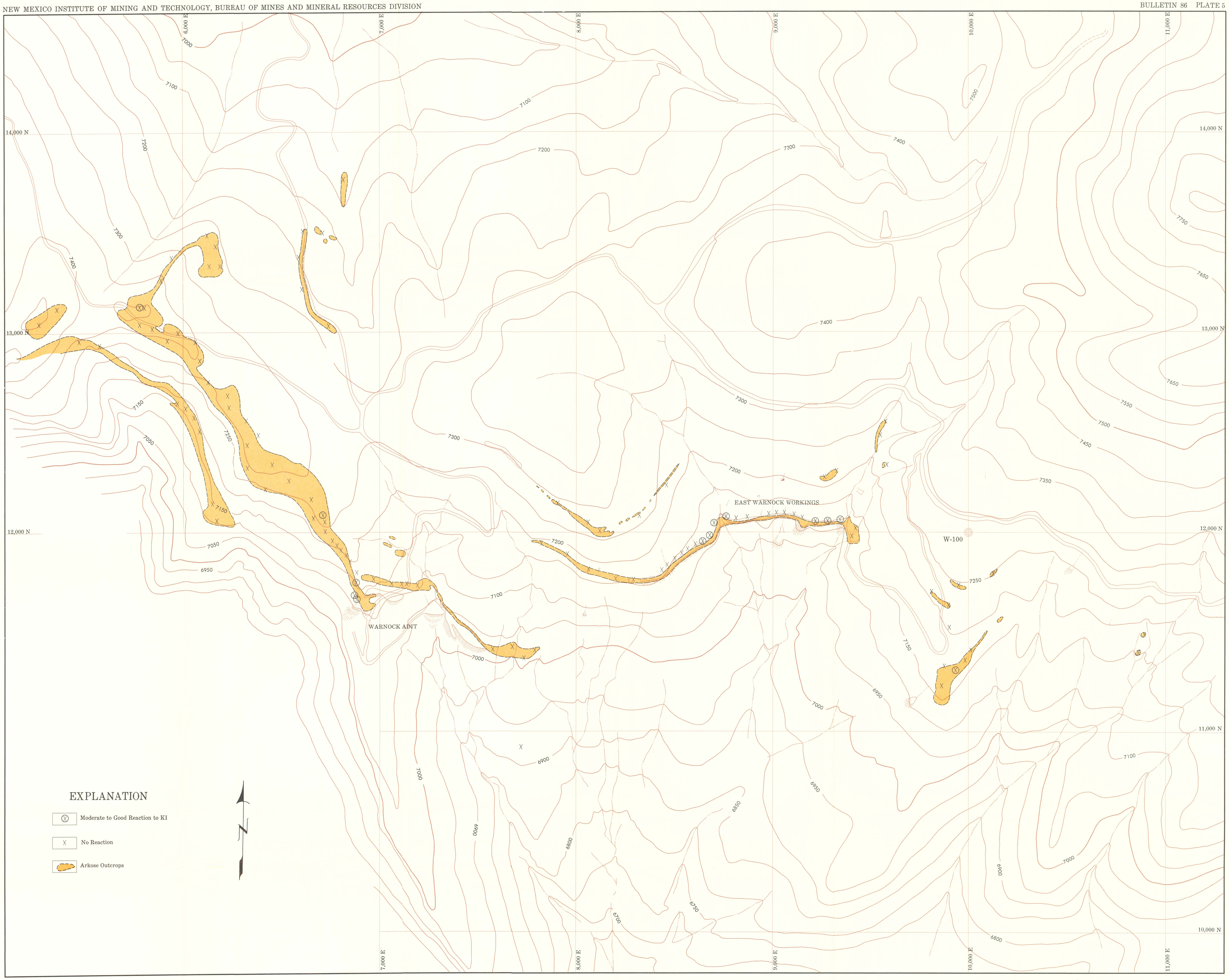
SURFACE GEOLOGY-WARNOCK AREA

SACRAMENTO (HIGH ROLLS) DISTRICT

Otero County, New Mexico

CONTOUR INTERVAL 50 FEET

200 0 200 400 600 800 Feet



RESULTS OF KI TESTING WARNOCK SURFACE AREA

SACRAMENTO (HIGH ROLLS) DISTRICT

Otero County, New Mexico

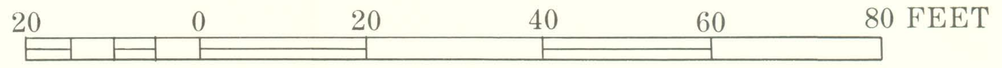
CONTOUR INTERVAL 50 FEET

200 0 200 400 600 800 Feet

ASSAY DATA

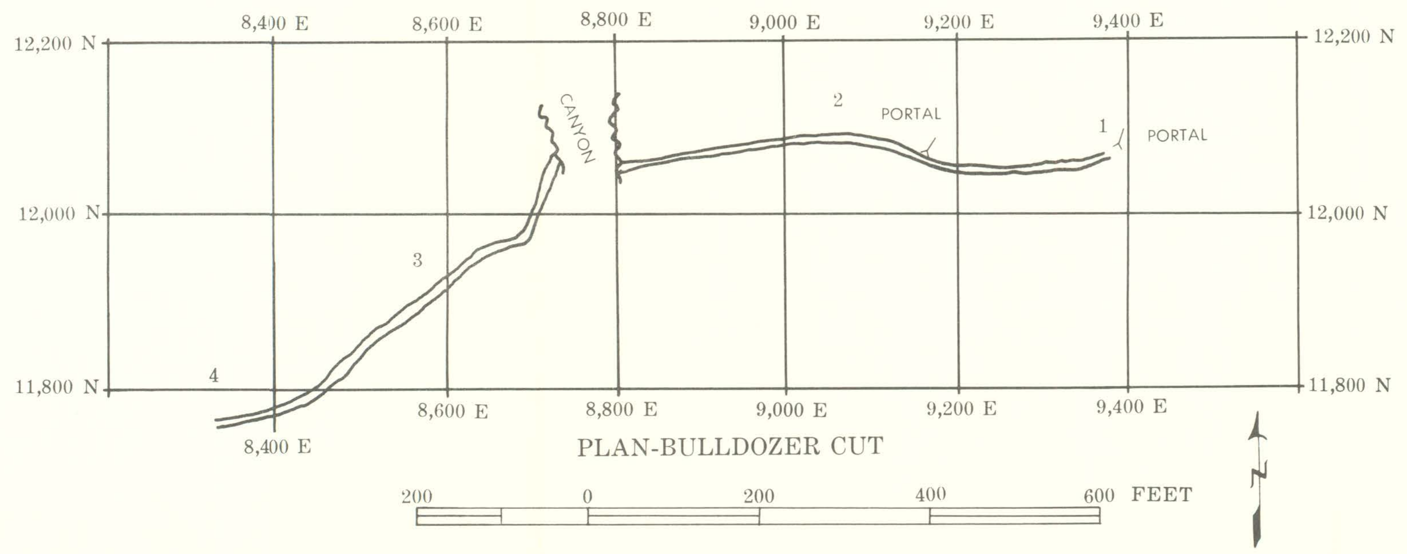
SAMPLE	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
412	Chip	Total	4.5'	0.05	NA	Tr.	0.05	Tr.
413	Comp. Chip	"	2'	0.05	"	0.10	0.32	"
414	Chip	"	3.5'	Tr.	"	0.10	0.46	"
415	Comp. Chip	"	2.5'	0.05	"	Tr.	0.32	0.06
416	Chip	Bottom	4'	0.12	"	Tr.	0.45	0.04
417	"	Total	5'	Tr.	"	0.15	0.62	Tr.
418	"	"	4'	0.10	"	0.10	0.80	0.06
419	"	Bottom	4'	0.15	"	0.10	0.11	0.06
420	"	Total	3.5'	0.10	"			
421	"	"	2'	0.10	"	Tr.	0.08	Tr.
422	"	"	3'	Tr.	"	0.10	0.04	"
423	Chip	Float Blocks	8'	Tr.	"	Tr.	0.04	Tr.
424	"	Top	4'	0.15	"	0.10	Tr.	"
425	"	Middle	5'	5.10	"	0.10	0.28	"

SECTION
BULLDOZER CUT
LOOKING NORTH



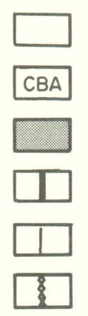
ASSAY DATA

SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
399A	Chip	Total	2'	14.70	NA	0.10	0.26	0.20
400	Comp. Chip	"	2'	17.10	"	0.15	0.19	0.26
401	Chip	"	2.5'	0.55	"	0.10	0.06	Tr.
402	"	"	6'	Tr.	"	Tr.	0.08	"
403	Comp. Chip	"	3'	0.22	"	0.10	0.09	0.06
404	Chip	"	4'	0.35	"	0.15	0.16	0.04
405	"	Bottom	2'	Tr.	"	0.15	0.08	Tr.
406	"	"	3'	0.10	"	0.10	0.09	NA
407	"	Horiz. along T.	6'	Tr.	"	0.15	0.68	0.08
408	"	Horiz. along B.	1.5'	"	"	0.15	0.08	Tr.
409	"	Bottom	3.5'	0.10	"	NA	NA	NA
410	"	Total	4'	0.10	"	0.15	0.14	Tr.
411	"	Bottom	4'	0.12	"	0.10	0.10	0.04



