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Geology and Gold Mineralization at the Toiyabe Project, Lander County, Nevada

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Introduction

The Toiyabe project is located in east central Lander County, Nevada, in the northernmost Toiyabe Range, approximately 20 km south-southwest of the Cortez mine. Figure 1 is a location map that shows the position of the Toiyabe project in Lander County and in relation to some of the major gold mines in Nevada. Previous work includes reconnaissance mapping of the northernmost Toiyabe Range by Stewart & Mckee (1969) and by Gilluly & Mazursky (1965). Madrid & Roberts further evaluated the Toiyabe project mine property for ore potential in 1990. Fieldwork during the 1998 field season focused on geologic and alteration mapping of the open pits, and geologic mapping of approximately 5 square miles of the surrounding mine property. The map area includes all of sections 7 and 18, and parts of sections 5, 6, 8, 17, 19 and 20 of T25N, R47E, and sections 12 and 13, and parts of sections 1, 2, 11, 14, 23 and 24 of T25N, R46E. The mapping has provided valuable information about the nature of the Lower Paleozoic sedimentary rocks, the structural characteristics of Antler age deformation, and the structural controls that localized the ore body.

Lower Paleozoic sedimentary rocks are well represented within the mine property. The Lower Paleozoic sequence includes miogeoclinal rocks of the dominantly carbonate, eastern facies and eugeoclinal rocks of the siliceous and volcanic, western facies. The eastern and western facies rocks are juxtaposed across the Late Devonian to Early Mississippian Roberts Mountains thrust. Other rock units in the project area include a dolostone of uncertain affinity, a thick pile of uplifted Tertiary alluvium, and intrusive rocks of probable Tertiary age. The mine property contains three small open pits that provide excellent exposures of both the western and eastern facies rocks, and the Roberts Mountains thrust. Outside the pits exposures are generally poor, particularly in the dominantly carbonate, eastern facies rocks. A small oxide ore body composed of finely disseminated "invisible" gold was mined between 1989 and 1991 leaving the existing open pits. The gold mineralization appears to be controlled by a complex shear zone that is part of the Roberts Mountains thrust.

Lithology

In order to clarify the relative age and superposition relations of the rock units discussed below, an informal columnar section (figure 2) is included in the discussion

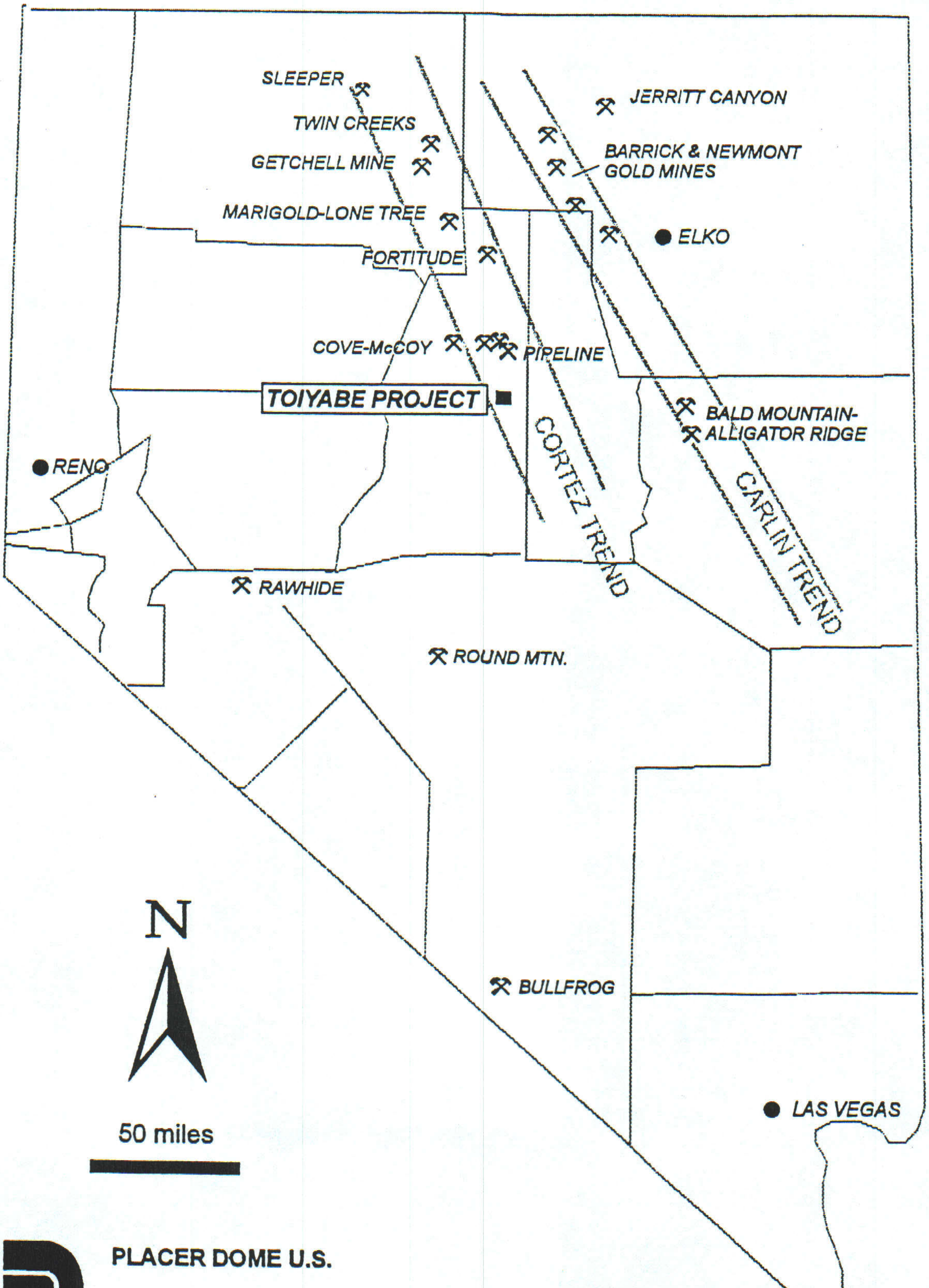

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Figure 1. Index map, Toiyabe project.

of lithologies. A geologic map (figure 3) showing the distribution of the major units in the map area, is included in the structure discussion.

Lower Paleozoic Carbonate Rocks

Lower Paleozoic carbonate rocks make up the lower plate of the Roberts Mountains thrust and consist of calcareous siltstone, silty limestone and minor micritic limestone. Contacts between these rock types are usually gradational over 1 to 3 m. Three samples of micritic limestone were collected and processed in the UNR micropaleontology laboratory, but were devoid of microfossils. Based on lithotype, the carbonate rocks are tentatively assigned to the Siluro-Devonian Roberts Mountains Formation.

The dominant lithology of the lower Paleozoic carbonate rocks is a monotonous, finely laminated, light to medium gray, weakly to strongly calcareous siltstone. The calcareous siltstones make up approximately 80% of the exposed carbonate rocks. Bedding is remarkably planar and consists of fine laminations, 0.1 to 2 mm thick. Individual laminations can be traced for 10 m or more where the rocks are not structurally disturbed. The fine lamination produces a well-developed bedding plane fissility that causes the rock to split into 1 to 10 cm thick plates. Parting planes have an abundance of fine organic material that produces a dark gray phyllitic sheen. The calcareous siltstones are a very weak lithology and usually do not form outcrops. Where outcrops are present they are commonly less than 20 cm high. Colluvium consists of equant, polygonal, pale tan to pale red brown chips, which are 0.2 to 2 cm thick and 1 to 25 cm in diameter.

