Field Guide to the Superior District, Pinal County, Arizona

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Guidebook for the
Arizona Geological Society
Fall Field Trip
October 28, 1995

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Arizona Geological Society
PO Box 40952 Tucson, AZ 85717

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Tucson, AZ 85717

October 28, 1995

Dear Field Trip Participant,

Welcome to the 1995 AGS Fall Field Trip to examine the Geology and Ore Deposits of the Superior District in Pinal County, Arizona. The trip is split into two sections with part of the group going underground at the Magma Mine, owned and operated by Magma Copper Company. Our hosts, Alex Paul and Matt Knight will educate us about geology and mining of the Superior Copper Deposit. At the same time, Jim Sell will be conducting a tour describing the surface geology of the Superior District. The road log that Jim has prepared is very informative and entertaining.

I would like to thank several people who have been invaluable in the preparation of this field trip and the guidebook: Jim Sell for assembling the guidebook and organizing the surface tour of the district, Kathie Harrigan at Asarco for word processing, and Rob Vugteveen for editing and desktop publishing. Without their help this event would not have been possible.

Enjoy the day!

Sincerely,

Mark

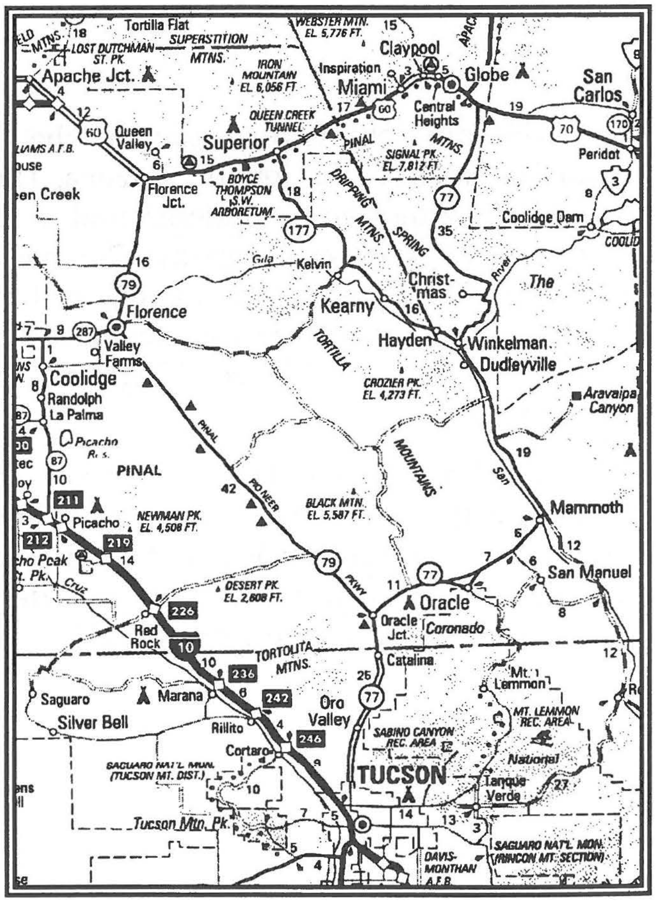
Mark Miller
Vice-President of Field Trips

Starting in **Tucson**, we'll follow

Arizona Highway 77 north to **Oracle Junction**,

Arizona Highway 79 northwest to **Florence Junction**,

US Route 60 east to **Superior**.



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ORACLE JUNCTION – FLORENCE – SUPERIOR

Note, as the first freebie, you get the road log from Ina Road, however, you probably will not see the Guidebook until Oracle Junction, so this part is for your leisure trip in the future. Happy Outing!