PLAN-BULLDOZER CUT

EXPLANATION

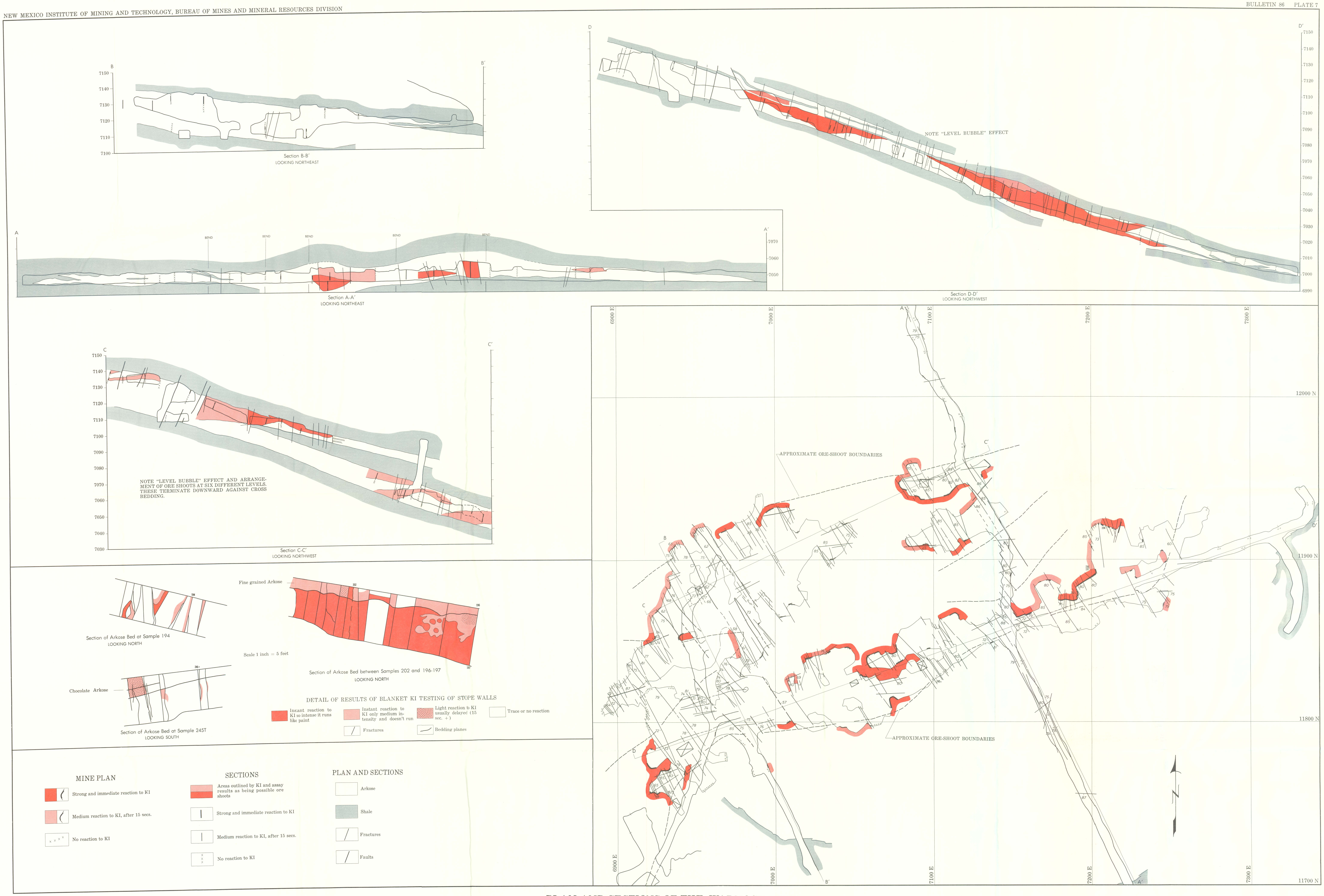


Cream Arkose
Chocolate Brown Arkose
Shale
KI Result—Strong-Medium
KI Result—Weak
KI Result—Negative

RESULTS OF SAMPLE AND KI TESTING-EAST WARNOCK BULLDOZER CUT

SACRAMENTO (HIGH ROLLS) DISTRICT

OTERO COUNTY, NEW MEXICO



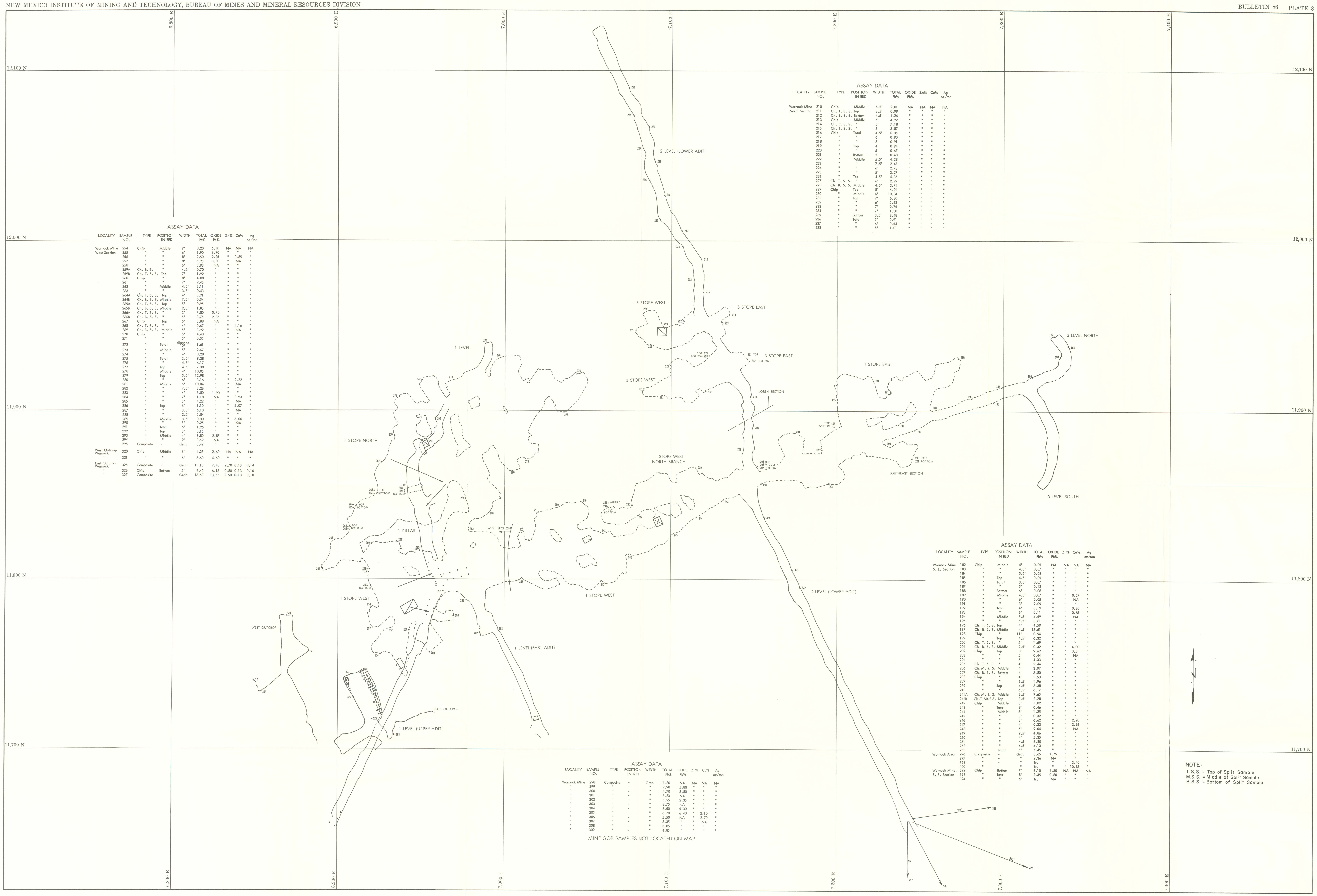
PLAN AND SECTIONS OF THE WARNOCK MINE

(SHOWING GEOLOGY AND GENERALIZED RESULTS OF SAMPLING AND TESTING WITH KI)

SACRAMENTO (HIGH ROLLS) DISTRICT

OTERO COUNTY, NEW MEXICO

20 0 20 40 60 80 FEET



ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Warnock Mine North Section	210	Chip	Middle	6.5'	2.01	NA	NA	NA	NA
	211	Ch. T. S. S.	Top	3.5'	0.99	"	"	"	"
	212	Ch. B. S. S.	Bottom	4.5'	4.26	"	"	"	"
	213	Chip	Middle	5'	4.92	"	"	"	"
	214	Ch. B. S. S.	"	5'	7.18	"	"	"	"
	215	Ch. T. S. S.	"	6'	3.87	"	"	"	"
	216	Chip	Total	4.5'	0.35	"	"	"	"
	217	"	"	6'	0.90	"	"	"	"
	218	"	"	6'	0.91	"	"	"	"
	219	"	Top	4'	0.94	"	"	"	"
	220	"	"	5'	0.67	"	"	"	"
	221	"	Bottom	5'	0.48	"	"	"	"
	222	"	Middle	5.5'	4.28	"	"	"	"
	223	"	"	7.5'	2.47	"	"	"	"
	224	"	"	6'	2.73	"	"	"	"
	225	"	"	5'	3.27	"	"	"	"
	226	"	Top	4.5'	4.36	"	"	"	"
	227	Ch. T. S. S.	"	6'	2.99	"	"	"	"
	228	Ch. B. S. S.	Middle	4.5'	3.71	"	"	"	"
	229	Chip	Top	8'	4.01	"	"	"	"
	230	"	Middle	6'	10.04	"	"	"	"
	231	"	Top	7'	6.30	"	"	"	"
	232	"	"	6'	5.62	"	"	"	"
	233	"	"	7'	2.75	"	"	"	"
	234	"	"	7'	1.30	"	"	"	"
	235	"	Bottom	3.5'	2.48	"	"	"	"
	236	"	Total	5'	0.91	"	"	"	"
	237	"	"	6'	0.54	"	"	"	"
	238	"	"	5'	1.01	"	"	"	"

ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Warnock Mine West Section	254	Chip	Middle	9'	8.20	6.10	NA	NA	NA
	255	"	"	6'	9.90	6.90	"	"	"
	256	"	"	8'	2.50	2.25	"	0.85	"
	257	"	"	8'	5.95	3.80	"	NA	"
	258	"	"	6'	5.93	NA	"	"	"
	259A	Ch. B. S.	"	4.5'	0.70	"	"	"	"
	259B	Ch. T. S. S.	Top	7'	1.92	"	"	"	"
	260	Chip	"	8'	4.88	"	"	"	"
	261	"	"	7'	2.45	"	"	"	"
	262	"	Middle	4.5'	3.11	"	"	"	"
	263	"	"	3.5"	0.43	"	"	"	"
	264A	Ch. T. S. S.	Top	4'	3.91	"	"	"	"
	264B	Ch. B. S. S.	Middle	7.5'	0.54	"	"	"	"
	265A	Ch. T. S. S.	Top	5'	0.95	"	"	"	"
	265B	Ch. B. S. S.	Middle	2.5'	1.85	"	"	"	"
	266A	Ch. T. S. S.	"	3'	7.80	0.70	"	"	"
	266B	Ch. B. S. S.	"	5'	3.75	2.35	"	"	"
	267	Chip	Top	6'	3.88	NA	"	"	"
	268	Ch. T. S. S.	"	4'	0.67	"	"	1.16	"
	269	Ch. B. S. S.	Middle	5'	3.92	"	"	NA	"
	270	Chip	"	5'	4.40	"	"	"	"
	271	"	"	5'	0.55	"	"	"	"
	272	"	Total	diagonal 12'	1.61	"	"	"	"
	273	"	Middle	5'	9.67	"	"	"	"
	274	"	"	4'	0.28	"	"	"	"
	275	"	Total	3.5'	9.28	"	"	"	"
	276	"	"	4.5'	6.17	"	"	"	"
	277	"	Top	4.5'	7.38	"	"	"	"
	278	"	Middle	4'	10.05	"	"	"	"
	279	"	Top	5.5'	12.98	"	"	"	"
	280	"	"	6'	3.16	"	"	2.22	"
	281	"	Middle	5'	10.04	"	"	NA	"
	282	"	"	7.5'	3.26	"	"	"	"
	283	"	"	4'	3.80	1.90	"	"	"
	284	"	"	7'	1.18	NA	"	0.93	"
	285	"	"	5'	4.22	"	"	NA	"
	286	"	Top	6'	1.10	"	"	2.07	"
	287	"	"	3.5'	6.10	"	"	NA	"
	288	"	"	2.5'	5.84	"	"	"	"
	289	"	Middle	3.5'	0.30	"	"	6.00	"
	290	"	"	5'	0.25	"	"	NA	"
	291	"	Total	6'	1.26	"	"	"	"
	292	"	Top	3'	0.15	"	"	"	"
	293	"	Middle	4'	3.80	2.85	"	"	"
	294	"	"	9'	0.59	NA	"	"	"
	295	Composite	-	Grab	3.42	"	"	"	"
West Outcrop Warnock	320	Chip	Middle	6'	4.25	2.60	NA	NA	NA
"	321	"	"	6'	6.60	4.60	"	"	"
East Outcrop Warnock	325	Composite	-	Grab	10.15	7.45	2.70	0.13	0.14
"	326	Chip	Bottom	5'	9.40	6.15	0.80	0.13	0.10
"	327	Composite	-	Grab	16.60	13.55	2.50	0.13	0.10

ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Warnock Mine S. E. Section	182	Chip	Middle	4'	0.05	NA	NA	NA	NA
	183	"	"	4.5'	0.07	"	"	"	"
	184	"	"	5.5'	0.08	"	"	"	"
	185	"	Top	4.5'	0.05	"	"	"	"
	186	"	Total	3.5'	0.07	"	"	"	"
	187	"	"	5'	0.12	"	"	"	"
	188	"	Bottom	6'	0.08	"	"	"	"
	189	"	Middle	4.5'	0.07	"	"	0.57	"
	190	"	"	6'	0.05	"	"	NA	"
	191	"	"	3'	9.05	"	"	"	"
	192	"	Total	4'	0.19	"	"	0.30	"
	193	"	"	6'	0.11	"	"	0.65	"
	194	"	Middle	5.5'	4.59	"	"	NA	"
	195	"	"	5.5'	3.81	"	"	"	"
	196	Ch. T. S. S.	Top	4'	4.59	"	"	"	"
	197	Ch. B. S. S.	Middle	4.5'	13.61	"	"	"	"
	198	Chip	"	11'	0.54	"	"	"	"
	199	"	Top	4.5'	6.32	"	"	"	"
	200	Ch. T. S. S.	"	5'	1.69	"	"	"	"
	201	Ch. B. S. S.	Middle	2.5'	0.32	"	"	4.00	"
	202	Chip	Top	8'	9.69	"	"	0.51	"
	203	"	"	5'	0.44	"	"	NA	"
	204	"	"	6'	4.33	"	"	"	"
	205	Ch. T. S. S.	"	4'	2.44	"	"	"	"
	206	Ch. M. S. S.	Middle	4'	3.97	"	"	"	"
	207	Ch. B. S. S.	Bottom	4'	3.80	"	"	"	"
	208	Chip	"	4'	1.53	"	"	"	"
	209	"	"	6.5'	1.96	"	"	"	"
	239	"	Top	4.5'	3.38	"	"	"	"
	240	"	"	6.5'	6.17	"	"	"	"
	241A	Ch. M. S. S.	Middle	2.5'	9.65	"	"	"	"
	241B	Ch. T. &B. S. S.	Top	3.5'	2.28	"	"	"	"
	242	Chip	Middle	5'	1.82	"	"	"	"
	243	"	Total	8'	0.46	"	"	"	"
	244	"	Middle	5'	1.25	"	"	"	"
	245	"	"	3'	0.32	"	"	"	"
	246	"	"	3'	6.62	"	"	2.20	"
	247	"	"	4'	0.33	"	"	2.26	"
	248	"	"	5'	9.04	"	"	NA	"
	249	"	"	2.5'	4.86	"	"	"	"
	250	"	"	4'	5.35	"	"	"	"
	251	"	"	4.5'	6.80	"	"	"	"
	252	"	"	4.5'	4.13	"	"	"	"
	253	"	Total	5'	7.45	"	"	"	"
Warnock Area	296	Composite	-	Grab	3.65	1.75	"	"	"
	297	"	-	"	2.36	NA	"	"	"
	328	"	-	"	Tr.	"	"	3.40	"
	329	"	-	"	Tr.	"	"	10.15	"
Warnock Mine, S. E. Section	322	Chip	Bottom	7'	3.10	1.30	NA	NA	NA
	323	"	Total	8'	2.35	0.80	"	"	"
	324	"	"	6'	Tr.	NA	"	"	"

ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Warnock Mine	298	Composite	-	Grab	7.80	NA	NA	NA	NA
"	299	"	-	"	9.90	5.80	"	"	"
"	300	"	-	"	4.70	3.80	"	"	"
"	301	"	-	"	3.83	NA	"	"	"
"	302	"	-	"	5.55	2.35	"	"	"
"	303	"	-	"	3.75	NA	"	"	"
"	304	"	-	"	6.50	5.30	"	"	"
"	305	"	-	"	6.70	6.40	"	2.10	"
"	306	"	-	"	5.50	NA	"	2.70	"
"	307	"	-	"	3.35	"	"	NA	"
"	308	"	-	"	3.86	"	"	"	"
"	309	"	-	"	4.85	"	"	"	"

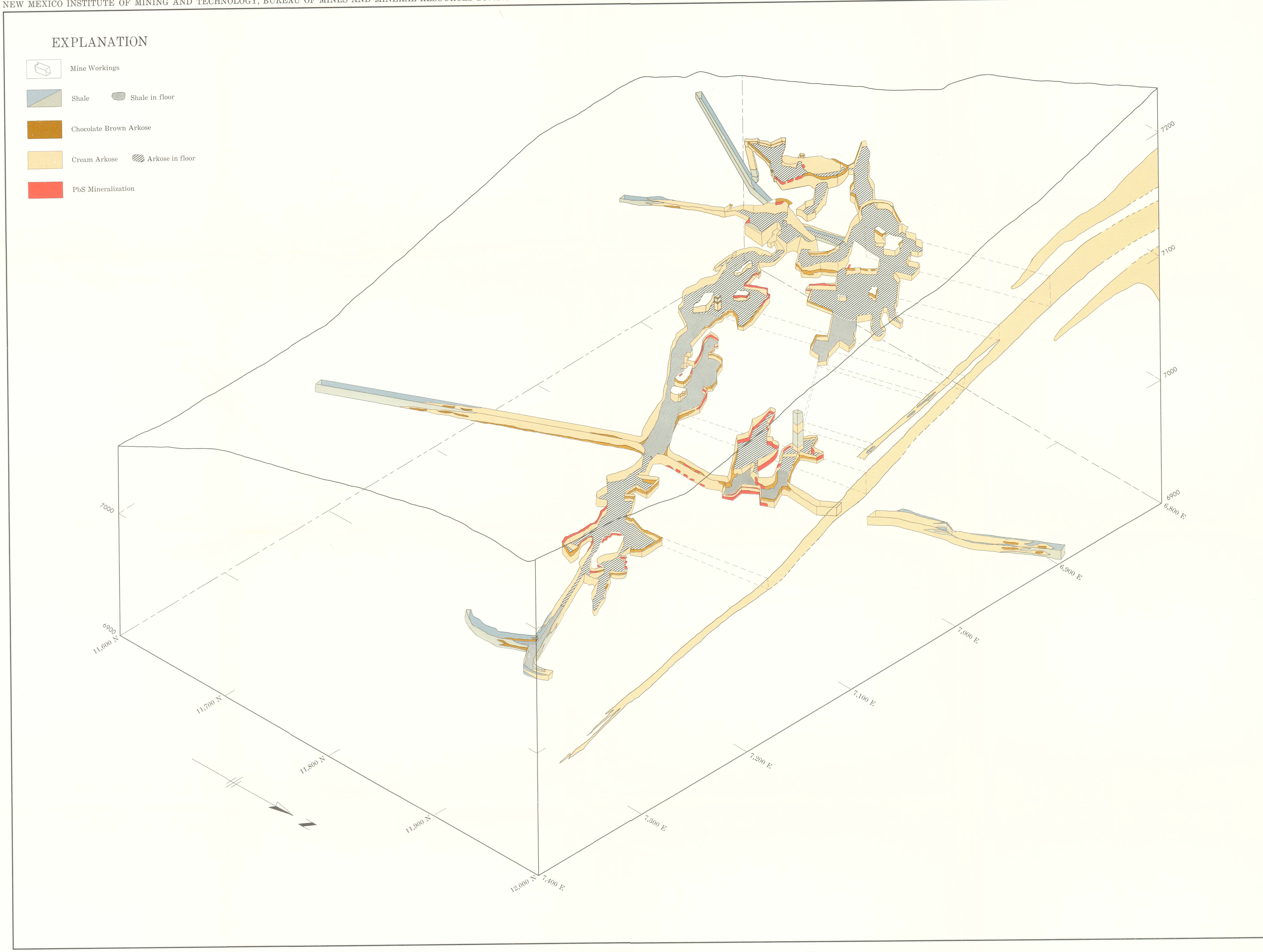
MINE GOB SAMPLES NOT LOCATED ON MAP

NOTE:
T. S. S. = Top of Split Sample
M. S. S. = Middle of Split Sample
B. S. S. = Bottom of Split Sample

THE NEW JERSEY ZINC COMPANY, THE NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, AND THE WRITERS ASSUME NO RESPONSIBILITY FOR THE ACCURACY OF THE ASSAY DATA.