Silty limestone is commonly medium to dark gray, strongly calcareous, bedded, and makes up approximately 15% of the exposed carbonate rocks. Bedding is generally irregular and wavy with individual beds ranging from 0.5 to 3 cm thick. Silty limestone forms low flat outcrops less than 20 cm high. Colluvium consists of equant to very elongate, irregularily shaped, medium gray to orange brown chips, which are about 1 to 25 cm in diameter.

Micritic limestone is volumetrically minor in the Lower Paleozoic carbonate rocks and makes up about 5% of the total. Fresh rock is medium to dark gray. Sequences of micritic limestone are massive and can be up to 20 m thick. Bedding is commonly absent, except where the micritic limestones grade into silty limestones. Fine fossil hash, composed of crinoid, sponge, and possibly bryozoa fragments are

Age		Thickness	Formation	Graphic	Description
Cenozoic	Tertiary	~150m	Alluvium		Older alluvium with clasts of quartz arenite, chert, and volcanic rock
Mesozoic	Triassic?	<75m	?		Dolostone, dolostone breccia and conglomerate, calcarenite, and silty limestone
Paleozoic	Devonian	>450m	Slaven Formation		Chert, argillaceous chert, siltstone argillite, and greenstone
		~15m	upper carbonate		Fine grained dolostone interbedded with calcareous siltstone and thin argillite layers
		~20m	transitional conglomerate		Matrix supported conglomerate, chert argillite, and thin ash layers
					RMT
	Silurian-Devonian	>300m	Roberts Mountains Formation		Finely laminated, calcareous siltstone, silty limestone, and micritic limestone

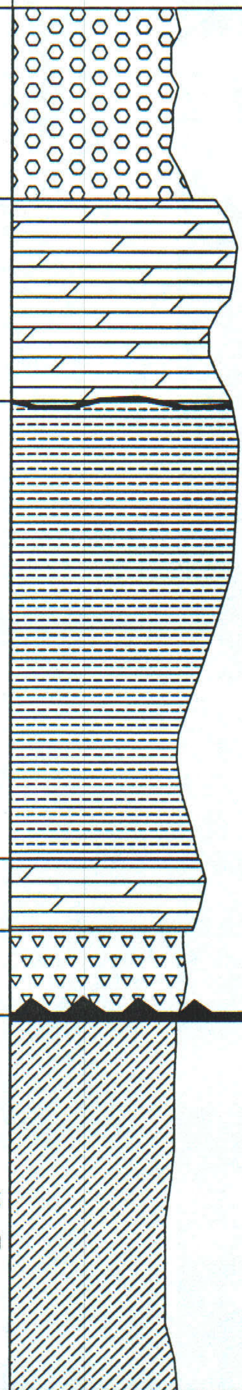


Figure 2. Informal Columnar Section for the Toiyabe Project

common locally. White calcite veins, up to 3 cm across, are ubiquitous. The micritic limestone is more resistant than the other carbonate lithologies and forms outcrops up to 3 m high and 50 m long. The relatively large outcrops are valuable marker horizons for interpreting structural details. Colluvium is composed of equant, light gray chips and blocks up to 0.5 m in diameter.

Transitional Units

Several minor units, which appear transitional between miogeoclinal and eugeoclinal facies, are exposed in the open pits. These units have been informally named the transitional conglomerate and the upper carbonate. These units are most likely fairly local. The transitional conglomerate appears to be more widespread than the upper carbonate.

Transitional Conglomerate

The unit informally named the Transitional Conglomerate is a heterogeneous unit that directly overlies the Lower Paleozoic carbonate rocks in the open pits. This unit can also be identified in colluvium near the Roberts Mountains thrust throughout much of the map area. The transitional conglomerate is composed of argillaceous cherts, argillites, ash layers, and a distinctive conglomerate. Black to very dark gray, argillaceous cherts are thin bedded and form sequences up to 2 m thick. Individual beds are 1 to 3 cm thick. Medium brown, gray argillite forms thin partings between chert beds, and tectonic lozenges and layers up to 0.5 m thick. White to buff ashy layers are interbedded with the brownish gray argillites and form layers 1 to 20 cm thick. The conglomerate unit is a brownish gray, poorly sorted, matrix supported diamictite. The matrix, which makes up about 85% of the rock, is composed of argillaceous mudstone with sand to fine pebbles throughout. Elongate, subrounded, 1 to 8 cm, chert, quartz arenite, and greenstone clasts make up the remaining 15% of the rock. The transitional conglomerate has a distinctive goethite/manganese oxide staining in the production pits.

Upper Carbonate

The upper carbonate is exposed only in the middle and south production pits where it forms the base of the Lower Paleozoic siliceous volcanic rocks. The lower contact of the upper carbonate is usually a shear zone. The upper contact is gradational with siltstones at the base of the Lower Paleozoic siliceous and volcanic sequence. The upper carbonate consists of interbedded dolostone, calcareous siltstone, and argillite. Very dark gray, finely crystalline dolostone forms beds 5 to 40 cm thick. Interbedded with the dolostone layers are medium greenish gray, weakly calcareous siltstone beds, 2 to 20 cm thick. Medium gray to black argillite layers form thin partings between siltstone or dolostone beds, and thicker beds up to 5 cm thick.

Lower Paleozoic Siliceous & Volcanic Rocks

Lower Paleozoic siliceous and volcanic rocks make up the upper plate of the Roberts Mountains thrust. The siliceous and volcanic rocks are composed of chert, argillaceous chert, argillaceous siltstone, siltstone, greenstone, and rare sandstone. The upper carbonate, siltstone, and rare sandstone dominate the base of the sequence, which is exposed in the production pits. Moving up through the section the proportion of argillite, argillaceous chert, chert, and greenstone increases and the proportion of siltstone decreases. Seven samples of the allochthonous cherts were collected and processed in the UNR micropaleontology laboratory. Radiolarians were present in all samples but were invariably recrystallized to featureless glassy spheriods that were undatable. Based on lithotype, the Lower Paleozoic siliceous and volcanic rocks are tentatively assigned to the Devonian Slaven Formation.

Tan gray, dark gray, and black, thin-bedded chert makes up 20% of the Lower Paleozoic siliceous volcanic rocks in the study area. Chert sequences observed in the production pits and in outcrop are less than 20 m in thickness. However, drill hole data indicate that individual sequences may exceed 100 m locally. Individual beds are 1 to 10 cm thick. Beds can be laterally continuous over 4 m but are often lensoidal or even nodular. Greenish gray, brownish gray, and reddish brown argillaceous chert and cherty argillite make up another 30% of the siliceous and volcanic sequence. The impure chert and cherty argillite differs from the pure cherts in being more deeply colored, slightly thicker bedded, and duller and less vitreous. Pure chert forms outcrops up to 4 m high and 30 m long. Impure chert forms somewhat smaller outcrops. Colluvium derived from the thicker chert sequences is a blocky talus composed of cobbles and boulders up to 1 m in diameter. The blocky talus forms long scree slopes in declivities on the steeper hillsides.

