GEOLOGY OF THE ALUM AREA,

ESMERALDA COUNTY, NEVADA

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INTRODUCTION

Esmeralda County is in southwestern Nevada adjacent to the California border (Fig. 1). The county is traversed by a number of hard surfaced all-weather roads and numerous graded roads and/or dirt roads provide access to nearly all parts of the county.

The county is sparsely populated. Goldfield, the county seat, is the main center of population. Fish Lake Valley in the extreme western part of the county is an area of extensive farming and ranching.

Location and Access

The Alum prospect is located on the western flank of the Weepah Hills in the central part of Esmeralda County (Fig. 1), approximately ten miles north of the town of Silverpeak. Access to the property is good with the all weather, black-topped State Highway 47 leaving U.S. Highway 50 at Blair Junction. The main part of the Alum prospect lies about two miles east of Highway 47 and can be reached by means of an unmaintained dirt road (Plate I). Several dirt roads provide access to most parts of the property.

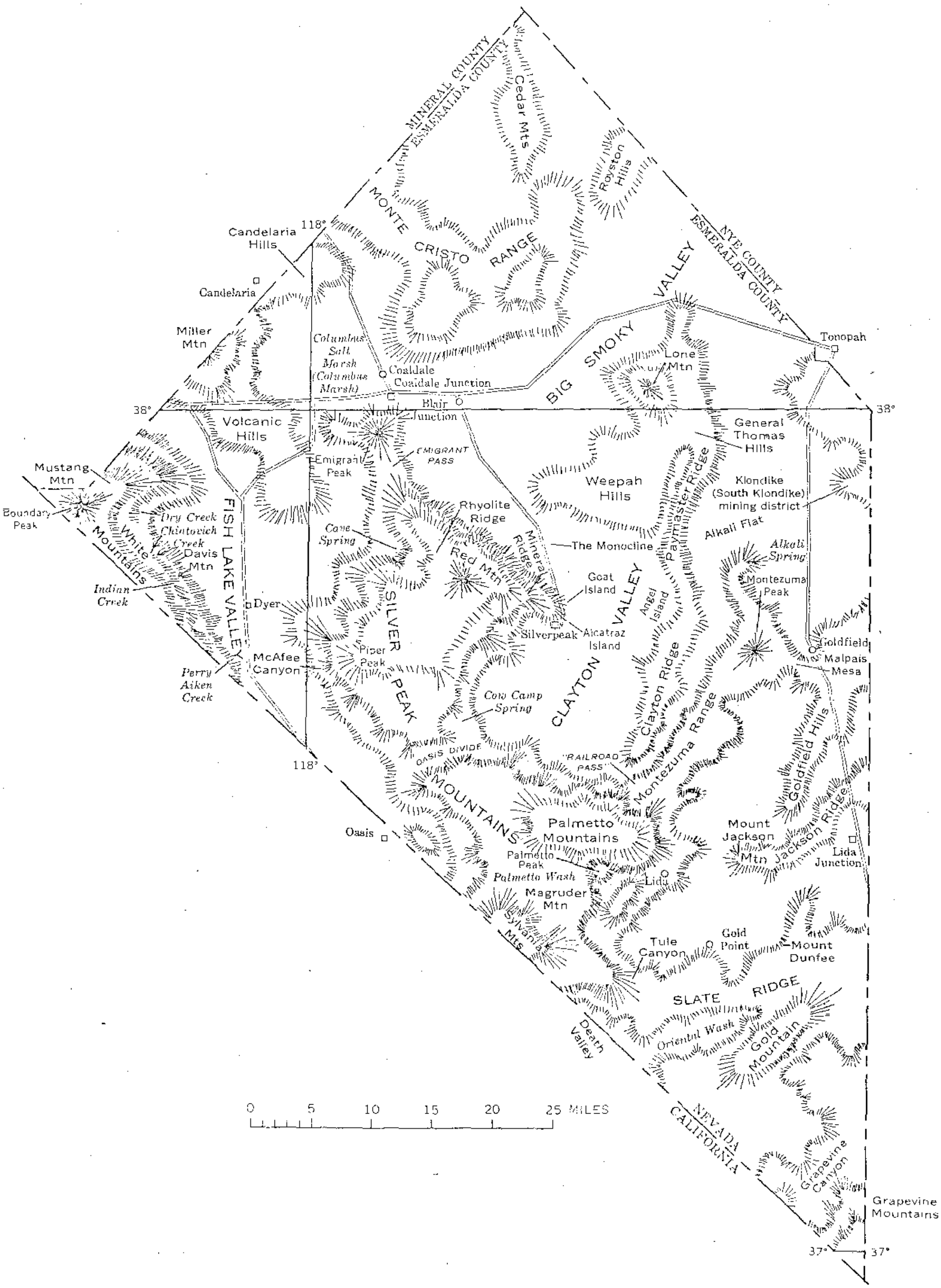

Figure 1. Index map of Esmeralda County, Nev., showing physiographic features and major roads.

Climate and Vegetation

The Alum property is located on the drainage divide between the Big Smoky Valley on the north and the Clayton Valley to the south. Elevavations in the area range from 4,200 feet in Clayton Valley to over 7,000 feet in the Weepah Hills.

The climate of Esmeralda County is arid to semi-arid with extreme temperature ranges. Three (3) weather stations are located in the county so that some idea of climatic averages can be obtained. At Dyer, approximate elevation of 4,850 feet, the mean annual temperature is $10.8^{\circ}C(51.4^{\circ}F)$ and the average annual precipitation is about 5.53 inches.

Vegetatation in the valleys and on the lower slopes consists of sagebrush and other desert plants. Trees of the poplar family grow around some of the springs. Pinon and Juniper appear on the hills above 6,000 feet.

Previous Work

The first geologic mapping in Esmeralda County was by H.W. Turner (1900) of the U.S. Geological Survey. Spurr (1906) described the ore deposits of the county. Bailey and Phoenix (1944) described the mercury deposits of Esmeralda County. Robinson, et al. (1968) described in detail the Esmeralda Formation in the Alum area and its relation to Cenozoic volcanism. A good summary of the geology and mineral deposits is given by Albers and Stewart (1972).

ROCK DESCRIPTIONS

Rocks rangings in age from Precambrian to Quaternary are exposed in the central portion of Esmeralda County. For the present report the rock descriptions will be confined to those which outcrop in the Weepah Hills area.

Precambrian Rocks

The Precambrian rocks exposed in the Weepah Hills occur within or on the flanks of granitic plutons. The strata are concordant with the pluton, although large amounts of the strata have probably been incorporated into the granitic rocks.