ASSAY MAP-WARNOCK MINE
SACRAMENTO (HIGH ROLLS) DISTRICT
OTERO COUNTY, NEW MEXICO

20 0 20 40 60 80 FEET



BLOCK DIAGRAM OF THE WARNOCK MINE

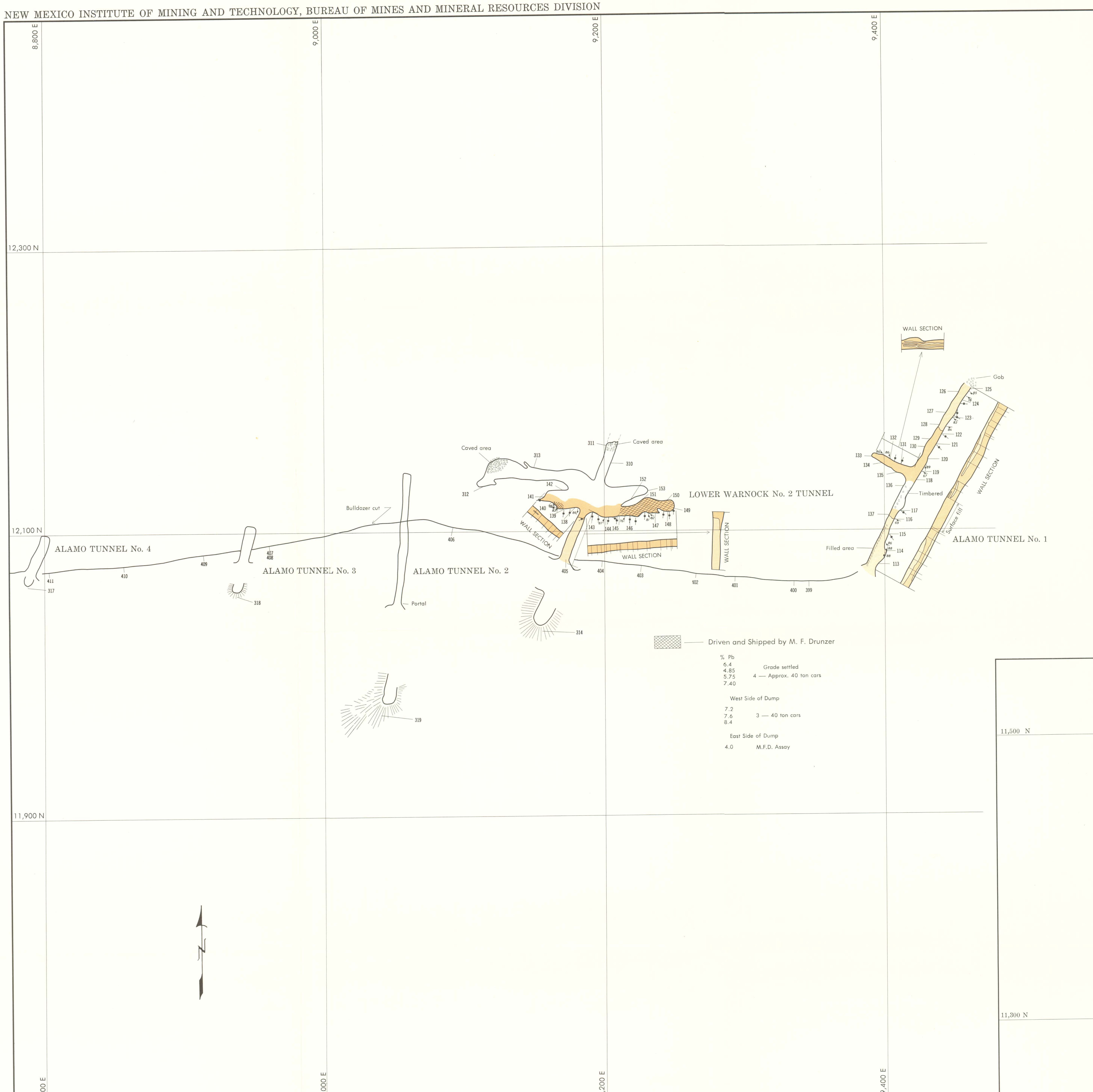
(Showing geological relationships and distribution of visible galena)

SACRAMENTO (HIGH ROLLS) DISTRICT

Otero County, New Mexico

40 0 40 80 120 160 FEET

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY, BUREAU OF MINES AND MINERAL RESOURCES DIVISION



ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Alamo Tunnel, #1	113	Chip	Middle	3'	1.31	NA	NA	0.05	NA
"	114	"	Top	3'	0.16	"	"	Nil	"
"	115	"	Bottom	3.5'	0.27	"	"	"	"
"	116	"	"	5'	0.64	"	"	"	"
"	117	"	Middle	6'	3.28	0.80	0.30	0.05	"
"	118	"	"	6'	2.62	1.58	0.80	0.05	"
"	119	"	"	6.5'	1.58	NA	NA	Nil	"
"	120	"	"	6'	1.73	"	"	"	"
"	121	"	"	6'	0.62	"	"	"	"
"	122	"	"	6'	0.22	"	"	"	"
"	123	"	"	6'	0.89	"	"	NA	"
"	124	"	Bottom	6'	1.15	"	"	"	"
"	125	"	"	6'	1.25	"	"	"	"
"	126	"	Middle	6.5'	0.04	"	"	"	"
"	127	"	Bottom	6.5'	1.56	"	"	"	"
"	128	"	"	6'	0.80	"	"	"	"
"	129	"	Middle	6'	0.62	"	"	"	"
"	130	"	"	6'	1.27	"	"	"	"
"	131	"	"	5'	1.18	"	"	"	"
"	132	"	"	8'	0.92	"	"	"	"
"	133	"	"	7'	0.72	"	"	"	"
"	134	"	"	7'	0.99	"	"	"	"
"	135	"	"	6'	4.31	"	"	"	"
"	136	"	"	5.5'	2.78	2.16	1.40	"	"
"	137	"	Top	5'	0.36	NA	NA	"	"
Lower Warnock, #2	138	"	Total	4'	5.45	"	"	"	"
"	139	"	"	4'	1.88	"	"	"	"
"	140	"	"	4.5'	3.57	1.35	0.10	"	"
"	141	"	"	4.5'	3.73	1.72	0.10	"	"
"	142	"	"	4.5'	2.98	2.18	0.20	"	"
"	143	"	"	4'	4.51	NA	NA	NA	NA
"	144	"	"	4'	0.25	"	"	"	"
"	145	"	"	4'	1.32	"	"	"	"
"	146	"	"	3.5'	3.91	2.58	0.30	"	"
"	147	"	"	3.5'	4.82	NA	NA	"	"
"	148	"	"	3.5'	2.47	"	"	"	"
"	149	"	"	3'	5.70	2.57	0.10	"	"
"	150	"	"	3.5'	1.86	NA	NA	"	"
"	151	"	"	3.5'	8.30	3.40	0.10	"	0.10
"	152	"	"	4'	6.19	NA	NA	"	NA
"	153	"	"	4'	5.34	"	"	"	"
"	310	"	"	5.5'	0.67	"	"	"	"
"	311	"	"	5.5'	0.88	"	"	"	"
"	312	"	"	4'	6.15	3.55	"	0.13	"
"	313	"	Middle	4.5'	2.10	1.00	1.75	0.10	"
Lower Warnock, #2 Dump	314	Composite Grab	-	Dump	3.75	2.90	NA	0.60	"
Alamo Tunnel, #4 Dump	317	"	-	"	Tr.	NA	"	0.10	"
Alamo Tunnel, #3 Dump	318	"	-	"	Nil	"	"	0.08	"
Alamo Tunnel, #2 Dump	319	"	-	"	"	"	"	0.08	"
Bulldozer Cut	399A	Chip	Total	2'	14.70	"	0.10	0.26	0.20
"	400	Comp. Chip	"	2'	17.10	"	0.15	0.19	0.26
"	401	Chip	"	2.5'	0.55	"	0.10	0.06	Tr.
"	402	"	"	6'	Tr.	"	Tr.	0.08	"
"	403	Comp.Chip	"	3'	0.22	"	0.10	0.09	0.06
"	404	Chip	"	4'	0.35	"	0.15	0.16	0.04
"	405	"	Bottom	2'	Tr.	"	0.15	0.08	Tr.
"	406	"	"	3'	0.10	"	0.10	0.09	NA
"	407	"	Horiz. along T.	6'	Tr.	"	0.15	0.68	0.08
"	408	"	Horiz. along B.	1.5'	"	"	0.15	0.08	Tr.
"	409	"	Bottom	3.5'	0.10	"	NA	NA	NA
"	410	"	Total	4'	0.10	"	0.15	0.14	Tr.
"	411	"	Bottom	4'	0.12	"	0.10	0.10	0.04

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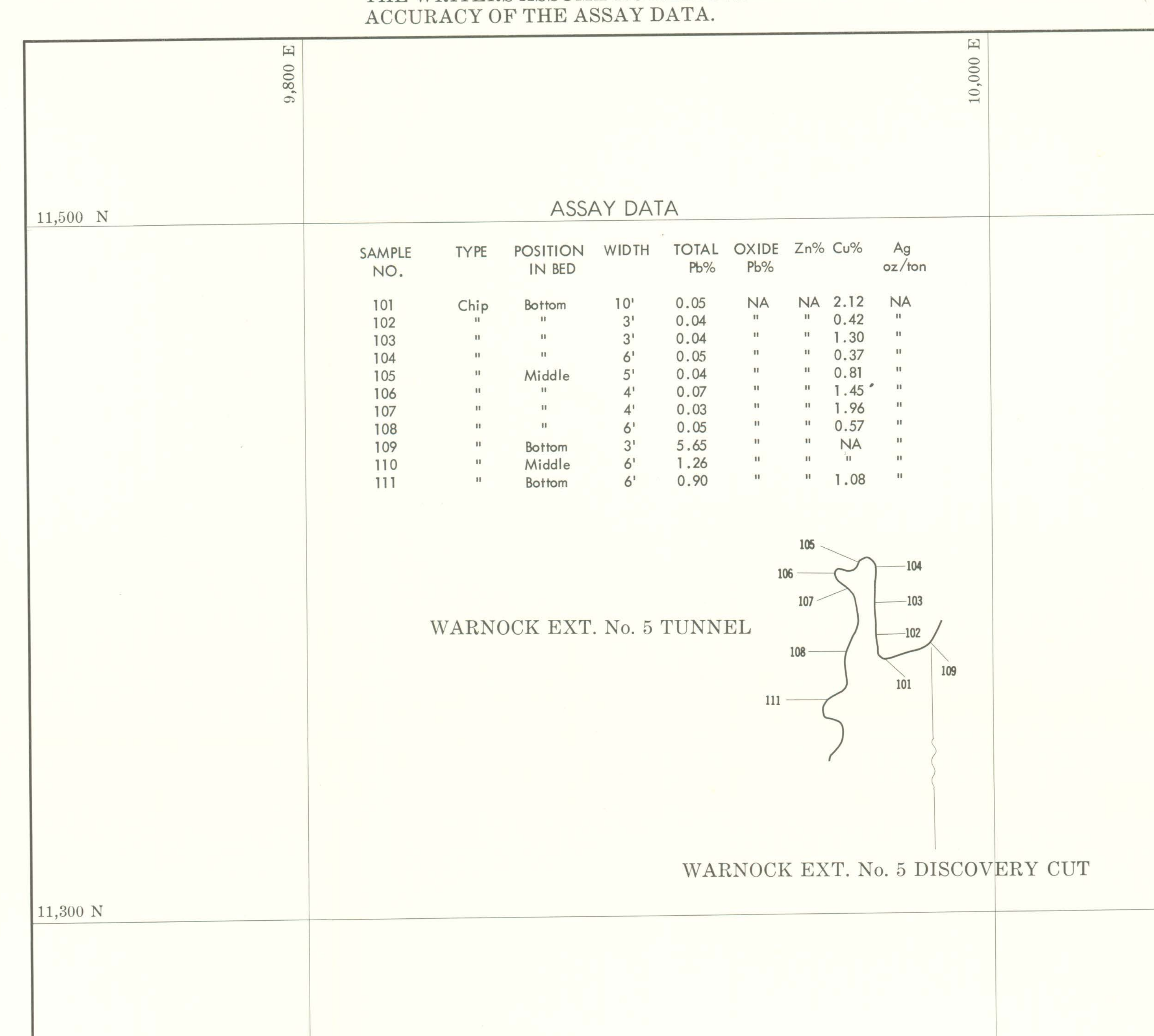
ASSAY DATA

SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
101	Chip	Bottom	10'	0.05	NA	NA	2.12	NA
102	"	"	3'	0.04	"	"	0.42	"
103	"	"	3'	0.04	"	"	1.30	"
104	"	"	6'	0.05	"	"	0.37	"
105	"	Middle	5'	0.04	"	"	0.81	"
106	"	"	4'	0.07	"	"	1.45	"
107	"	"	4'	0.03	"	"	1.96	"
108	"	"	6'	0.05	"	"	0.57	"
109	"	Bottom	3'	5.65	"	"	NA	"
110	"	Middle	6'	1.26	"	"	"	"
111	"	Bottom	6'	0.90	"	"	1.08	"



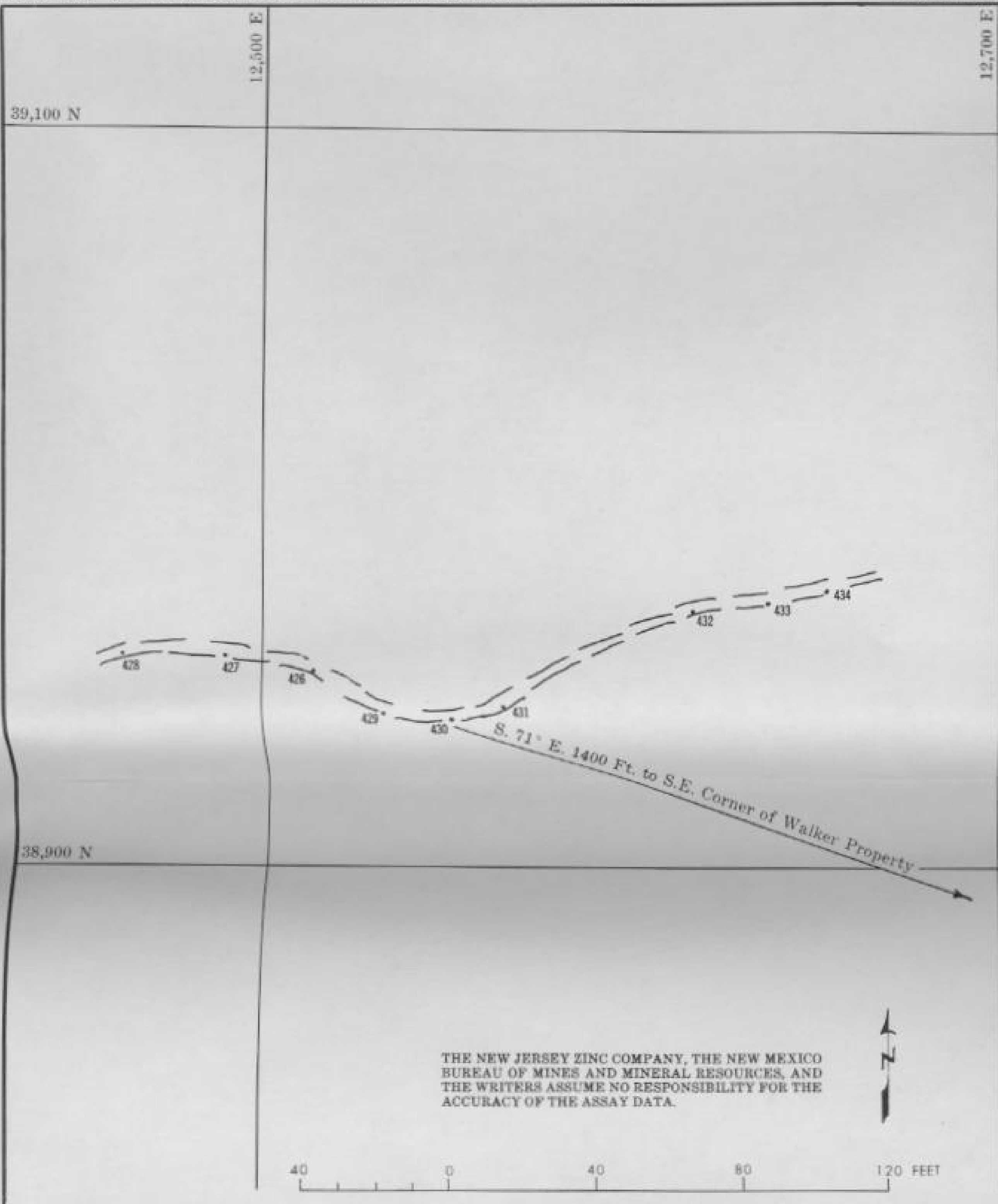
INSERT

GEOLOGY AND ASSAY MAP-EAST WARNOCK AREA

SACRAMENTO (HIGH ROLLS) DISTRICT

Otero County, New Mexico

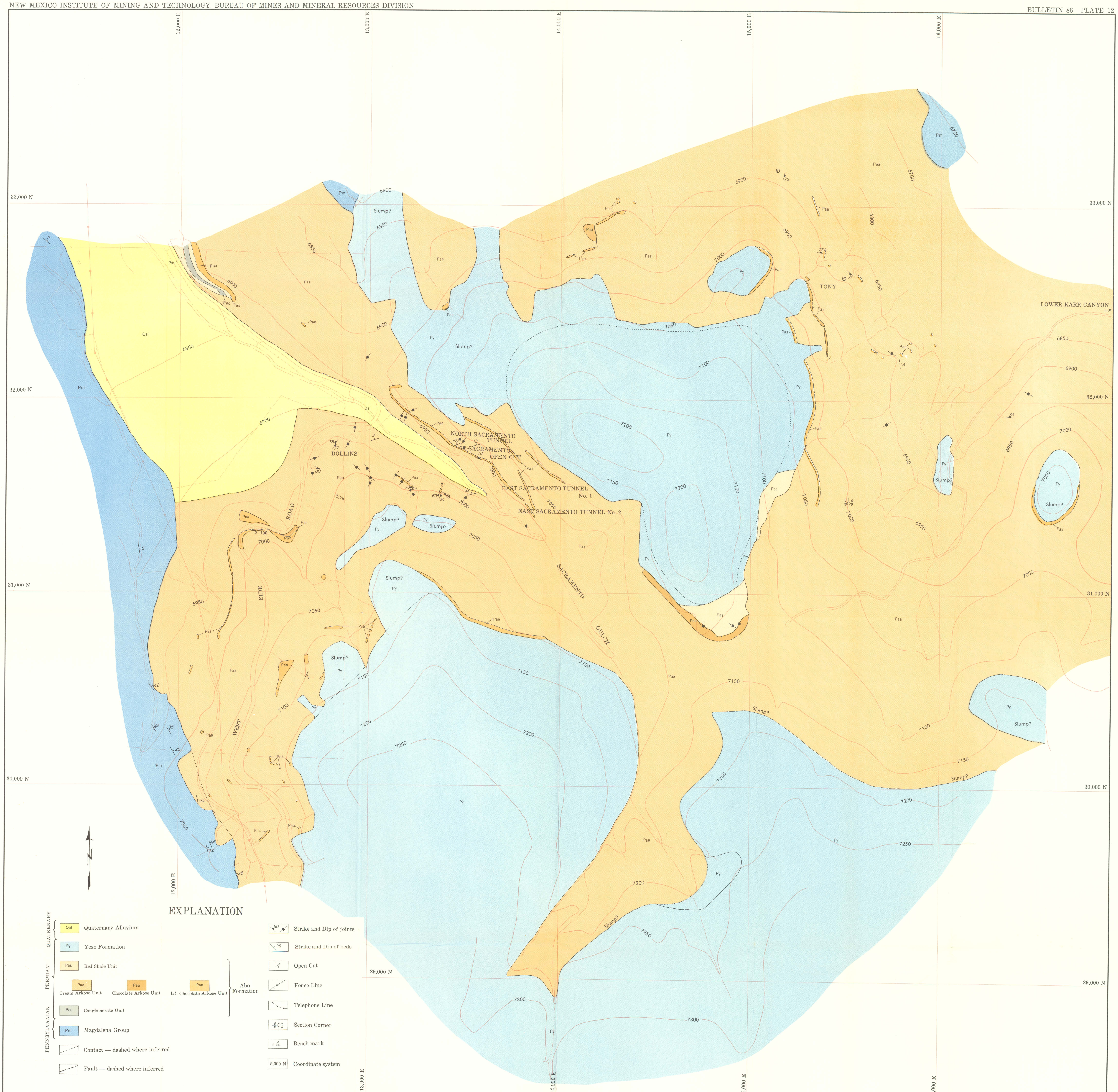
40 0 40 80 120 160 FEET



ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Red Hill	426	Chip	-	Float Blocks	1.00	NA	11.25	0.08	0.06
"	427	"	Middle	4'	0.10	"	0.10	0.05	Tr.
"	428	Composite Chip	"	2'	Tr.	"	0.10	0.06	"
"	429	Chip	"	7'	2.10	"	6.30	0.10	0.06
"	430	"	"	8.5'	1.20	"	4.50	0.08	0.04
"	431	"	"	6'	0.70	"	5.65	0.04	0.06
"	432	"	"	5'		SAMPLE	LOST		
"	433	"	"	4'	Tr.	NA	0.10	Tr.	Tr.
"	434	"	"	3'	"	"	0.10	0.05	"

ASSAY MAP
RED HILLS AREA
SACRAMENTO DISTRICT
(HIGH ROLLS)
Otero County, New Mexico