Mile Post	Cumulative Mileage	
74.8	0.0	Ina Road at Oracle Highway. This log utilizes the GREEN Arizona milepost markers located each mile. From Tucson, the Oracle Highway has climbed several terraces of the Rillito River system and presently traverses over the outwash fans from the Santa Catalina Mountain Complex. The Santa Catalina Mountains (1-3 o'clock) are a metamorphic core complex. (Banks, 1976; Keith, 1980) The Tucson Mountains and Safford Peak (7-9 o'clock) are part of a volcanic complex (Mayo, 1963, 1968). Far away, Ragged Top and the Silver Bell Mountains (9-10 o'clock) peer through the haze. (See AGS Field Trip #10, 1981). At 11 o'clock, the Tortolita Mountain Range occupies much of the view (Banks, 1976, 1977). For the next several miles, note the profusion of townhouses, condos, and Circle K varieties of foothillies who live above the lower Tucson haze habitat. At the left end of the Tortolita Mountains, on a good day, the top of Picacho Peak can be seen (Shafiquillah, 1976). Picacho Peak in the past was a landmark for travelers leaving the Presidio de Tucson and making their way to the Pima Villages and thence to California via the Gila River. Now the Picacho Peak area is probably best known for the ostrich farm at its base.
77.2	2.4	Start to drop off the fan deposits. Excellent end-on view of Pusch Ridge (3 o'clock)--home of the Arizona Big Horn Sheep and the dissertation of McCullough (1963).

Mile Post	Cumulative Mileage	
79.0	4.2	The Cañada del Oro drainage has a wide outer flood plain which has been truncated, and then entrenched by itself, in the gravel-mudstone terrace fan deposits (which you passed through on the long curve between MP 78 and 79). Vegetation of mixed desert broom, mesquite, palo verde. As you continue north, note the two terrace development levels on your right. Pusch Ridge escarpment (3 o'clock).
80.5	5.7	Before the new road construction, there was an Arizona Highway Department roadside marker here (9 o'clock). *"Cañada del Oro. For earlier travelers, the road through this Canyon was one of the most dangerous to Arizona. Indians attacked lone riders and wagon trains along this route from Tucson to Old Camp Grant on the San Pedro River. Despite the Canyon's name, very little gold was ever found here."* Press on, but not too fast, as the Oro Valley police like to catch speeders along here and collect their own gold!
		Peering over the gravel deposits (2 o'clock), prior to traversing the bridge over the Cañada del Oro stream, you will note a ridge of the metamorphic complex exhibiting a large amplitude fold.
80.9	6.1	Bridge over Cañada del Oro. At 2:30 o'clock, looking down axial plane of the anticlinal fold (Pashley, 1963; McCullough, 1963).
81.5	6.7	Climbing out of Cañada del Oro, with the road alongside Big Wash cutting through dissected gravel-silt terrace deposits.
81.8	7.0	Good view (4 o'clock) of the anticlinal folding in metamorphic complex along lower slope of range.
82.0	7.2	View of terrace surfaces (9 o'clock).
82.2	7.4	The rough "granite" exposure (3 o'clock) at the foot of the Santa Catalina Mountains is the quartz monzonite (20-24 my) of Samaniego Ridge, as are the upper skyline crags (Banks, 1976; Creasey, *et al.*, 1976).
		In the Tortolita Mountains (9-11 o'clock), the low foothill granites are a younger phase of the Catalina Complex (Creasey, *et al.*, 1976; Banks, *et al.*, 1977).

Mile Post	Cumulative Mileage	
84.8	10.0	White scars (2:30 o'clock) in the Tortolita Mountains are marbleized Permian units being quarried for roof covering, front yard decoration, etc.
85.1	10.3	Ex-missile silo complex (2 o'clock). Sleep Tight, Big Brother was Watching Over You. Now it's a land fill area.
86.0	11.2	Welcome to Trailerville—Land of Sunshine and Hope. The Tortolita Land Plan Complex on left side of road expected "100,000 people by 1985". Buy now! Oops, may be too late in 1995 to get in on the ground floor, but you can still purchase a pink-roofed home back at Rancho Vistoso, or be an early one here.
87.8	13.0	Entering Pinal County. Horse breeder-training complex (2-3 o'clock) — a very nice addition to the visual impact of the area, however, the fences need repainting.
90.5	15.7	Junction with Arizona Highways 77 and 79, and our starting point for AGS Fall Field Trip, 1995, is one-half mile ahead.
91.0	16.2	Oracle Junction. See Arizona Bureau of Mines (now Arizona Geological Survey) Bulletin 176 (Peirce, H.W., 1976) for road log to Oracle and north along Highway 77, or see AGS Spring Field Trip of 1994.