Wyman Formation - The oldest Precambrian rocks exposed in the Weepah Hills belong to the Wyman Formation (Albers and Stewart, 1972). The sedimentary strata are everywhere in intrusive contact with granitic rocks or in fault contact with Tertiary rocks. Therefore, the total thickness of the unit is unknown. The Wyman Formation is composed of phyllitic siltstones, claystones, limestones and sandstones. The rocks are all metamorphased on a regional basis, and grade into calc-silicate hornfels adjacent to the plutons. The contact with the overlying Reed Dolomite appears to be conformable.

Reed Dolomite - The Reed Dolomite consists of a sequence of white to gray, yellow-gray or yellow-brown medium to coarse-grained dolomite. Most original bedding has been obliterated due to movement and/or recrystallization.

Precambrian-Lower Cambrian

Sedimentation continued uninterrupted from Precambrian into Lower Cambrian time in this part of Nevada. The transitional rocks in Esmeralda County have been mapped as the Campito Formation (Nelson, 1962).

Campito Formation - The Campito Formation consists of a basal unit of dark-colored quartzite and siltstone and an upper unit of greenish-gray siltstone. The rocks of the lower unit are dominantly very fine-grained quartzites which vary in color from gray-green to olive-green to yellow brown. The lower unit weathers to brownish-black and forms rubble covered slopes.

The upper unit is commonly metamorphased to phyllitic siltstone or phyllite. The unit is laminated to thin bedded and at some outcrops shows a cleavage which makes a small angle with bedding. A few thin limestone beds occur, near the top of the section. The contact with the overlying Poleta formation is transitional.

Lower Cambrian

Poleta Formation - The Poleta Formation crops out widely in the Weepah Hills and is characterized by three members (Fig 2). The lower member consists of gray limestone with some interebedded gray-green or olive-green siltstone. The lower unit appears to be of variable thickness and lithologic character from area to area (Albers and Stewart, 1972).

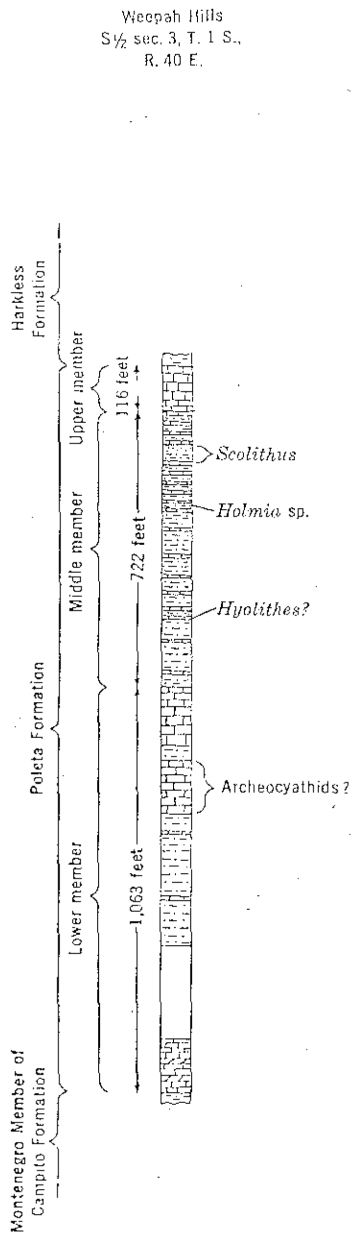

Figure 2. Columnar section for the Poleta Formation, Weepah Hills (after Albers and Stewart, 1972).

The middle member of the Poleta Formation (Fig. 2) consists of siltstones, limestones and quartzites. The dominant rock type is gray-green to olive-green siltstones and/or phyllitic siltstone. The limestones are medium-gray, aphanitic to medium-grained and occur interstratified with the siltstones. Only a minor part of the middle member in the Weepah Hills area is made up of pale-brown, very fine-grained quartzites.

The contact between the Poleta Formation and the overlying Harkless Formation is sharp.

Harkless Formation - The Harkless Formation (Fig. 3) is about 3,500 feet thick in the Weepah Hills area. The lower third of the formation consists of dark greenish-gray quartzitic siltstone with a few interstratified limestones. The silt to very fine-grained sand grains occur in a matrix of chlorite, muscovite and carbonate minerals.

The upper two thirds of the unit (Fig. 3) is composed of greenish-gray siltstone and/or phyllitic siltstones with a few interbedded limestone. As the degree of metamorphism increases, the unit is difficult to distinguish from the Campito Formation.

Mule Spring Limestone - The Mule Spring Limestone is the youngest of the Lower Cambrian sediments in the area. The rock consists of medium gray, finely crystalline to aphanitic limestone with abundant concretionary algal structures. The contacts with the underlying Harkless Formation and the overlying Emigrant Formation are sharp.