The remaining 50% of the siliceous and volcanic sequence is composed of argillite, siltstone, and greenstone. Argillites are black to light greenish gray and weather to greenish or reddish brown. Wavy, anastomosing laminations that show a phyllitic sheen on parting planes are characteristic of argillites. Individual beds range from 1 mm partings between chert and siltstone beds to thin bedded sequences 2 m thick

Siltstone sequences are fairly heterogeneous and range from fine argillaceous siltstone to silty sandstone. In the production pits siltstone sequences are up to 20 m thick. A greenish gray color, that is characteristic of the upper plate siltstones, distinguishes them from the medium gray siltstones of the lower plate. Individual beds are 2 to 10 cm thick. Bedforms are commonly wavey or cross-stratified and cross beds, 2 to 5 cm in length, and 1 cm high are common. Outside the production pits exposures of siltstone are rare. Where siltstone makes up a significant part of the bedrock, the colluvium consists dominantly of angular to subangular, equant, 1 to 6 cm clasts of tan to ochre brown siltstone.

Greenstone is a fairly minor constituent in the Lower Paleozoic, siliceous and volcanic sequence. Fresh greenstone is commonly dark grayish green. Lava flows, and breccia masses containing subangular, 1mm to 10 cm clasts, are common. Greenstone colluvium is composed of irregular, greenish gray to tan brown fragments that range from 1 to 25 cm in size. The distribution of colluvium indicates that concealed greenstone bodies are small lenticular masses that do not exceed 50 m in length and 10 m in thickness.

Late Paleozoic – Early Mesozoic(?) Dolostone

An enigmatic dolostone unit is exposed discontinuously along the western side of the main north, south trending canyon that cuts through the entire length of the northernmost Toiyabe Range. The unit is extremely heterogeneous and consists of massive crystalline dolostone, dolostone breccias and conglomerates, calcarenite, and small lenses of silty, micritic limestone. Clastic units show rapid lateral and vertical variation. Three samples of the dolostone unit were collected and processed at the UNR micropaleontology laboratory. All three samples consisted of crystalline dolomite and were devoid of microfossils. Based on the lithotype and the structural characteristics of the unit, described below, the dolostone is interpreted to be a Late Paleozoic or Early Mesozoic unit.

The dominant lithology is a light to dark gray crystalline dolostone with abundant light gray to white, 1 to 20 mm thick, calcite and dolomite veins. Bedding is absent and massive sequences 20 to 30 m thick are common. Dolostone breccias are important locally, particularily due west of the 401 pit. The dolostone breccias are weakly clast supported and extremely poorly sorted. Breccia clasts are angular to subangular, 1 cm to several meters in size, and are commonly a medium to dark gray color. Breccia matrix consists of course, moderately sorted, pebbly calcarenite. Matrix rich parts of the dolostone breccias grade into more massive fractured dolostone over 1-m intervals.

Interbedded with the dolostone breccias are dolostone conglomerates and calcarenites. Dolostone conglomerates are poorly sorted and weakly matrix supported. Clasts consist of medium to dark gray, subrounded, dolostone pebbles and cobbles, which form lenses and stringers in a moderately sorted, calcarenite matrix. Calcarenite sequences are commonly less than 2 m thick, and grade into dolostone conglomerates and breccias over 0.5 to 1-m intervals. Irregular crossbeds, 25 to 50 cm in length and 5 to 10 cm high are common. Individual beds range from 2 mm to 10 cm thick and show normal graded bedding. Typically, the calcarenite will grade from coarse sand to fine silty sand over 2 to 4 cm. Colluvium derived from the Paleozoic dolostone is composed of subrounded cobbles and boulders scattered over the slopes beneath outcrops. Weathering of the dolostone units produces a slight bleaching of the medium to dark gray dolomite.

Tertiary Alluvium

To the west of the production pits, extending along the entire length of the northernmost Toiyabe Range, lies a thick pile of Tertiary alluvium. The alluvium has been uplifted by Basin and Range extension to form the steep rolling hills characteristic of the western half of the range. West of the study area, the alluvium is overlain by Oligocene ash flow tuffs. Drill hole data indicate that the alluvium varies from less than 30 m thick in the hills directly northwest and north-northwest of the production pits, to over 150 m thick in the southwest part of the map area. The alluvium is an extremely poorly sorted diamict composed of subangular to subrounded pebbles, cobbles and boulders of chert, siltstone, quartz arenite, and volcanic rock.

Tertiary Intrusive Rocks

Intrusive rocks are widely distributed throughout the study area but are rarely exposed at the surface. The best exposures are in the middle and 401 production pits. For the most part, intrusive rock forms small dike or sill like bodies, less than 3 m thick that intrude stratigraphic discontinuities such as the Roberts Mountains thrust. Drill hole data indicate that some of the intrusive bodies thicken to 10 m or more at depth. All the intrusive bodies consist of aphanitic quartz porphyry. Small quartz phenocrysts are sparse. Aphanitic groundmass consists of intergrown quartz and sanadine with minor plagioclase. Alteration is generally intense and is characterized by groundmass silicification and alteration of feldspars to kaolinite, smectite and sericite. In the production pits primary textures are completely destroyed and the rock is altered to a quartz, sericite, pyrite assemblage. Oxidation of abundant pyrite gives the rock a distinctive ochre brown color.

Structural Geology

The Toiyabe Project displays a wide variety of structural elements. Some Structures are clearly related to the Antler Orogeny and Basin and Range extension. The origin of other structures is ambiguous at best. Structural interpretation is difficult because less than 5% of the Paleozoic bedrock is exposed. Lithologic boundaries have been mapped based on the distribution of colluvium. Often the nature of these boundaries has to be inferred from map patterns or broad scale regional relations. Additional constraint is provided by lithologic data from 133 reverse circulation, exploration drill holes. The production pits provide excellent exposures over a small area. Detailed mapping of the pits has generated a structural data set that augments the regional mapping. Figure 3 is a simplified geologic map of the study area that should help clarify details of the structure discussion.