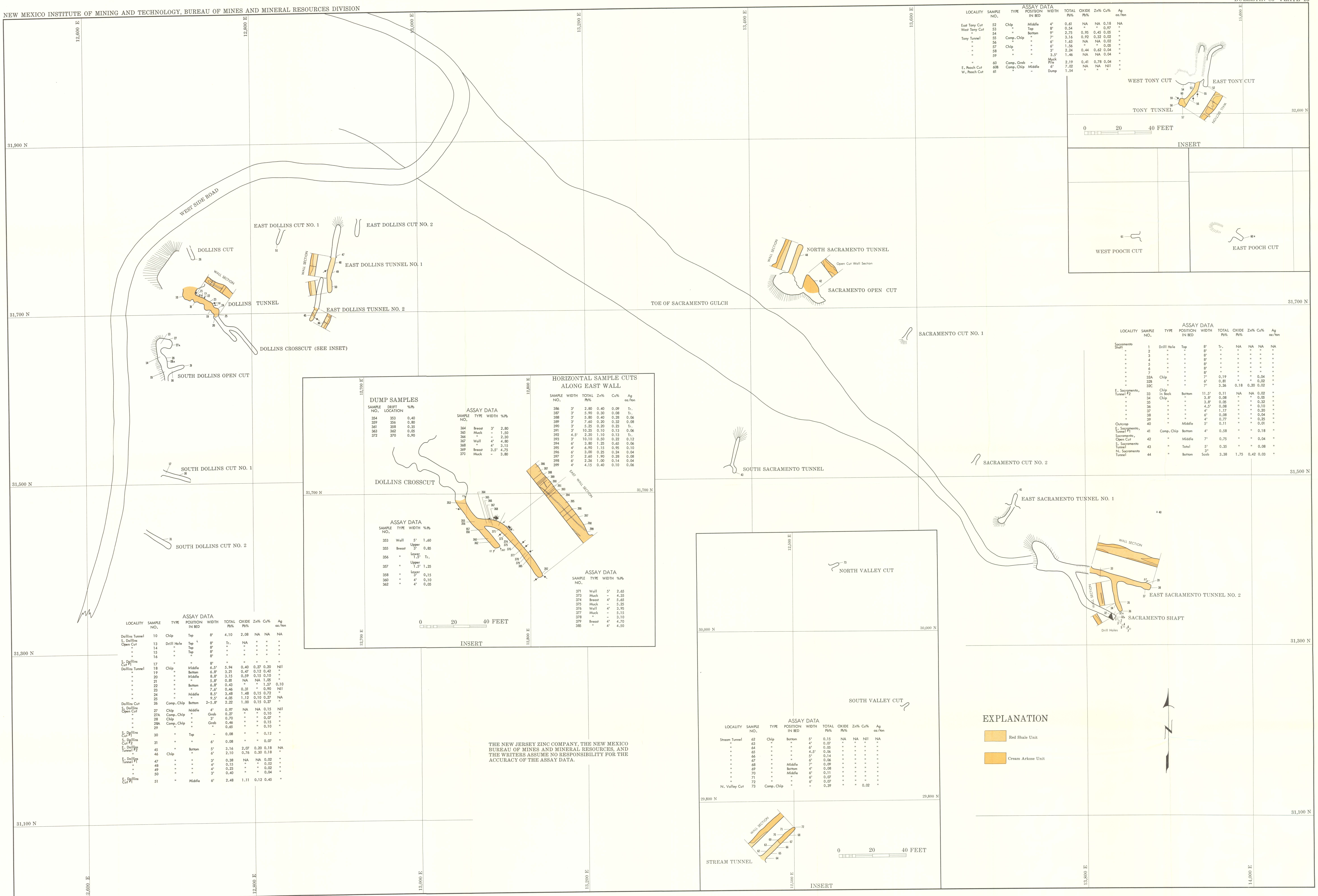


SURFACE GEOLOGY-SACRAMENTO GULCH AREA
SACRAMENTO (HIGH ROLLS) DISTRICT
Otero County, New Mexico

CONTOUR INTERVAL 50 FEET

200 0 200 400 600 800 Feet

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY, BUREAU OF MINES AND MINERAL RESOURCES DIVISION

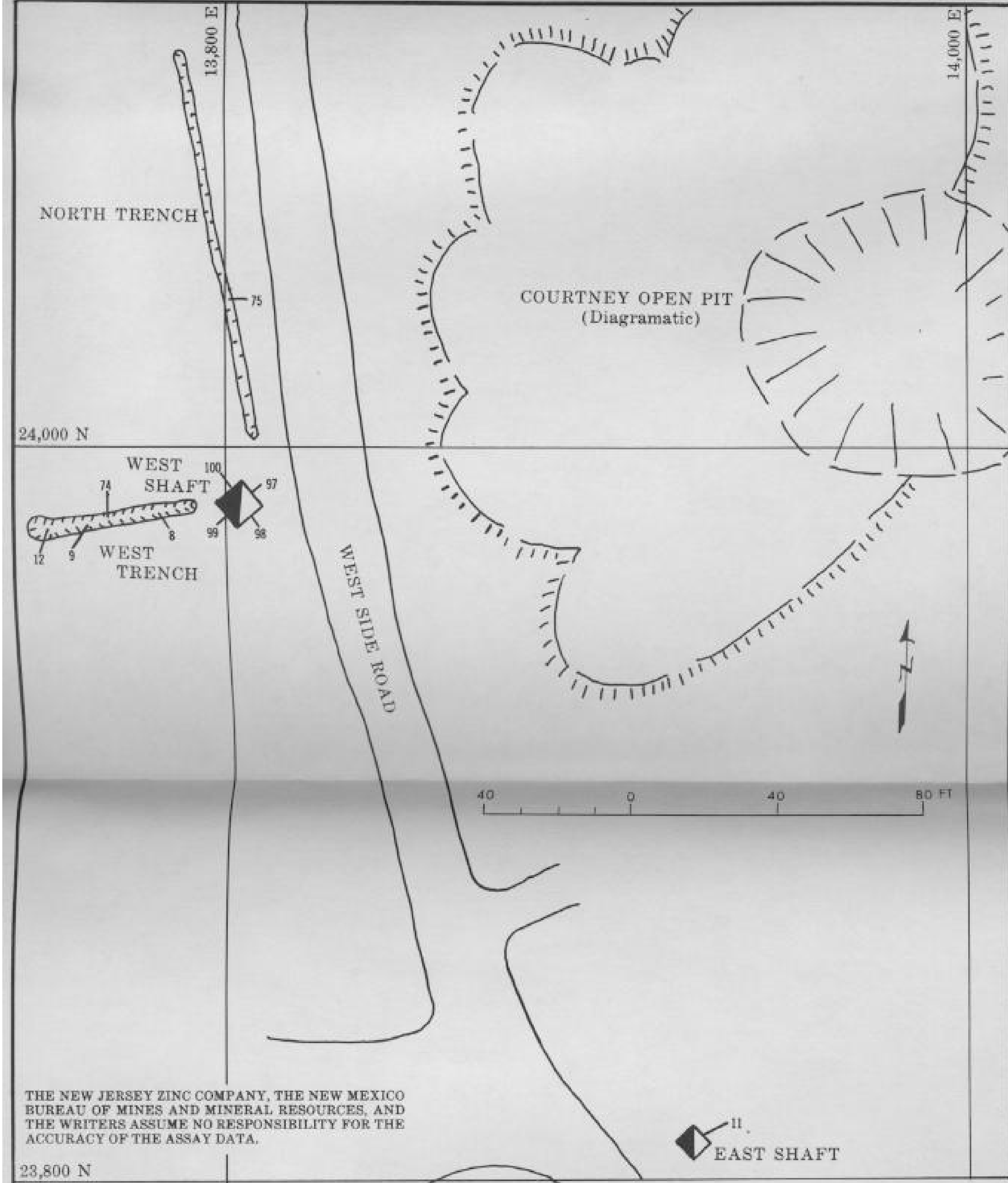


GEOLOGY AND ASSAY MAP-SACRAMENTO GULCH AREA

SACRAMENTO (HIGH ROLLS) DISTRICT

Otero County, New Mexico

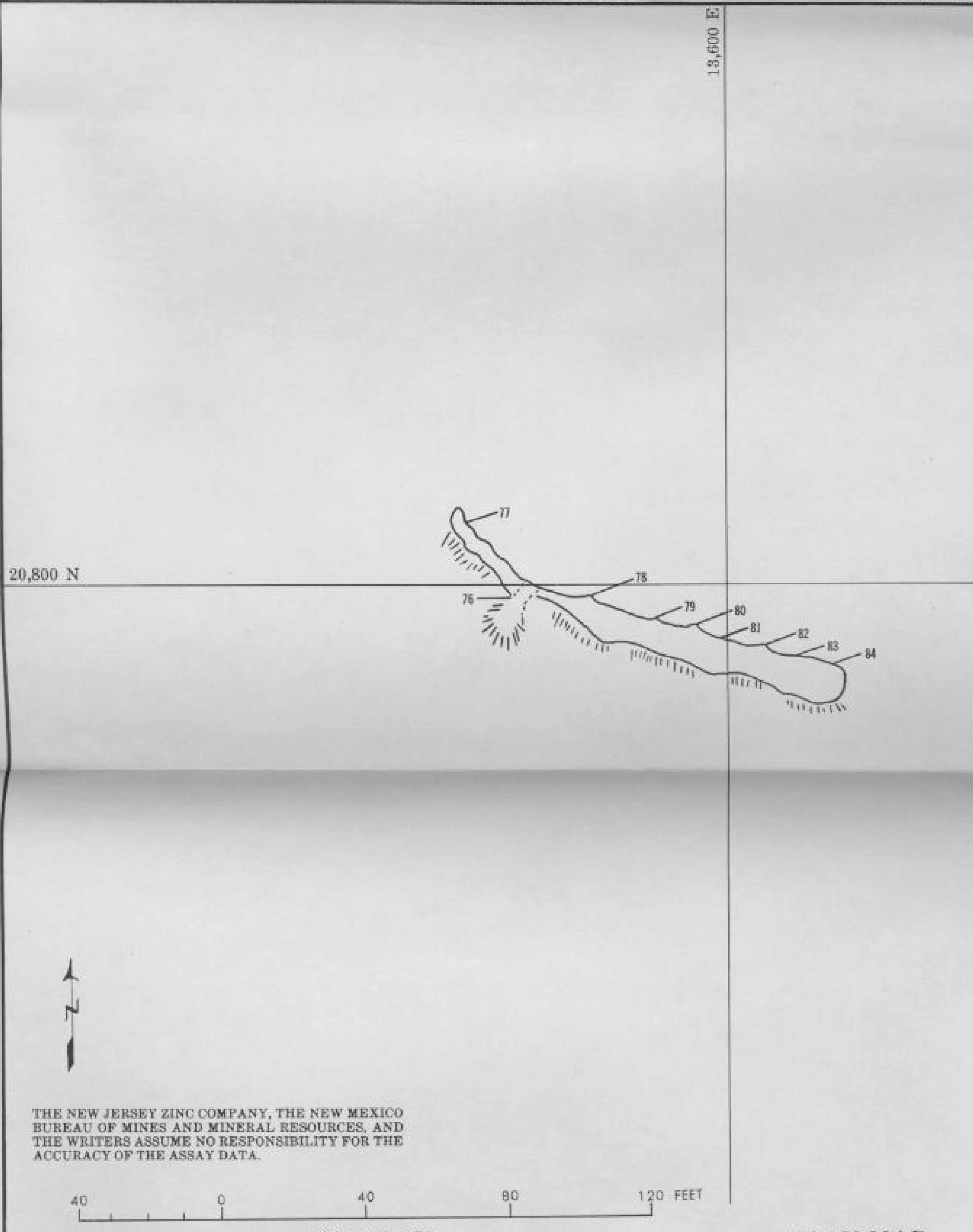
40 0 40 80 120 160 FEET



ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
West Trench	8	Drill Hole	Top	8'	Tr.	NA	NA	NA	Na
"	9	"	"	"	"	"	"	"	"
East Shaft	11	Chip	"	8.5'	"	"	"	"	"
West Trench	12	Drill Hole	"	8'	Tr.	"	"	"	"
"	74	Composite Chip	"	4'	0.05	"	"	Nil	"
North Trench	75	"	"	2'	0.30	"	"	"	"
West Shaft	97	Chip	Total	5'	0.36	"	"	"	"
"	98	"	"	12'	0.61	"	"	"	"
"	99	"	"	12'	0.50	"	"	"	"
"	100	"	"	12'	0.34	"	"	"	"