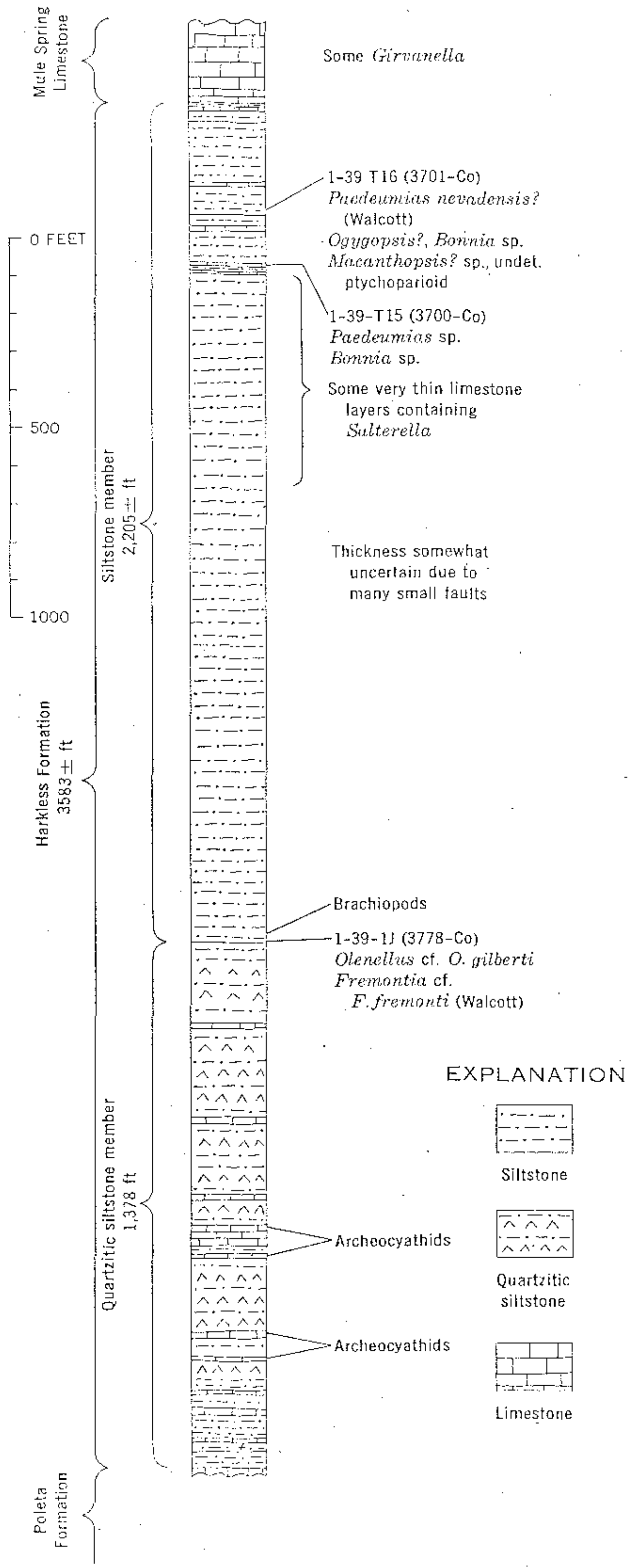

Figure 3. Stratigraphic section of Harkless Formation in Weepah Hills (after Albers and Stewart, 1972).

Middle and Upper Cambrian

Emigrant Formation - The Emigrant Formation was named for exposures near Emigrant Pass (Fig. 1). In the Weepah Hills the section consists of a basal siltstone member, a middle shale member and an upper limestone member. The lower unit is made up of gray, red or purple siltstones with minor interbedded gray limestones.

The shale member is olive-green to greenish-gray thin bedded shale. The rocks weather to yellow brown. The upper unit is gray limestone and chert.

Mesozoic and Tertiary Plutonic Rocks

The Weepah pluton (Fig. 4) is a coarse-grained quartz monzonite with an equigranular texture. The essential minerals are plagioclase, k-feldspar and quartz with some biotite, musconite, sphene, apatite and magnetite as accessory minerals. The age of the plutonism appears to have spanned the Jurassic, Cretaceous and Early Tertiary.

Tertiary Rocks

The Tertiary rocks of Esmeralda County include welded and non-welded ash flow tuffs, lava flows, volcanic breccias, volcaniclastic rocks and sedimentary rocks. Turner (1900) originally defined the Tertiary rocks

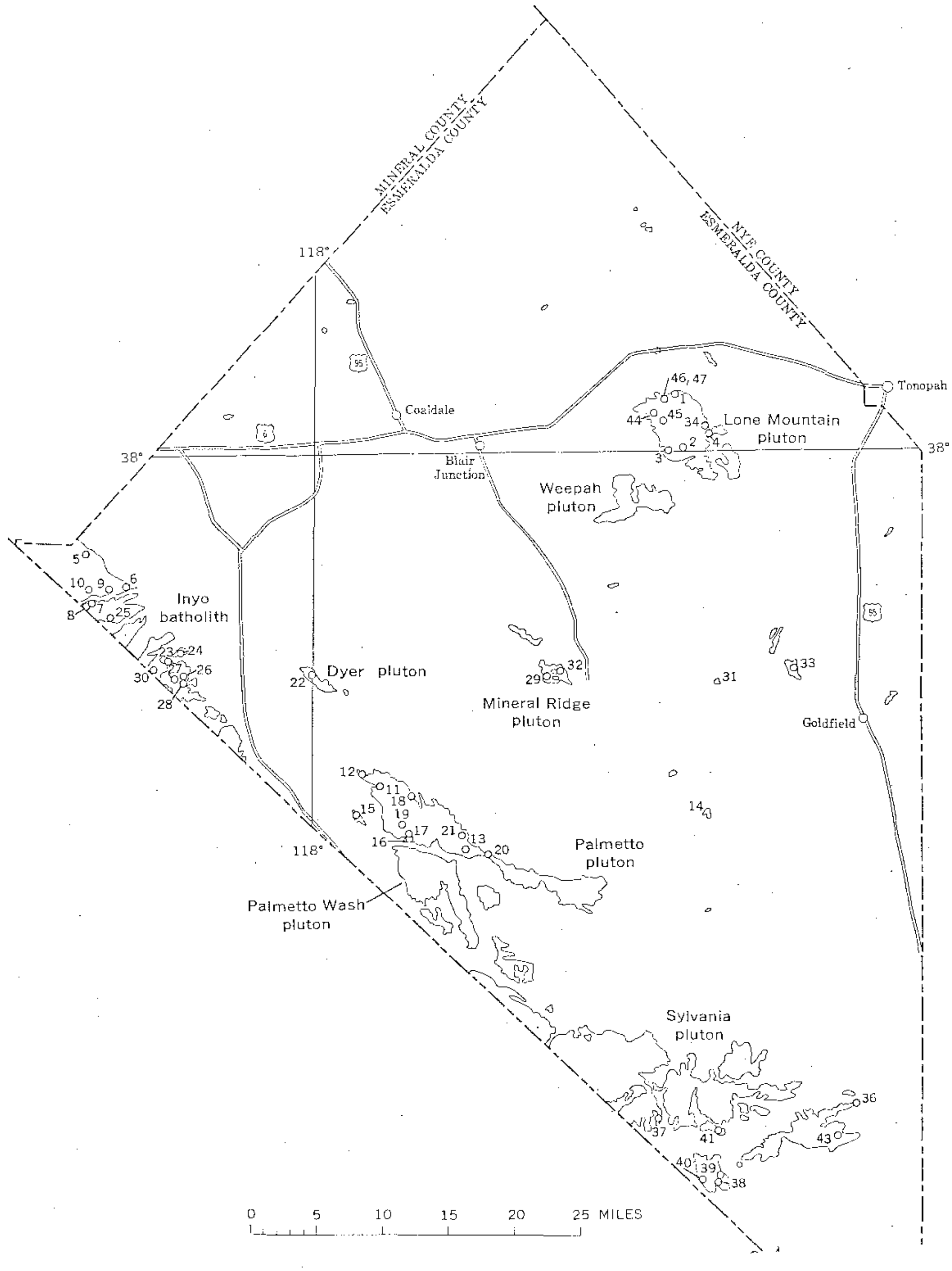

Figure 4. Distribution of plutons in Esmeralda County, Nevada (after Albers and Stewart, 1972).

in the Silver Peak area as the Esmeralda Formation. Robinson (1964) described the Cenozoic stratigraphy of the Silver Peak range in considerable detail. Robinson et al. (1968) described approximately 9,000 feet of Esmeralda Formation in the Alum area. A rhyolite flow or plug intrudes the Esmeralda Formation in the southern part of the Weepah Hills.