Antler Age Structure

The most important structural element in the study area is the Late Devonian to Early Mississippian Roberts Mountains thrust. The thrust is responsible for the emplacement of Lower Paleozoic siliceous and volcanic rocks over coeval carbonate rocks. The map pattern reveals that the Roberts Mountains thrust is a highly irregular surface. Erosion has produced two structural windows, through the siliceous and volcanic rocks, that expose the underlying carbonate rocks. For clarity the northern

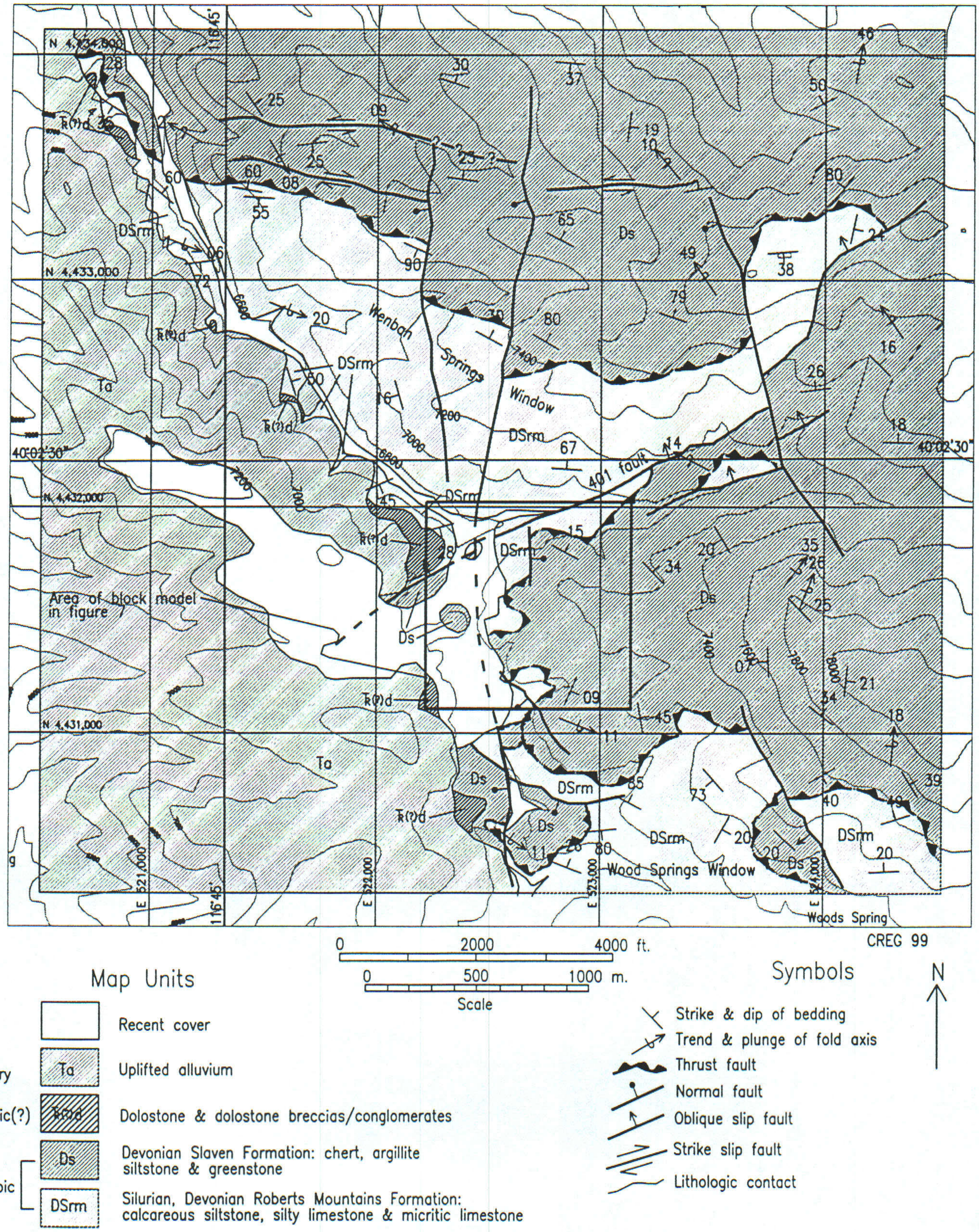


Figure 3. Simplified Geologic Map of the Toiyabe Project

and southern windows have been named the Wenban Springs and Wood Springs windows respectively. The complicated geometry of the structural windows is the result of the intersection of a highly irregular thrust surface with several generations of moderate to high angle, normal and oblique slip faults.

The production pits provide excellent exposures of the Roberts Mountains thrust along a 2500-ft interval. Exposures in the pits reveal that the Roberts Mountains thrust is comprised of a complex set of discontinuous, anastomosing, brittle shear zones. Shear zones range in thickness from hairline discontinuities to 4 m thick. The shear zones bound flat, interleaved lozenges and thrust slices of both carbonate and siliceous volcanic rocks, which are up to 15 m thick and 150 m long. Shear zones between thrust slices are generally sub-parallel to bedding. Classic duplexes, and associated ramp structures and footwall cutoffs are rare.

Both the autochthonous and allochthonous rocks are intensely deformed. Folding persists for at least 75 m below the Roberts Mountains thrust and is ubiquitous throughout the entire thickness of the allochthonous section. Figure 4 is a stereographic projection of linear structural elements from the 1:6000 scale map. Folds in upper and lower plate rocks are generally tight, and overturned to recumbent. Fold axes in the lower plate carbonate rocks commonly plunge gently to the south-southeast. Folds in the upper plate siliceous and volcanic rocks show more variation in attitude. West-northwest and south-southeast trending fold axes are dominant but north and northeast trending fold axes are also present. The variation in upper plate fold orientations is probably due to higher strain in the allochthonous rocks and/or rotation of imbricate thrust plates during thrusting.

The production pits provide the best exposures of lower plate structural elements and also clarify the relation between the tight overturned folds, in the upper and lower plate, and thrusting. Figure 5 is a stereographic projection of linear structural elements in the production pits. Folds are distributed throughout the entire upper and lower plate section exposed in the open pits. Boudins with eliptical to circular cross sections are found exclusively within shear zones. The lower plate folds, whose axes are plotted on the equal area projection, are essentially shear folds that develop in the manner depicted in figure 6. In the production pits, the shear planes that truncate fold limbs are roughly parallel to the larger shear zones that comprise the Roberts Mountains thrust. The tight overturned folds in the production pits, and by inference similar folds throughout the study area, are believed to be the