ASSAY MAP
COURTNEY AREA
SACRAMENTO DISTRICT
(HIGH ROLLS)
Otero County, New Mexico



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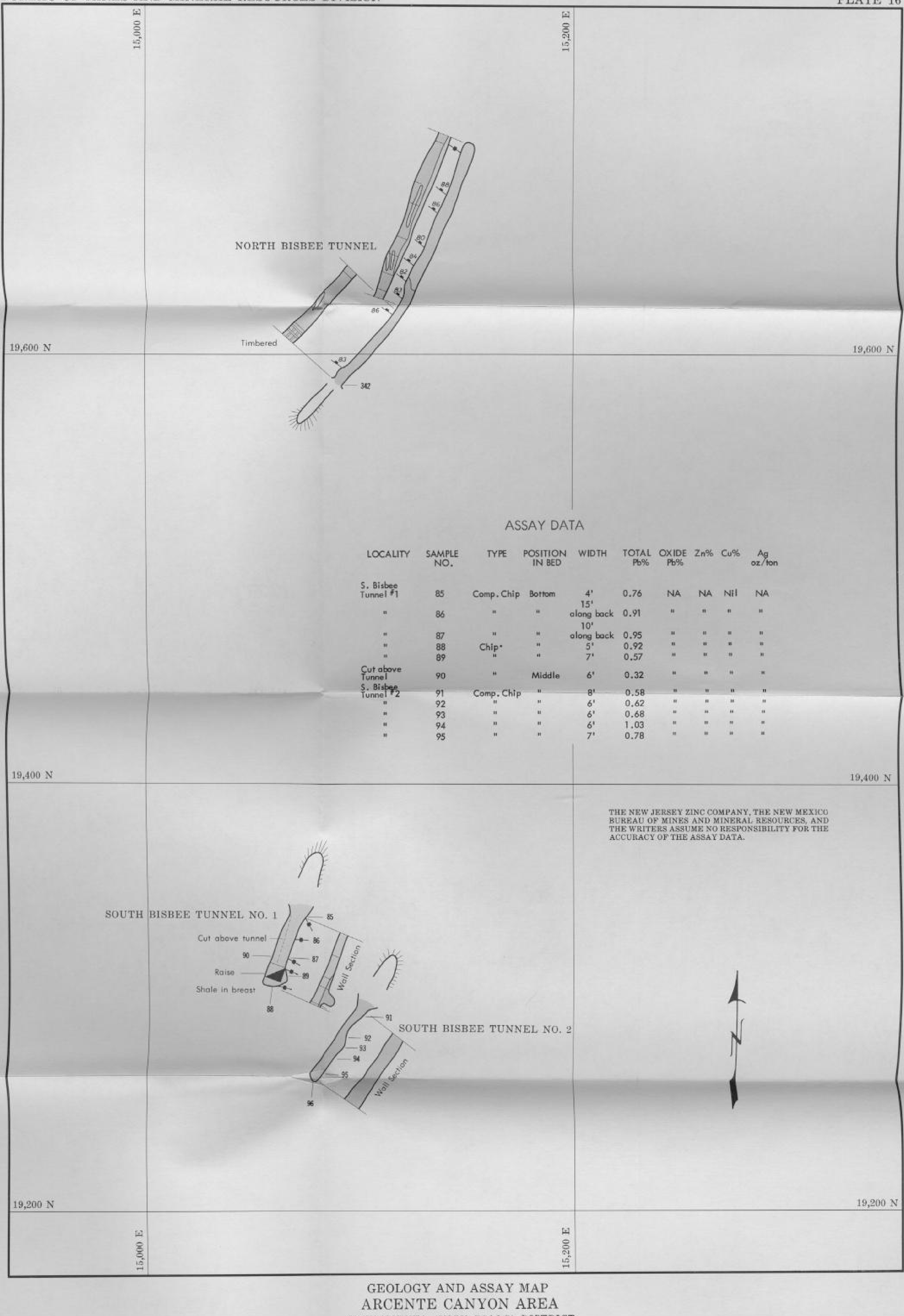
ASSAY MAP
BLACK BEAR
SACRAMENTO DISTRICT
(HIGH ROLLS)
Otero County, New Mexico

ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Open Cut	76	Composite Chip	Middle	5'	1.10	NA	NA	NIL	NA
"	77	Chip	"	5'	0.12	"	"	"	"
"	78	"	"	7'	0.40	"	"	"	"
"	79	"	"	10'	0.55	"	"	"	"
"	80	"	"	12'	0.62	"	"	"	"
"	81	"	"	10'	0.35	"	"	"	"
"	82	"	"	7'	0.51	"	"	"	"
"	83	"	"	5'	0.51	"	"	"	"
"	84	"	"	5'	0.46	"	"	"	"



ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
S. Bisbee Tunnel #1	85	Comp. Chip	Bottom	4'	0.76	NA	NA	Nil	NA
"	86	"	"	15' along back	0.91	"	"	"	"
"	87	"	"	10' along back	0.95	"	"	"	"
"	88	Chip*	"	5'	0.92	"	"	"	"
"	89	"	"	7'	0.57	"	"	"	"
Cut above Tunnel	90	"	Middle	6'	0.32	"	"	"	"
S. Bisbee Tunnel #2	91	Comp. Chip	"	8'	0.58	"	"	"	"
"	92	"	"	6'	0.62	"	"	"	"
"	93	"	"	6'	0.68	"	"	"	"
"	94	"	"	6'	1.03	"	"	"	"
"	95	"	"	7'	0.78	"	"	"	"

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GEOLOGY AND ASSAY MAP
ARCENTE CANYON AREA
SACRAMENTO (HIGH ROLLS) DISTRICT
Otero County, New Mexico

40 0 40 80 120 160 FEET

ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Tunnel No. 1	315	Chip	Bottom	6'	1.30	NA	0.75	NA	NA
"	316	"	Total	6'	3.05	0.50	0.45	0.05	NA
Cut	332	Composite	-	Float	7.40	1.15	NA	0.13	NA
War. Ext. #3 Placer	333	"	-	"	3.65	1.00	0.60	0.08	NA
War. Ext. #4 Placer	334	"	-	"	3.45	3.10	0.10	1.30	NA

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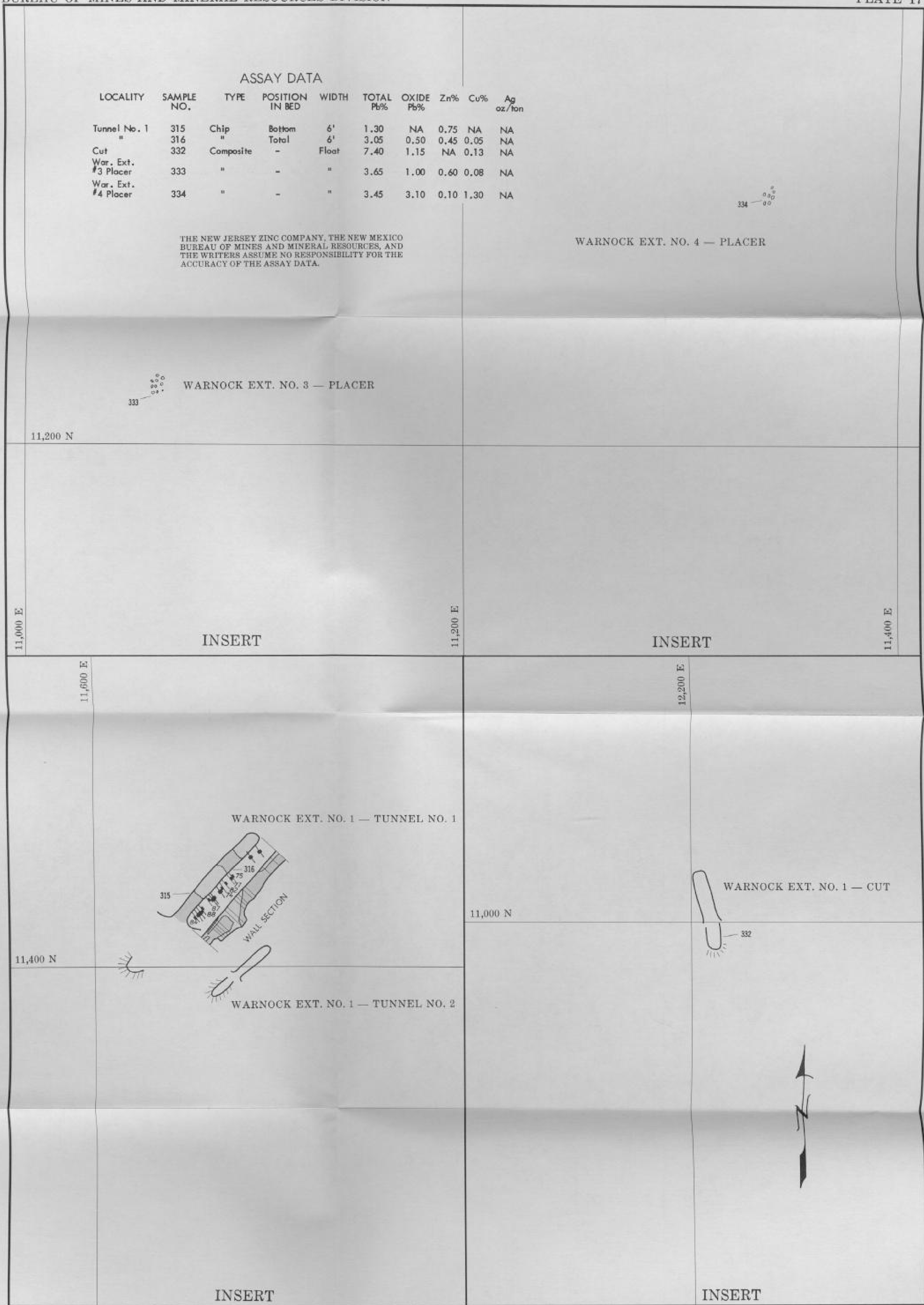
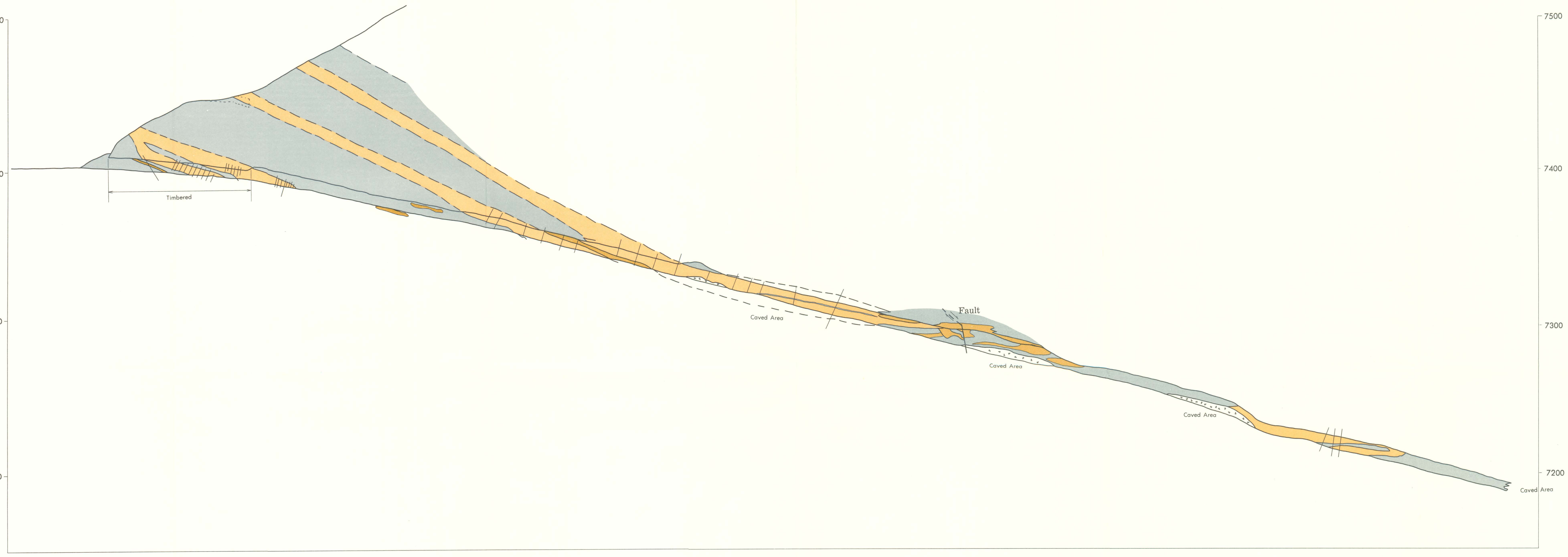
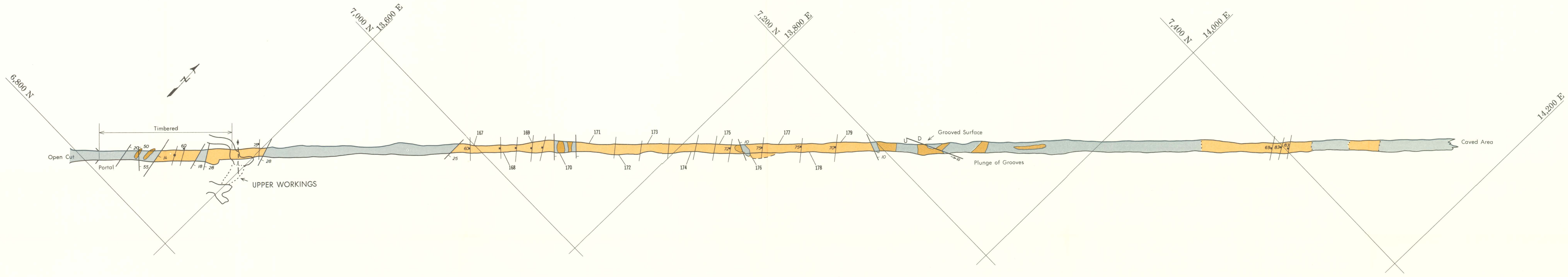