Esmeralda Formation - Robinson and others (1968) measured over 9,000 feet of Esmeralda formation (Fig. 5) in the Alum area. The formation thins rapidly eastward and pinches out on the pre-Tertiary rocks in the Weepah Hills. Neither the base nor the top of the sequence is exposed in the Alum area. The Esmeralda Formation has been divided into seven units (Fig. 5).

Unit A

The lower most exposures of the Esmeralda Formation in the Alum area is a 540 foot thick sequence of pebble conglomerate with interbedded sandstone, siltstones and limestones. The conglomerates are brown to greenish-gray in color and are composed of chert, limestone and quartzite pebbles in a silty to sandy matrix. The pebbles range from 5 to 50mm in diameter.

The interbedded sandstones, siltstones and fresh water limestones comprise about 10 percent of the unit. The sandstones are fine to medium-grained feldspathic or lithic sandstones. The composition of the rock includes angular grains of feldspar, quartz and rock fragments set in an iron-stained silty or argillaceous matrix.

Lenticular masses of grayish-blue limestone breccia occur at several horizons in Unit A near the eastern margin of the area. The brecciated limestone clasts are from the Lower Cambrian units and were interpreted by Robinson, et al. (1968) as landlide or talus debris.

Unit B

Unit A grades upward into a sequence of sandstones and siltstones with abundant vitric material. Yellow-orange, thin to thick-bedded poorly sorted feldspathic lithic sandstones constitute about 70 percent of the unit. Pre-Tertiary rock fragments comprise about 50 percent of the average rock and vitric material makes up as much as 25 percent of the sandstones. The vitric material has been devitrified to zeolites or montmorillonite. Grayish-orange, sandy, tuffaceous siltstones form about 30 percent of Unit B.

Unit C

Unit C consists of 880 feet of white to pale orange siltstones and shales with thin interbedded pale orange to yellow-brown sandstones. The rocks contain abundant epiclastic volcanic debris, feldspar, quartz, biotite and hornblende in a matrix of vitric material which has been altered to zeolites, opal or montmorillonite.

Unit D

Unit D is a wedge-shaped body of conglomerates, sandstone, siltstone and tuff. The coarse clastics predominate in the western part of the

Alum area whereas the fine clastic make up most of the section in the eastern part of the area. The rocks contain a high percentage of pyroclastic and epiclastic volcanic debris. White to pale-green tuffs are common in the lower part of the unit and grade laterally and vertically into reworked tuffs.

The vitric material which makes up the matrix of the conglomerates, sandstones, siltstones and tuffs has been altered to mixtures of zeolites, montmorillonite and opal.

Unit E

Unit E is a 2,400 foot thick sequence of gray to yellow-gray thin bedded siltstones, white to gray sandstones and yellow-gray to pale-orange shales with intertongues of conglomerate which wedges out to the west. The fine grained rocks are rich in volcanic material and the conglomerates are made up clasts of Precambrian and Lower Paleozoic sediments; however, pebbles of granite and diorite occur in some of the conglomerates.

A few lenses of limestone breccia similar to those in Unit A occur at different horizons in the conglomerates. If the breccias have the same tectonic implications it suggests renewed movement along the bounding faults of the depositional basin.

Unit F

Unit F is the top of the lower part of the Esmeralda Formation in the Alum area. The unit is approximately 2,700 feet thick (Fig. 5). The

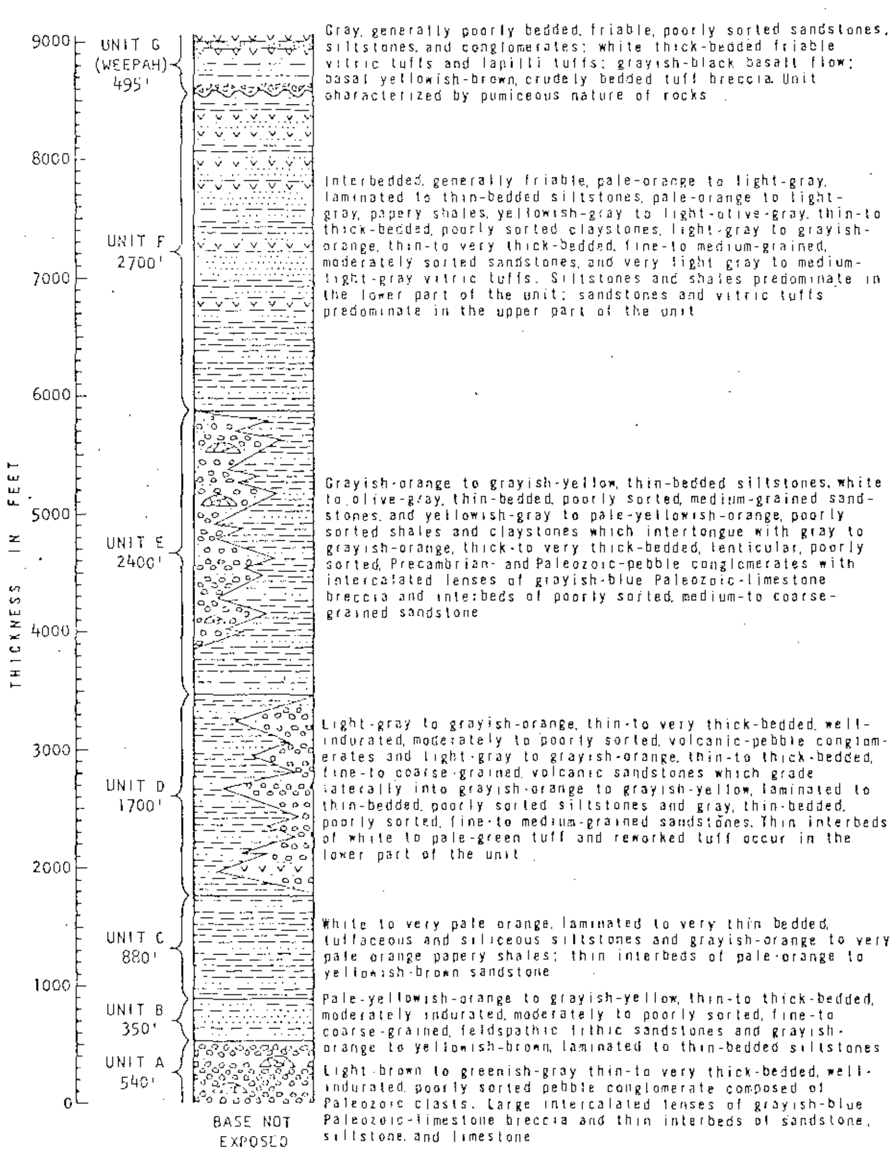

Figure 5. Composite measured section of the Esmeralda Formation in the Alum area (after Robinson et al, 1968).

siltstones and shales of the lower third of the unit are thin bedded, varicolored and friable. Most of the rocks are tuffaceous and have some carbonaceous material. The matrix of the rock is mainly montmorillonite formed by the devitrification of volcanic glass.