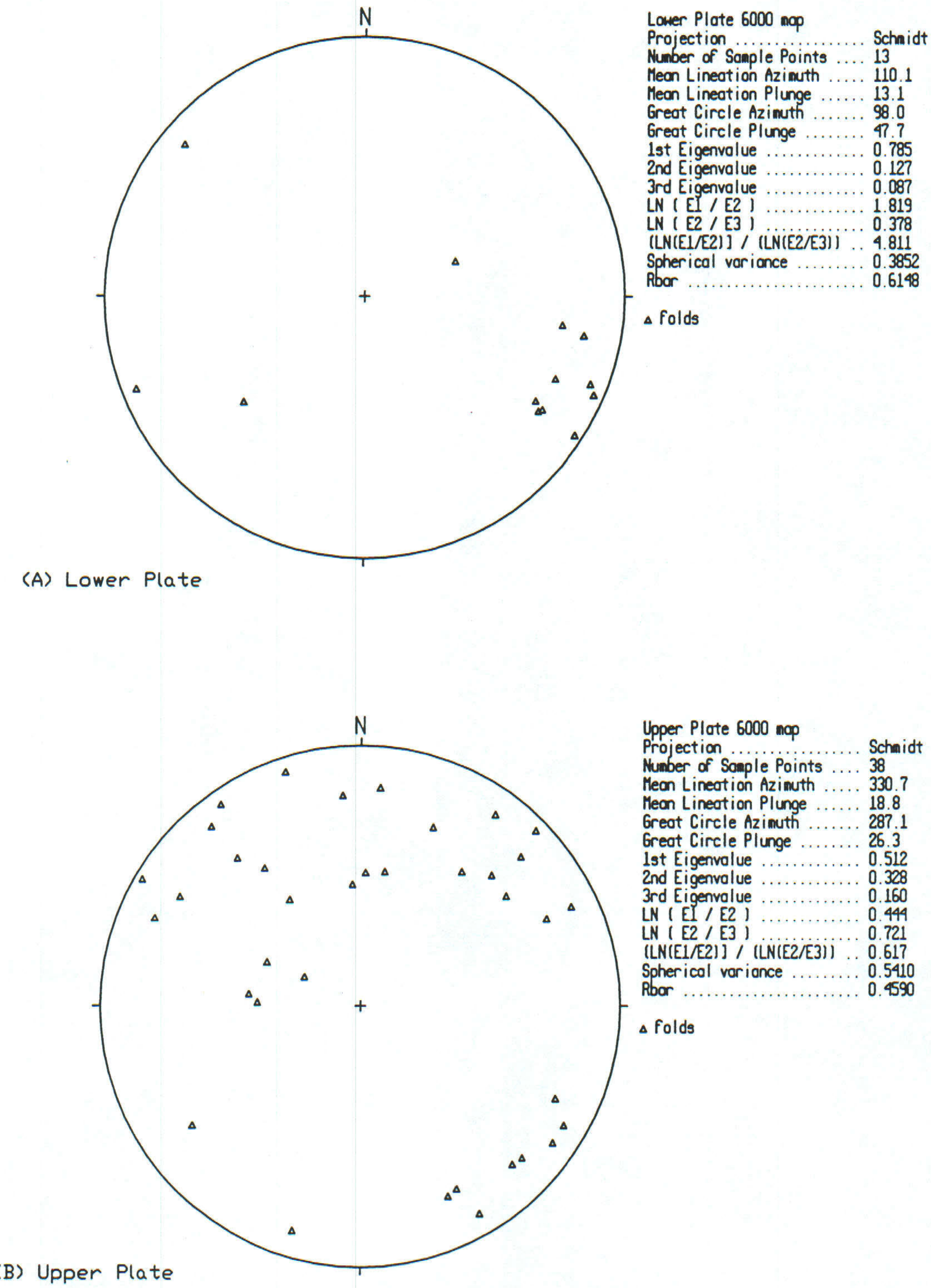
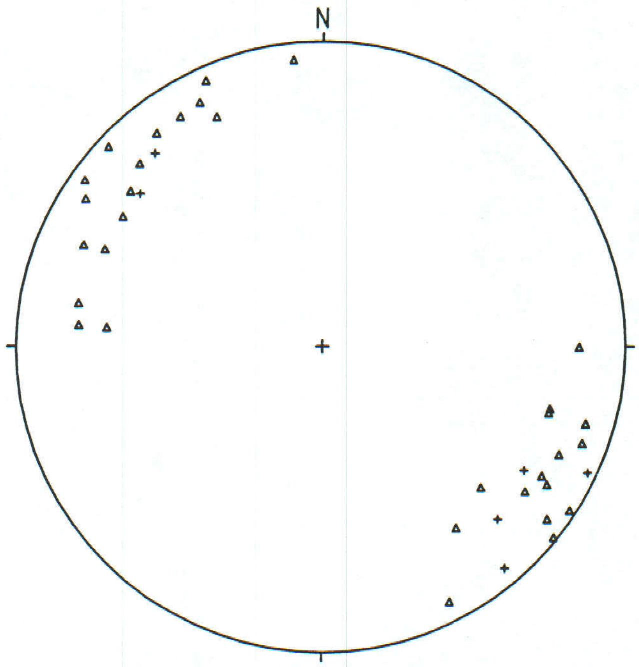


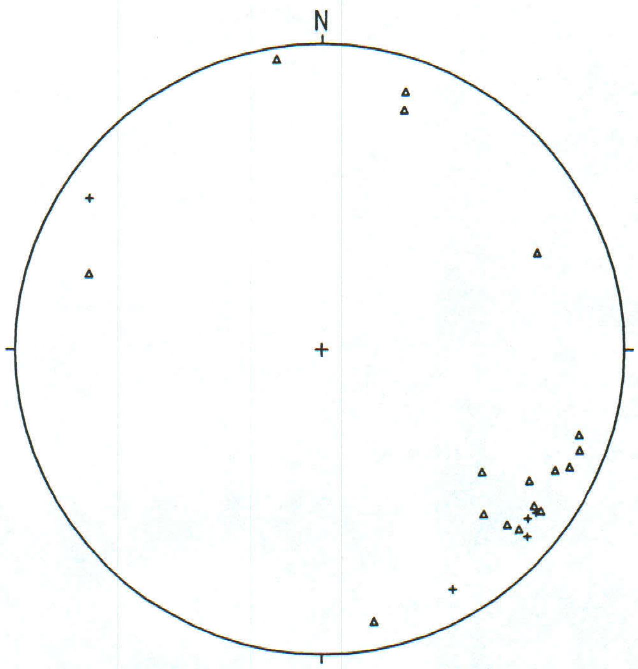
Figure 4. Linear Structural elements from the 1:6000 Scale Map



Linear elements L Plate Production Pits
Projection .... Schmidt
Number of Sample Points 39
Mean Lineation Azimuth 306.5
Mean Lineation Plunge 0.9
Great Circle Azimuth 304.5
Great Circle Plunge 23.4
1st Eigenvalue 0.839
2nd Eigenvalue 0.091
3rd Eigenvalue 0.070
LN (E1 / E2) 2.223
LN (E2 / E3) 0.256
(LN(E1/E2)) / (LN(E2/E3)) .. 8.697
Spherical variance 0.7507
Rbar 0.2493

△ folds
\+ boudins

(A) Lower Plate



Linear elements U. plate Production Pits
Projection .... Schmidt
Number of Sample Points 22
Mean Lineation Azimuth 129.0
Mean Lineation Plunge 10.5
Great Circle Azimuth 347.8
Great Circle Plunge 16.5
1st Eigenvalue 0.786
2nd Eigenvalue 0.180
3rd Eigenvalue 0.034
LN (E1 / E2) 1.476
LN (E2 / E3) 1.669
(LN(E1/E2)) / (LN(E2/E3)) .. 0.884
Spherical variance 0.3872
Rbar 0.6128

△ folds
\+ mineral lineations

(B) Upper Plate

Figure 5. Linear Structural elements from the Production Pits

result of Antler age deformation for two reasons. (1) The fold axes are subparallel to the long axes of shear boudins found within the shear zones that comprise the Roberts Mountains thrust. (2) The folds have formed by shearing along planes that are parallel to the larger shear zones that comprise the Roberts Mountains thrust. Fold axes and the long axes of the shear boudins are interpreted to lie perpendicular to the direction of maximum shortening that prevailed during Antler age deformation. The dominant northwest southeast, trend of Antler age, linear structural elements indicates northeast directed thrusting in this area during the Antler Orogeny.