RESET YOUR ODOMETER TO ZERO AT ORACLE JUNCTION.

91.1	0.0	Oracle Junction, take left road to Florence on AZ 79.
91.4	0.4	Entering Pinal Pioneer Parkway. Monument built of schist, gneiss, quartzite, granitoids, and quartz vein materials from Tortolita complex, plus odds and ends of epidote, azurite, malachite, and chrysocolla. Vegetation here is dominantly catclaw, mesquite, desert broom, various cholla, yucca, prickly pear, and hackberry (Wells, 1960).
91.5	0.5	Bridge over Big Wash. Note the ground cover difference between Parkway and outside of grazing fence. High fire fuel feed along the Parkway is easily set afire and then burns large swaths into outside grazing areas.
96.0	5.0	Black Mountain with Tortolita Mountains and Antelope Peak behind (1-2 o'clock). Galiuro Range across San Pedro River in far skyline (3-4 o'clock) (See AGS Spring Field Trip, 1994).

Mile Post	Cumulative Mileage	
98.0	7.0	Durham Hills-Owl Heads (10 o'clock) in near range of hills. On skyline is massive "granite" (grey) of Picacho Mountain complex (10-11 o'clock) (Yeend, 1976), with jagged volcaniclastic units (dark grey black) of Picacho Peak at far 2 o'clock. (In between, 65 miles away, in further background, are Table Top Mountains located southwest of the Sacaton Mine.) Note that the vegetation here at 3,400 feet has given way to palo verde, cholla, prickly pear, catclaw, greasewood flora.
99.0	8.0	Volcanics at 12 o'clock with former Titan missile site at base. As you go around the corner, you'll see it is now a ranch house area.
99.7	8.7	Conglomerates in curve roadcut (Ts of Banks, *et al.*, 1977).
100.3	9.3	Three Buttes at 9 o'clock. (Banks, *et al.*, 1977), map Tbasalt intruding Tos, older sediment, and Tys, younger sediments.
101.4	10.4	Junction; stay on Pioneer Parkway. The road left is Park Link Drive to Red Rock and Eloy. Ragged Top and Silver Bell Mountains in far distance (9:30 o'clock). (See Field Trip #15, AGS Fall 1994, "Bootprints"). Owl Head Buttes, 6 miles away at 9 o'clock.
101.9	10.9	Cadillac Wash Bridge with reddish conglomerates (Tos?) in right hand wash wall and bottom. Named many years ago for the brand new Cadillac which was caught in a desert rain runoff and washed downstream and buried by the sand in the days before bridges.
102.3	11.3	Low rolling slope, at 9 o'clock next to road, is a dike of Tertiary basalt with undifferentiated Tertiary sediments on both sides (probably Tys).
102.5	11.5	Conglomerate in roadcut on curve before Forman Wash Bridge.
104.0	13.0	Suizo Mountains (10-11 o'clock). Picacho Peak and Mountain in far background.
104.3	13.3	Olson Wash Bridge with Tertiary basalt in right side wash wall.
104.6	13.6	Roadcuts in "schist-gneiss" of Oracle Granite derivation.