The upper two thirds of the unit consists of interbedded sandstones and vitric tuff. The sandstones are gray to grayish-orange, fine to medium-grained, poorly sorted and contain abundant pyroclastic material. The vitric tuffs are light-gray, friable and consist of shards and crystals of quartz, feldspar and biotite.

Unit G

Unit G unconformably overlies Unit F and consists of approximately 500 feet of tuff, tuffaceous sandstone, siltstone and conglomerate. On the Monocline (Plate I) in the southern part of the area the sediments are capped by an olivine basalt flows (Fig. 6). On the Monocline a tuff breccia marks the basal unconformity which truncates rocks of Unit F at angles of 5^0 to 15^0.

The hill to the north of the old Alum and Sulphur workings is capped with conglomerates of Unit G. The conglomerates unconformably overly siltstones of Unit F (Fig. 7). Conglomerates of Unit G unconformably overlies siltstones of Unit F on a small hill in the western part of the area (Plate I).

Figure 6. Unit G of the Esmeralda Formation overlain by basalt on the Monocline, Alum area. A K-Ar age of 6.9my was obtained on biotite from tuff beds in Unit G.

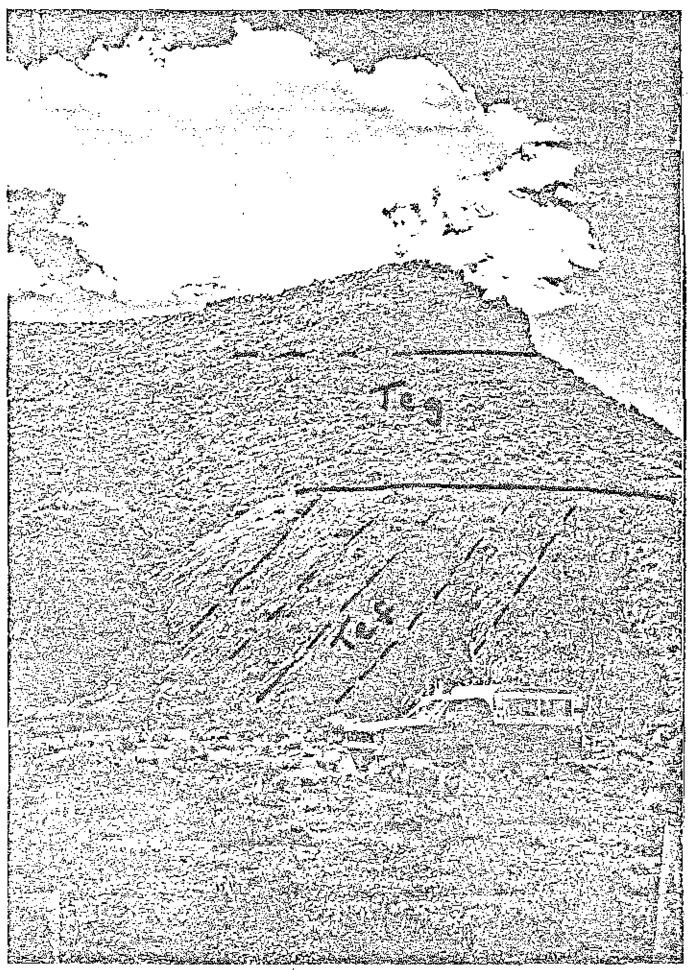

Figure 7. Conglomerates of Unit G unconformably overlying siltstones of Unit F north of the Alum mine workings.

Age of Alum Sequence

Robinson et al. (1968) suggest the rocks of Units A, B, C, and D are Barstrovian and possibly Hemingfordian in age or 12-20 m.y. old A biotite tuff in Unit G has been K-Ar dated at 6.9 m.y.

Rhyolite Ash-Flow and Domes - Rhyolite ash-flows or domes were reported by Spurr (1906) in the western part of the Weepah Hills. Albers and Stewart (1972) show an area of rhyolite ash-flow in the western part of the area. Recent mapping by Teplow (1981) has outlined additional areas of rhyolite ash-flow tuffs in the area around the Alum and Sulphur Mine (Plate I).

The area mapped as T_{af} (Plate I) along the western side of the Alum area is thought to be a tuff pipe (Fig. 8 and 9). The rock consists of pumice, rhyolite and quartzite lithic fragments and quartz, feldspar and biotite crystal fragments in a vitric groundmass. The tuff pipe may well serve as the source for other ash-flow units in the map area. The ash-flow unit appears to be identical with rhyolite ash-flow units in the Silver Peak Range dated as 6.0 m.y. (Robinson et al., 1968).

Tertiary and Quaternary Basalts - The Monocline at the south side of the Alum area shows the Unit G of the Esmeralda Formation overlain by a porphyritic olivine basalt (Fig. 6). The basalt overlies a tuff which has been K-Ar dated at 6.9 m.y. Small remnants of a massive white pumice lapilli tuff overlie the basalt and the tuff was interpreted by Robinson and others (1968) as a part of Unit G of the Esmeralda Formation.