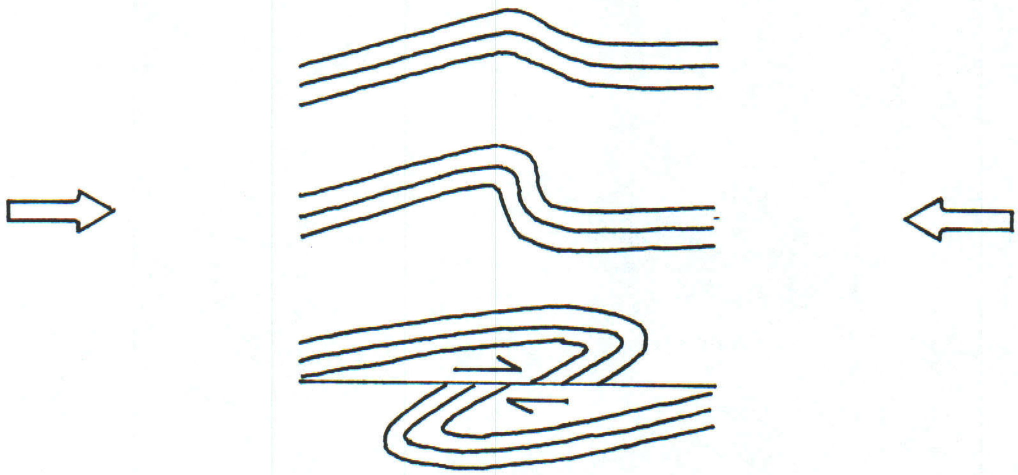


Figure 6. Development of shear related folds during thrusting

Post Antler Age Structure.

Late Paleozoic-Early Mesozoic dolostone.

The dolostone unit that forms discontinuous outcrops along the western half of the study area is structurally quite different from the Lower Paleozoic units that underlie it. The dolostone cuts across the Roberts Mountains thrust and rests on top of carbonate rocks of the lower plate and siliceous and volcanic rocks of the upper plate at different localities. This requires that either the dolostone was deposited unconformably on top of the Lower Paleozoic units subsequent to the antler orogeny, or that it was tectonically emplaced over the Roberts Mountains Formation and Slaven Formation sometime during or after the Antler Orogeny. In support of the second hypothesis, this unit has been regarded by numerous industry geologists, and by Roberts & Madrid (1990), as a thrust sliver of the Ordovician Hanson Creek Formation. In the absence of biostratigraphic data, the Hanson Creek hypothesis cannot be disproved. However several pieces of evidence are at odds with this hypothesis. First, all the Lower Paleozoic units are intensely deformed and the Roberts Mountains thrust itself is highly irregular. In contrast the dolostone is almost completely undeformed at the outcrop scale. Second, the outcrop pattern and drill hole data indicate that the dolostone unit is a fairly continuous, approximately 25 to 50 m thick sheet, which dips uniformly 5 to 10° to the west. The sheet-like and undeformed nature of this unit indicates it may have been deposited subsequent to the Antler Orogeny.

Cenozoic Structure

Moderate to high angle faulting dominates Cenozoic structure in the study area. Most faults appear to be Cenozoic but reactivation of older structures cannot be ruled out. At least three generations of moderate to high angle faults are present in the study area. Only structures with offsets greater than 100 m are obvious outside of the production pits. The earliest structures are northwest to north-northwest striking, moderately to steeply dipping faults. Displacement is usually normal but at least one northwest striking structure in the southeast corner of the map area displays dextral, oblique slip. In the production pits offsets along these structures average 10 to 20 m. The northwest striking faults are dominantly northeast dipping in the south pit and southwest dipping in the middle and 401 pits indicating a shallow graben between the middle and south pits. Slip surfaces are moderately planar and are characterized by 10 to 50 cm of crush micro-breccia and/or gouge. Fault surfaces may be either subparallel to bedding or cut bedding at high angles. The larger structures are continuous from the bottom to the top of the pit wall. Many of the smaller structures cannot be traced for more than one or two benches and often flatten into bedding parallel slip planes. The flattening may indicate that some of the NW striking faults are actually thrust related ramp structures that have been reactivated during extension. In the 401 and middle pits the northwest striking structures cut dikes believed to be Oligocene in age.

East-northeast to northeast striking faults comprise the second generation of moderate to high angle structures. The largest of these faults cuts through the northern edge of the 401 pit and forms part of the southern margin of the Wenban Srings window. For purposes of clarity this fault is named the 401 fault. Another east-northeast striking fault is located east of the 401 pit in the canyon, and a third is located approximately 2-km north of the 401 pit at the northern margin of the Wenban Springs window. The exposure in the 401 pit and drill hole data reveal that the 401 fault dips moderately to steeply to the north. Along the southeast margin of the Wenban Springs window the 401 fault places Siluro-Devonian Roberts Mountains Formation above Devonian Slaven Formation. West of the 401 pit, the 401 fault is offset by a Basin and Range structure and then displaces the western dolostone unit in a dextral sense. To account for these relations the 401 fault is interpreted to be an oblique slip fault with both dextral and reverse components. The 401 fault cuts northwest striking normal faults in the 401 pit and is tentatively interpreted to postdate the northwest striking faults. However, gold mineralization and hydrothermal alteration indicate that movement along the 401 fault was both pre and post mineral (more on this later). As a result, the actual age of the 401 fault cannot be constrained beyond being pre-Basin and Range. Because the original age of the northeast striking faults cannot be determined, it is possible that they pre-date the northwest striking normal faults.

North-northwest to north striking normal faults associated with Basin and Range extension comprise the latest generation of moderate to high angle structures. Associated with the normal faults in the northern part of the map area are east west striking, strike slip faults. Slip vectors for the strike slip faults are derived from well developed quartz slickenfibers. Drillhole data and offsets of earlier structures indicate that displacement along the Basin and Range age normal faults may exceed 150 m. Displacement along the associated strike slip faults is more difficult to establish because they do not cut earlier structures. Fault surfaces of the strike slip faults are usually simple slip planes without fault rock. The lack of fault rock probably indicates that displacement is small compared to the north trending normal faults. The strike slip faults are interpreted as minor slip planes that compensate for differential movement between adjacent blocks that are moving down to the west along the N trending normal faults. Three major north to north-northwest trending normal faults cut through the northern half of the map area. All dip to the west and offset the northern boundry of the Wenban Springs window. The middle fault cuts through the saddle area directly west of the production pits and continues south through the canyon to the southern edge of the map area. The western fault cannot be traced completely through the Wenban Springs window and may be a splay of the middle fault. The eastern fault offsets the eastern part of the Wenban Springs window.