GEOLOGY AND ASSAY MAP
WARNOCK EXTENSION AREA
SACRAMENTO (HIGH ROLLS) DISTRICT
Otero County, New Mexico

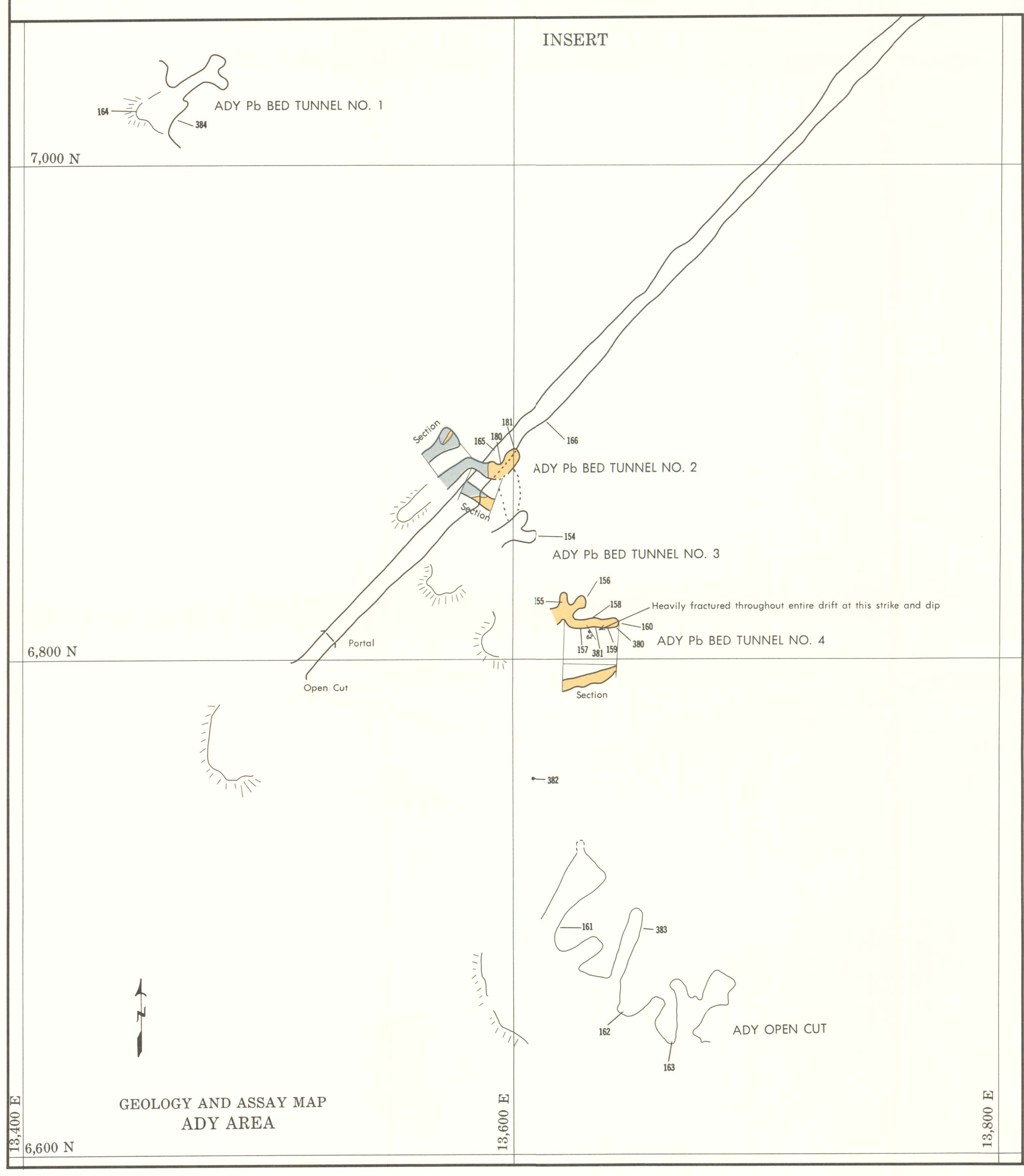
40 0 40 80 120 160 FEET



SECTION
LOOKING NORTHWEST



UNDERGROUND PLAN
ADY INCLINE



GEOLOGY AND ASSAY MAP
ADY AREA

EXPLANATION

- Red Shale Unit
- Cream Arkose Unit
- Chocolate Arkose Unit

ASSAY DATA

LOCALITY	SAMPLE NO.	TYPE	POSITION IN BED	WIDTH	TOTAL Pb%	OXIDE Pb%	Zn%	Cu%	Ag oz/ton
Ady Pb Bed, Tunnel #3	154	Comp. Chip	Middle	4.5'	0.05	NA	NA	0.25	NA
Ady Pb Bed, Tunnel #4	155	Chip	"	4.5'	0.05	"	"	1.36	"
"	156	Comp. Chip	"	2'	3.30	"	"	1.93	"
"	157	"	"	5'	0.08	"	"	0.87	"
"	158	"	"	5'	0.24	"	"	3.16	"
"	159	"	"	5'	6.49	5.83	0.20	2.40	"
"	160	"	"	5'	10.99	NA	NA	1.08	"
Ady Open Cut	161	Chip	Top	4.5'	0.03	"	"	2.76	"
"	162	"	"	7'	0.07	"	"	0.47	"
"	163	"	"	5'	0.07	"	"	3.56	"
Ady Pb Bed, Tunnel #1	164	Comp.	-	Grab	2.19	"	"	NA	"
Ady Incline	165	Chip	Top	8'	0.05	"	"	"	"
"	166	"	"	6'	0.08	"	"	"	"
"	167	"	Bottom	4'	0.05	"	"	"	"
"	168	"	Middle	6'	0.05	"	"	"	"
"	169	"	Top	6'	0.09	"	"	"	"
"	170	"	"	6'	0.05	"	"	"	"
"	171	"	"	5'	0.07	"	"	"	"
"	172	"	Middle	5'	0.04	"	"	"	"
"	173	"	"	6'	0.08	"	"	"	"
"	174	"	Top	6'	0.09	"	"	"	"
"	175	"	Middle	6'	0.04	"	"	"	"
"	176	"	"	6'	0.05	"	"	"	"
"	177	"	"	6'	0.05	"	"	"	"
"	178	"	"	6'	0.05	"	"	"	"
"	179	"	Bottom	4'	0.06	"	"	"	"
Ady Pb Bed, Tunnel #2	180	"	Top	4'	0.08	"	"	2.97	"
"	181	"	Middle	2.5'	0.05	"	"	1.36	"
Ady Pb Bed, Tunnel #4	380	"	"	4'	9.25	"	0.15	1.55	0.16
"	381	"	"	4'	0.85	"	0.20	4.15	0.06
Outcrop	382	Comp.	-	Grab	0.05	"	0.15	0.66	0.06
Ady Open Cut	383	Chip	Top	2'	0.05	"	0.20	6.60	1.14
Ady Pb Bed, Tunnel #1	384	Comp.	-	Grab	1.15	"	2.45	0.76	0.26

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GEOLOGY AND ASSAY MAP - ADY AREA
SACRAMENTO (HIGH ROLLS) DISTRICT
OTERO COUNTY, NEW MEXICO

40 0 40 80 120 160 FEET