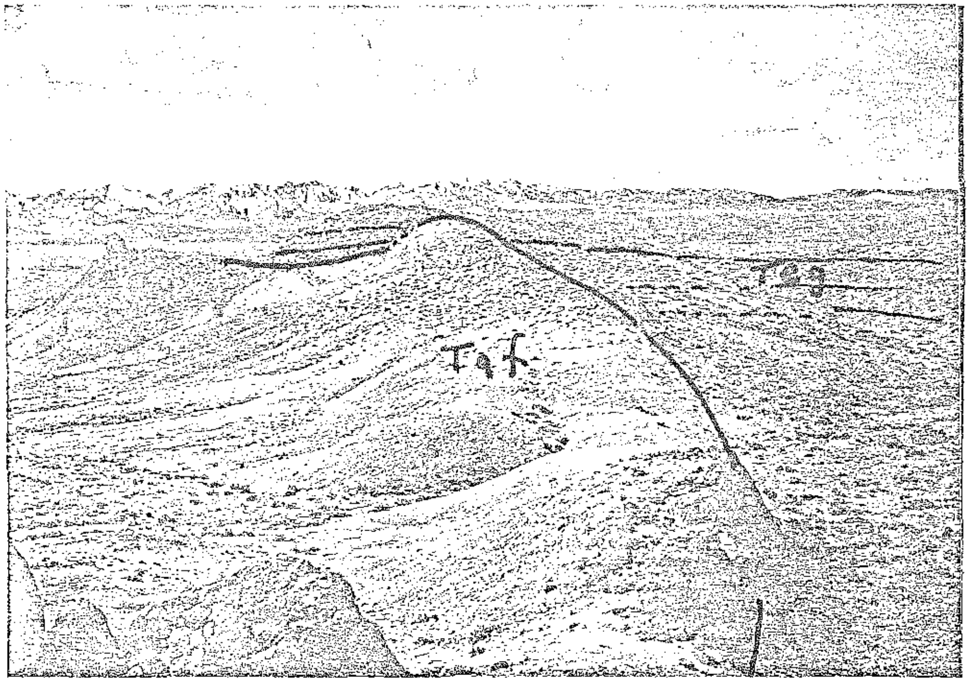

Figure 8. Rhyolite tuff pipe (Taf) intruded into sandstones and conglomerates of Unit G of the Esmeralda Fm.

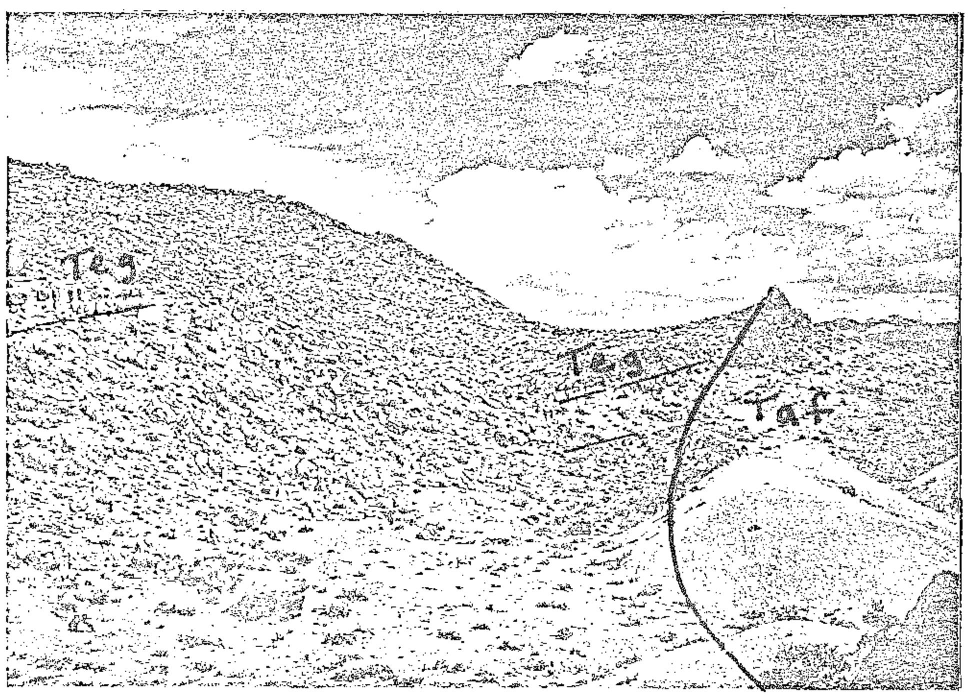

Figure 9. Rhyolite tuff pipe (Taf) intruded into sandstones and conglomerates of Unit G of the Esmeralda Fm.

Quaternary Rocks

Quaternary Older Alluvium - Large areas in the western part of the Weepah Hills are covered by coarse gravel and conglomerates (Plate I). The older alluvium probably represents pediment gravels which have since been dissected. In the Alum area the older alluvium is characterized by boulders and angular fragments of Paleozoic limestones. The boulders are well cemented and unit weathers to a distinctive yellow-brown. The older Quaternary gravels and conglomerates rest unconformably upon the Esmeralda Formation.

Basalt - A prominant basaltic cinder cone occurs at the northwestern edge of Clayton Valley (Plate I). The cone and related flows are considered to be late Pleistocene or Holocene age.

STRUCTURAL GEOLOGY

Esmeralda County lies within the transition zone between the Sierra Nevada block on the west and Great Basin on the east. Figure 10 shows the location of the plutons and the principal structure of the pre-Tertiary rocks. The arcuate structure has been termed the "Silver Peak - Palmetto - Montezuma oroflex" by Albers (1967).

Pre-Tertiary Structures

In the Weepah Hills the strikes of the Cambrian rock changes from west-northwest to east-west to north (Fig. 10). The arcuate structure in