Mineralization

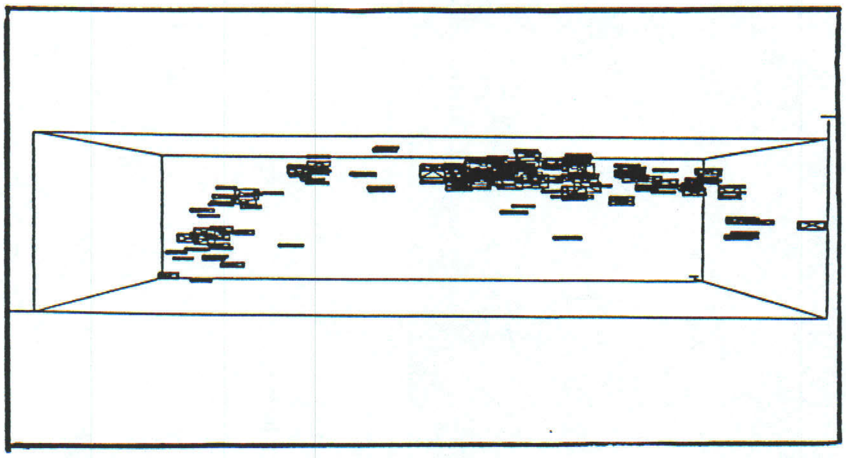
Mineralization at the Toiyabe mine consists of finely disseminated "invisible" gold typical of Carlin style gold deposits. The production pits sit within the oxide part of the mineralized zone. Pyrite, if originally present, has been destroyed. Hematite and goethite staining of the Roberts Mountains Formation and the overlying transitional conglomerate are probably the result of oxidation of both diagenetic and secondary pyrite. Unoxidized refractory ore is visible in the floor of the middle and south pits. In the unoxidized part of the ore body the Roberts Mountains Formation is weakly to moderately carbonaceous and contains less than 1-% submillimeter flecks of anhedral pyrite. Gold grades vary from subeconomic to 0.5 oz/ton.

Modeling of the Toiyabe ore body is difficult because geochemical and geologic data from the period of production no longer exist. An attempt to model the ore body has been made using assay data from closely space exploration drill holes that were drilled prior to production. Figure 7 shows the block model constructed from the drill hole intercepts. The block model is approximately 625 m thick and 3000 m square. The location of the block model is shown in figure 4. The ore blocks shown in figure 7 are based on a 0.05 oz/ton cutoff. Intercepts less than 10 ft thick were excluded from the model.

Figures 7(A) and 7(B) are views of the block model looking north and east respectively. These two perspectives reveal that the bulk of the ore body is remarkably tabular. The tabular morphology indicates the importance of the Roberts Mountains thrust in controlling mineralization. The most significant exception to the tabular morphology is found at the northeast end of the ore body. The ore blocks in this area define an east-northeast trending zone that dips moderately to the north. The dip is clearly seen in 7(B) and the east-northeast trend in 7(C). This ore zone is coincident with the north dipping 401 fault. Several factors indicate that the 401 fault is the main ore fluid conduit at the Toiyabe project. (1) The ore blocks at the northern end of the deposit are almost exactly coincident with the 401 fault and the ore trails off down the structure well below the level of the main ore body. (2) Two other resources, one to the northeast in the Wenban Springs window, and another to the

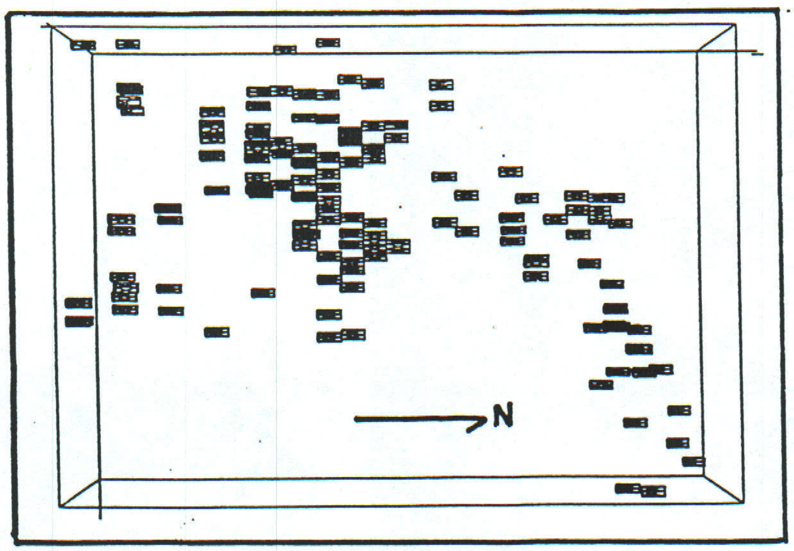
Looking North

(A)



Looking East

(B)



Looking Down

(C)

Figure 6. Ore Block Model of Toiyabe Gold Deposit

west-southwest under the process area, lie in close proximity to the 401 fault. The main tabular part of the ore body appears to be connected to the 401-fault mineralization by a discontinuous north-northwest trending zone (figure C). This zone is roughly coincident with the trace of northwest trending normal faults in the 401 pit. Ore fluids probably ascended along the 401 fault and then bled out to the south-southeast along the northwest trending structures. The main tabular ore body formed where the northwest trending structures intersected an especially favorable zone of prepared ground in the Roberts Mountains thrust. Mineralization in the southern end of the block model, in the south pit, is probably related to a large northwest striking normal fault that is exposed in the south highwall.

Alteration

Hydrothermal alteration at Toiyabe consists of weak to strong decarbonatization, weak to moderate silicification, and argillization. The exact relation of alteration to metallization cannot be determined because geologic data from the drill holes in the block model no longer exist. However, the relation between alteration and structure has been established through detailed pit mapping. Figure 8 is a simplified alteration map of the production pits. Argillization is confined to the immediate footwall of the 401 fault indicating fluids were fairly acidic as they ascended along the fault. Notably, the recrystallized limestone that makes up the hangingwall of the 401 fault is completely unaltered. Clearly the crystalline limestone must have been moved into its present position subsequent to alteration. This implies that the 401 fault was reactivated sometime after the mineralizing event.

In the 401 pit weak to moderate decarbonatization is largely confined to the footwall of a northwest striking normal fault. The weak to moderate decarbonatization becomes more tabular at the south end of the 401 pit and forms irregular semi-tabular bodies, usually just be below the Roberts Mountains thrust, in the middle and south pits. Strong decarbonatization is relatively rare and is usually confined to within a few meters of major structures. In the oxide zone, strongly decarbonatized rock is usually bleached, very light and porous, and sometimes dissagregates into argillaceous sand.

Weak silicification is the most common alteration type at the Toiyabe mine. Fine veinlets and vug fillings of quartz characterize weak silicification. In the 401 pit weak silicification is confined largely to the footwall of the large normal fault that cuts through the entire length of the pit. Weak silicification becomes more tabular at