Mile Post	Cumulative Mileage	
106.0	15.0	Vegetation at 2,800 foot elevation, giving way to greasewood (creosote bush), catclaw, palo verde, and saguaro assemblage.
108.0	17.0	Northern end of Durham Hills (10 o'clock) with pinkish Samaniego granite having a medium grey diorite border phase on last hill (11 o'clock). Entering magnetic sand project of Black Sands Iron Corporation. Do you have any stock???
110.0	19.0	Ninety Six Hills area (3 o'clock) and Picacho Peak Mountain (9-10 o'clock) showing through dense cover of palo verde and cholla forest. (What? A forest in this part of Arizona?)
111.6	20.6	Freeman Road cutoff to Dudleyville, with Pinal Schist hills (1 o'clock) cut by aplite, pegmatite, and dike of Samaniego diorite phase. Minor copper oxide occurrences.
114.0	23.0	Welcome to the Great American Pinal Parkway desert, with more saguaro now appearing.
115.5	24.5	Tom Mix Memorial rest area. *"Jan. 6, 1880 – Oct. 12, 1940... who's spirit left his body on this spot..."* No paved road and bridges then — just a dirt road and dips, which flipped his speeding vehicle.
117.0	26.0	Low hills (2 o'clock) of muscovite granite cut by numerous and diversified dikes of the 96 Hills SW complex.
117.9	26.9	Deep Well Ranch Road to left. Access to the Phillips Arizona State A-1 hole which bottomed at 18,013 feet, and the North Star Mine area.

As expressed by Reif and Robinson (1981), the State A-1 penetrated 700 feet of alluvium, then stayed in granite wash (valley fill) to 3,879 feet. Then, granite to granodiorite (Unit 1) of 1.39 billion year age was cut to 10,761 feet. Unit 2, a muscovite granite with a 47 million year age, was encountered to 12,755 feet. Unit 3, a biotite hornblende gneiss of plus 1.5 billion year age, completed the run to 18,013 feet T.D.

The two-mica granite of Unit 2 is highly brecciated and the base is probably the site of a large subhorizontal fault. Do you believe in large, or small, subhorizontal faults?

Mile Post	Cumulative Mileage	
		The North Star Mine area (Yeend, 1976) is in the low hills (10 o'clock) on north end of Picacho Mountains. Need to know more? Ask D. Hammer.
121.4	30.4	Leaving Pinal Pioneer Parkway.
125.0	34.0	Grayback Peak peeking through the forest at 3 o'clock.
127.6	36.6	Cactus Forest Junction. Note the 8-foot high round rock structure on the northeast side of the junction (look right). It is built out of altered and leached capping boulders with copper oxide. Probably from the Red Hills deposit off to the right. Also a few granite and latite boulders in the structure. Note flora change at 1,700 feet elevation to greasewood-cholla-saguaro format.
130.0	39.0	Superstition volcanic complex (1-2 o'clock) on far skyline, (Sheridan and Prowell, 1986.)
		North and South Buttes (3 o'clock), potential site of Buttes Dam of Central Arizona Storage Project. Note younger 'rift' volcanic complex behind the Buttes.
		Pinal Mountains (4 o'clock) is the far semi-rounded mass.
		Sacaton-San Tan Mountains complex of Balla, 1972 (10-11 o'clock).
		"F" Hill at Florence is the Poston Butte basalt (12 o'clock).
131.5	40.5	Ocotilla now appearing as part of the flora.
132.0	41.0	One-way road split. Keep right on AZ 79 North. Crossing CAP canal—the Lifeblood of Tucson!
133.0	42.0	Florence, Arizona. State Prison and fields on right. Do not pick up lady hitchhikers.
135.0	44.0	Poston Butte (11 o'clock), with rock pyramid on top. Basalt flows, tilted, with altered Precambrian granite at western base (AGS Fall Field Trip, 1973). Discovery outcrop of Asarco's Poston Butte Project, drilled with few holes and dropped, later picked up by Conoco (5 days ahead of Asarco's re-interest) and abundant drilling and $$$$$$ invested. Shaft and office building south of the butte; project put on the shelf. Now being drilled and evaluated by Magma Copper Company, and new home for Cori.
		Walker Butte cone at 9 o'clock.
135.2	44.2	New prison complex filling fields on right.