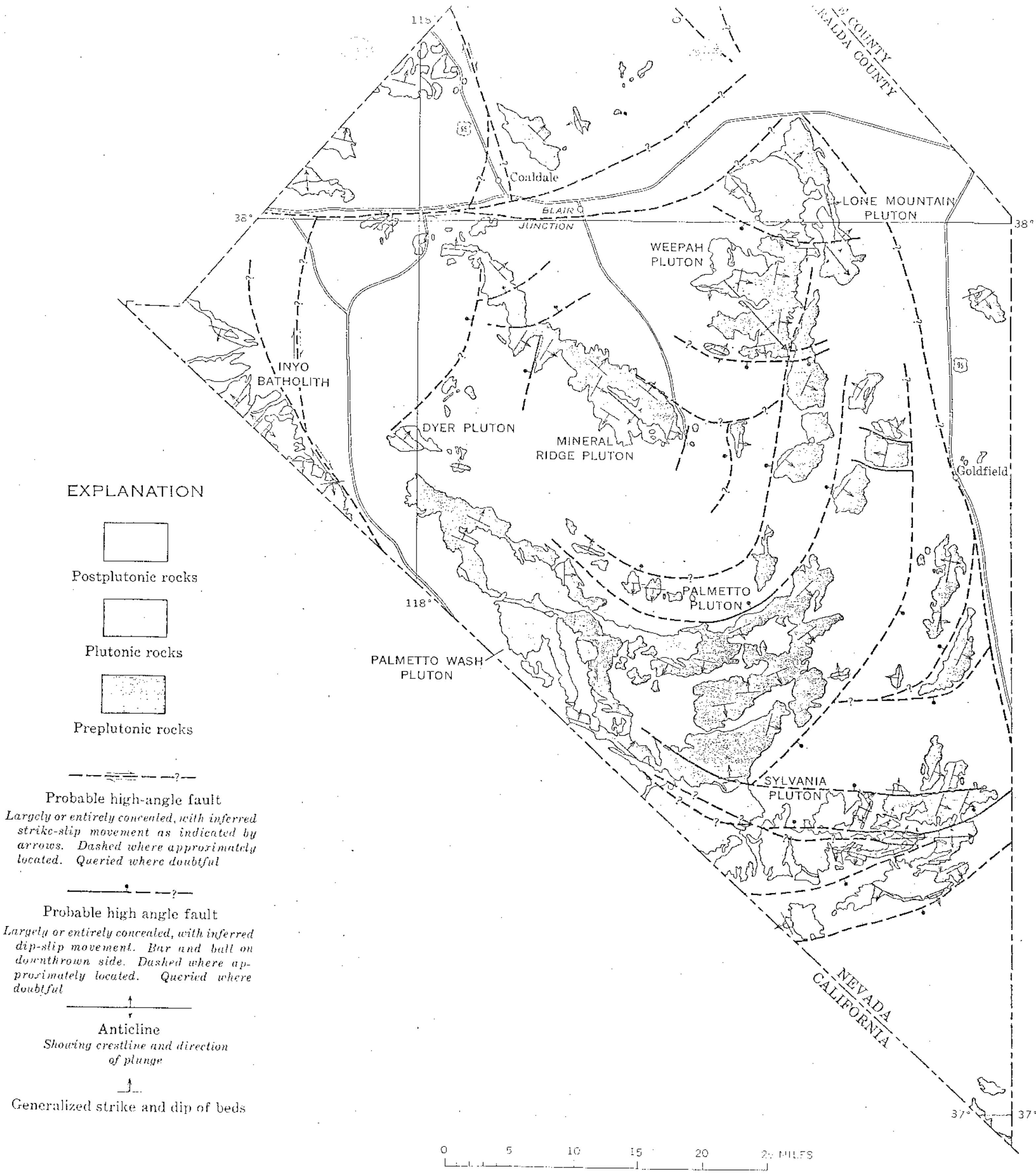

Figure 10. Map showing the location of plutons and principal structural features of the pre-Tertiary rocks in Esmeralda County (after Albers and Stewart, 1972).

the pre-Tertiary is repeated throughout the county. The arcs are cut by a series of high angle faults. Most of the faults are believed to have formed prior to the eruption of the Tertiary volcanic rocks.

Tertiary Structures

The Tertiary sediments of the Esmeralda Formation indiate periods of tectonic activity. For example, the basal conglomerate of Unit A indicates subsidence of the basin probably as a result of block faulting. Renewed subsidence and/or uplift of adjacent mountain blocks is indicated by the conglomerates and breccias of Unit D and E.

The beds of Units A through F were folded and tilted prior to the deposition of Unit G. The trend of the folds is N60-70W (Plate I).

Recent Structure

A series of recent fault scarps are present in the alluvium along the south side of Big Smoky Valley at the base of the Weepah Hills. All the faults are down dropped on the north side, and have a somewhat accurate trace.

GEOTHERMAL MANIFESTATIONS

Hydrogeochemical

There are no thermal springs within the boundaries of the Alum area. However, a total of ten spring samples and well samples have been compiled for the area (Plate II). Five of the samples, those with X10000 numbers, were taken from Asher-Bolinder and others (1980) and the remaining five were collected and analyzed by AMAX. Chemical analyses of the waters are shown in Table I.

Alteration and Mineralization

The sulfur mineralization in the Alum area was recognized in 1868 and was located and prospected many times. Spurr (1906) gave the first description of the area, and recognized the presence of alum, kalinite, as well.

The sulfur and alum mineralization occurs in vitric rhyolite tuffs of Unit F of the Esmeralda Formation (Fig. 11). The mineralization occurs in rocks which were previously altered to a mixture of opal, zeolites and montmorillonite (Fig. 12). The sulfur occurs as crystals and coatings on frac- ture surfaces. White opalite occurs as irregular pods along primary bedding and also along fractures. The kaolinite and/or alunite occurs in the form of irregular veins and stringers parallel to sheeting, strikes north and dip to east and also along fractures in the N60W direction with near vertical dip.

Figure 11. Altered and mineralized tuff in open pit wall, Alum prospect.

Figure 12. Fractured, altered, mineralized tuff, Alum prospect.

Spur (1906) commented that the bright red stains (Fig. 11 and 12) associated with the sulfur and alum mineralization might be cinnabar. Consequently, a mercury soil survey was done along three lines (Maurath, 1981). While the survey was of very limited extent (Fig. 13) it does show anomalous concentration along the north-south line which suggests ascension of mercury rich thermal vapors along the sheeting in the tuffs.

The alteration and mineralization could either be of solfafric origin or could be fumorolic in origin. The presence of native sulfur at the surface suggests a relatively young age for the mineralization.

Thermal Anomaly

Temperature measurements have been made in a total of 21 holes in the Alum area. One mineral exploration hole near the Alum prospect was measured and also a well in Sec. 34 T1N R38E was measured. A total of 19 thermal gradient holes were drilled to depths of 50 to 150 meters (Plate III). The thermal gradients range from a low of 36^{0}C/km to over 584^{0}C/km. Four pieces of information are given for each hole: (1) temperature gradients, (2) temperature at 100 meters, (3) depth to the 200^{0}C isotherm and (4) the heatflow at either a measured or assumed thermal conductivity.

The thermal anomaly is presented in terms of heatflow on Plate IV. Heatflow values range from 1.8 HFU to a high of 21.0 HFU. The three-dimensional character of the thermal anomaly is shown in contour form with maps of the temperature at 100 meters, 2,000 meters and 3,000 meters (Plates V, VI, and VII).