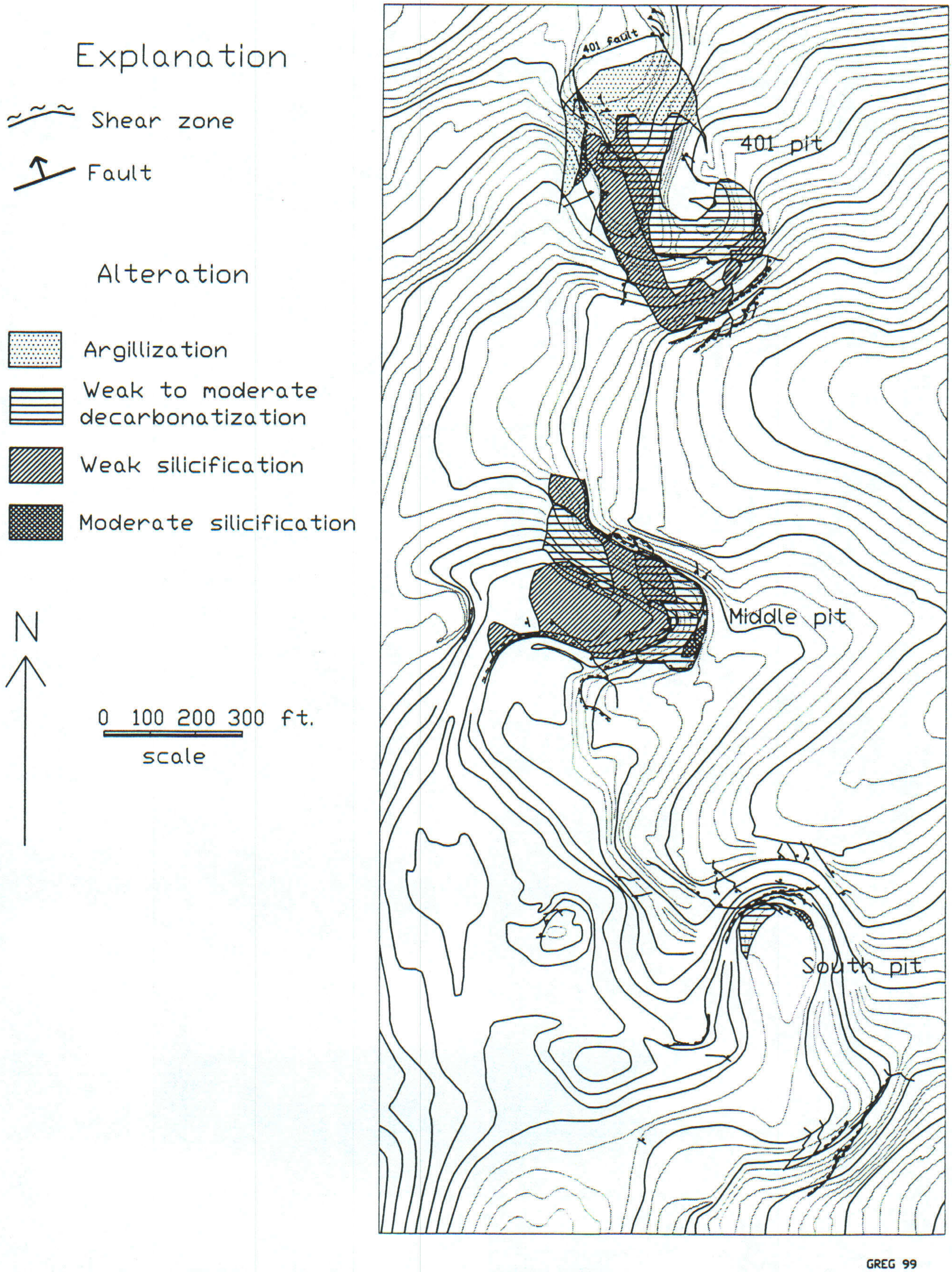


Figure 8. Simplified Alteration Map of Toiyabe Mine Production Pits

the south end of the 401 pit, and in middle pit, and dies completely in the north wall of south pit. Moderate silicification is relatively rare and commonly forms narrow zones around northwest striking normal faults or along shear zones. Moderate silicification tends to destroy or obscure the laminate bedding of the Roberts Mountains Formation and produces a hard, dark gray rock that yields with difficulty to a rock pick.

Conclusions

The geology of the Toiyabe Project area is dominated by Lower Paleozoic miogeoclinal carbonate rocks and eugeoclinal siliceous and volcanic rocks, which are juxtaposed by the Late Devonian to Early Mississippian Roberts Mountains thrust. Other rock units include an enigmatic dolostone, felsic intrusive rocks of probable Tertiary age, and uplifted Tertiary alluvium. Lower Paleozoic carbonate rocks consist dominantly of calcareous siltstone with subordinate silty limestone and have been tentatively identified as the Siluro-Devonian Roberts Mountains Formation. Lower Paleozoic siliceous and volcanic rocks consist of chert, argillaceous chert, siltsone, argillite, and minor greenstone. The siliceous and volcanic rocks have been tentatively identified as the Devonian Slaven Formation. The enigmatic dolostone consists of massive dolostone, dolostone breccia, and dolostone conglomerate. The designation of this unit as the Ordovician Hanson Creek Formation is probably an error. Based on structural relations the dolostone is probably late Paleozoic or Early Mesozoic in age. Felsic intrusive rocks consist of small dikes and sills of aphanitic quartz porphyry. Uplifted Tertiary conglomerate covers the western half of the Toiyabe Range and consists of a coarse diamict containing cobble to boulder sized clasts of chert, quartz arenite, and volcanic rocks.

Structure in the Toiyabe project area is complex. At least 4 episodes of deformation have affected the map area. The earliest structures consist of low angle shear zones and thrust faults, and tight, overturned to recumbent, southeast or northwest trending folds that formed during the Late Devonian to Early Mississippian Antler Orogeny. The dominant structural grain of all thrusting related structures northwest or southeast indicating northeast directed thrusting in this area during the Antler Orogeny. The next deformational episode involved extension in a northeast southwest direction producing a set of relatively minor northwest trending normal faults. In the production pits these faults cut the felsic intrusive rocks and are probably younger than middle Oligocene. Third Generation structures consist of east-northeast to northeast trending, steeply to moderately dipping, oblique slip faults with both dextral and reverse slip components. In the production pits these faults cut the northwest striking normal faults. However, hydrothermal alteration and mineralization patterns indicate some of these structures were re-activated subsequent to mineralization. Consequently, the original age of the northeast trending structures cannot be stated with confidence. The latest generation of structures consist of north to north-northwest striking normal faults that dip steeply to the west. These faults roughly parallel range front boundaries and are probably related to Basin and Range extension.

Mineralization at the Toiyabe mine consists of finely disseminated "invisible" gold. Gold mineralization was probably accompanied by weak pyritization. Block models of the Toiyabe mine ore body indicate that the locus of ore deposition was controlled by the moderate to high angle northeast and northwest trending structures, and by low angle shear zones within the Roberts Mountains thrust. The geometry of the northern end of the deposit suggests that the northeast trending, north dipping, oblique slip 401 fault was the primary ore fluid conduit. Hydrothermal alteration consists of weak to strong decarbonatization, weak to moderate silicification and argillization. Strong decarbonatization, argillization and moderate silicification are localized in narrow zones along moderate to high angle faults. Weak silicification and weak to moderate decarbonatization form broader tabular zones that are capped by the Roberts Mountains thrust. Weak silicification appears to form broad tabular zones that are most coincident with ore zones.

References Cited

Gilluly, J., and Mazursky, H., 1965, Geology of the Cortez quadrangle, Nevada: U.S. Geological Survey Bull. 1175, 117 pp.

Madrid, R., and Roberts, R., 1990, Evaluation of the ore reserve potential of the Inland Gold and Silver Corp. Toiyabe property: Contract Report for Inland Gold and Silver Corp.

Stewart, J., and Mckee, E., 1969, Geologic map of the Carico Lake quadrangle, Nevada: U.S. Geological Survey Open-File Report 69-268

Stewart, J., and Mckee, E., 1969, Geologic map of the Hall Creek and western part of the Walti Hot Springs quadrangle, Nevada: U.S. Geological Survey Open-File Report 69269