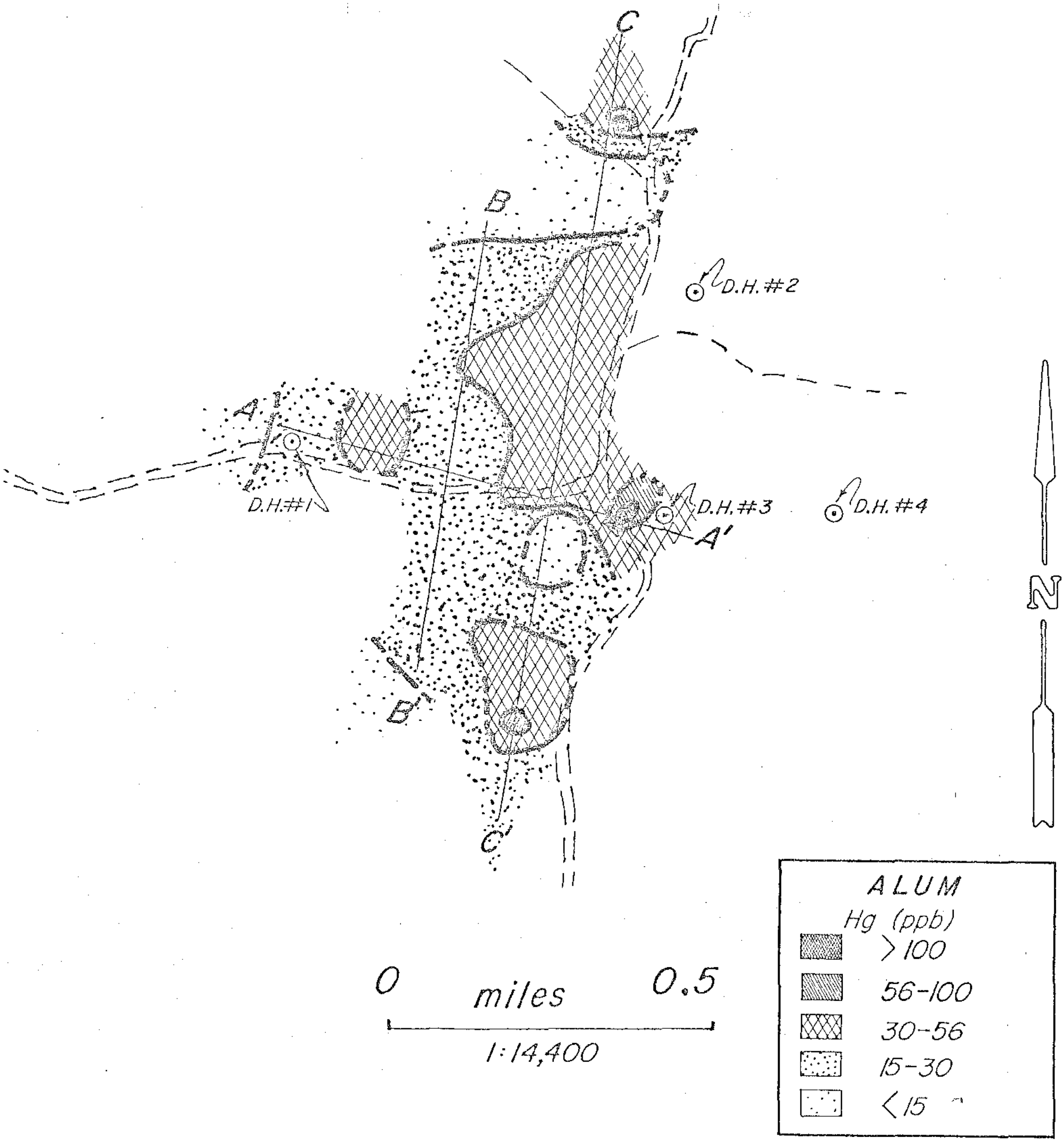

Figure 13. Mercury distribution, Alum prospect, (after Maurath, 1981).

UNIT AREA

The location of the boundary for the Alum Exploration Unit has been defined by the position of the 200^{o}C contour at a depth of 3,000 meters (Plate VII). The geographic criteria used in drawing the unit boundary as to follow section lines and to include all sections containing 50 percent or more areas within the 200^{o}C contour on Plate VII.

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Table I - Chemical Analyses of Waters from the Alum Area, Nevada

	X10009	X10021	X10023	X10024	X10025
T^oC	18.	22.	38.	33.	36.
Flow (gpm)	--	--	--	--	--
pH	8.4	7.8	8.0	8.0	7.8
Cl	420.0	13,000.0	15,000.0	6,000.0	21,000.0
F	1.9	1.5	4.9	2.9	1.7
SO_4	200.0	500.0	510.0	860.0	1200.0
HCO_3	---	---	---	---	---
CO_3	---	---	---	---	---
SiO_2	82.0	64.0	53.0	71.0	86.0
Na	600.0	7200.0	8400.0	10,000.0	13,000.0
K	58.0	520.0	850.0	920.0	1,300.0
Ca	13.0	450.0	240.0	320.0	270.0
Mg	6.7	180.0	30.0	87.0	78.0
Li	1.3	27.0	38.0	44.0	58.0
B	11.0	---	---	---	---
MO	---	---	---	---	---
NH_3	---	---	---	---	---
TDS	1750.0	---	---	---	---
Ec(k)	2750.0	31,000.0	37,500.0	42,500.0	51,000.0
T_qSiO_2	124.	113.0	105.	117.	126.
T_cSiO_2	96.	85.	75.	90.	101.
TNa-K	214.	191.	218.	210.	217.
TNa-K-Ca	150.	129.	150.	144.	152.

Table I. Chemical Analyses of Waters from the Alum Area, Nevada.

	W11112	W11113	W11119	W11122	W11123
$T^{o}C$	24.	17.	15.	15.	22.
Flow (gpm)	4.	10.	11.	2	--
pH	7.6	8.4	7.6	7.0	6.7
Cl	59.0	15.0	57.0	31.0	46,000.0
F	0.4	0.3	0.3	0.4	1.6
SO_4	---	80.0	---	46.0	2100.0
HCO_3	147.8	71.8	169.8	76.0	587.6
CO_3	0.0	2.4	0.0	0.0	0.0
SiO_2	21.0	31.0	49.0	77.0	70.0
Na	65.0	71.0	75.0	76.0	29,000.0
K	3.4	2.0	6.1	1.6	280.0
Ca	290.0	11.0	48.0	1.0	60.0
Mg	27.0	0.0	10.0	1.0	290.0
Li	---	0.2	0.1	0.1	120.0
B	0.4	0.0	0.7	0.4	49.0
MO	2.0	0.0	8.0	0.0	0.0
NH_3	0.13	0.0	0.0	0.0	2.21
TDS	614.1	284.7	416.0	310.6	33,956.0
Ec(k)	---	---	---	---	---
T_qSiO_2	71.	84.	102.	121.	117.
T_cSiO_2	33.	49.	71.	95.	90.
TNa-K	167.	128.	200.	112.	0.
TNa-K-Ca	89.	87.	118.	91.	23.