Mile Post	Cumulative Mileage	
135.5	44.5	Gila River Bridge. Associated flood plains of several stages, and wide inner terrace with shallow Gila River entrenchment.
135.9	44.9	ADH historic sign on left (west). *"Poston Butte – Final resting place of 'Father of Arizona', Charles D. Poston, born Kentucky, 1825, Arizona's first delegate to Congress is buried in accordance with his wishes atop the hill two miles west. It was to have been the site of Poston's Temple To The Sun, but that effort failed and he died in poverty in Phoenix in 1902. Not until years later were his remains brought to the place called Parsee Hill, but known to the local residents as Poston's Butte."*
136.4	45.4	Railroad crossing. Rails go upriver to Ray-Hayden-San Manuel.
136.8	45.8	Florence Federal Detention Facilities (former WWII POW camp) on left, followed by retirement trailers for sunshine and golf.
137.5	46.5	Near low hills (1 o'clock) of basalt interlayered with gravels of the Gila River system. Major skyline (2-3 o'clock) is mainly a volcanic-tuff-conglomerate complex of mid-Tertiary age. View (3 o'clock) of North and South Buttes in mid-background, with Gila River drainage in between. On far background to right of South Butte is the Grayback Mountain cone.
138.2	47.2	Rising out of the road (12 o'clock) is the Three Peaks of the Mazatzal Range, some 65 miles away.
139.0	48.0	Superstition Mountains volcanic complex (11-1 o'clock). Smog of Phoenix to left. Left side cliff face of Superstition is the Geronimo Head dacite, the oldest intrusive-extrusive of the complex. Note layered flows to right, then jumbled units which are the youngest of the complex and lie within the rift portion. Far right background is schist-gneiss Precambrian complex on the far side of the rift. As at the Buttes area, outflow units lap out onto the higher basement walls on both sides of the rift.
140.4	49.4	Road on the left to Arizona Farms. At the northeast corner of the junction, a local air-hammer driller (on State Lease) drilled through the surface sands and gravels, then a layer of basalt, and back into gravels. While daydreaming and drilling ahead, the hole ballooned on him and cuttings piled up behind the bit and he was stuck before he could

Mile Post	Cumulative Mileage	
		react. All tools and the rig were abandoned for several weeks before he returned and was successful in working the string free. Ah, those good olde days!
142.0	57.0	Increasing better views of Superstition Mountain in front. Near skyline masses at 3 o'clock are Precambrian Pinal Schist with rift volcanics peeking from behind. At 2 o'clock is small white outcrop at base of schist—a weakly altered porphyry having its share of drill holes in it.
147.1	56.1	Left side of road across fence are pits and piles left from an oil well test. The 20-inch hole cratered and the hole abandoned in the gravels.
148.0	57.0	Change in flora to greasewood with mesquite and ironwood in drainage.
148.3	57.3	Magma Arizona Railroad
149.0	58.0	Low hills in front (1-2 o'clock) are dacite of Geronimo Head resting on Precambrian granite. These are outside the inner rift boundary.
150.2	59.2	Florence Junction. Keep right to Superior on US 60 East.
150.7	59.7	Hardys Turquoise Factory on left.
	NOTE:	AZ highway marker number designation changed at the junction. Total cumulative mileage continues.
213.0	59.7	Hardys Turquoise Factory. Closer view of dacite (9 o'clock) at south side of Superstition Range. The volcanic unit rests on Precambrian granite and Apache Group.
214.3	61.0	Queen Valley Road to left, and crossing Magma Arizona Railroad. Stay on US 60 east.
214.5	61.2	Pink brown dacite hills (12 o'clock) resting on grey-green Pinal Schist on hills behind.
215.0	61.7	At 10 o'clock, a quick glimpse of valley with reddish dacite on left, gray-green schist on right. Beyond is jumbled volcanics in rift. Far skyline is Precambrian metamorphic complex. At 9 o'clock, a good view of Weaver's Needle within the Superstition Wilderness area.
215.9	62.9	9-10 o'clock. View of younger jumbled units within rift.
216.7	63.4	3 o'clock. View of outflow dacite block with Precambrian Pinal Schist in gulch.

Mile Post	Cumulative Mileage	
218.0	64.7	Climbing up through Pinal Schist.
218.6	65.3	Gonzales Pass. Occasional glimpses (9 o'clock) of jumbled volcanics in lowered rift zone, flanked on road side by Precambrian schist, with Precambrian metamorphics on skyline in back on northern side of rift.
219.2	65.9	Hulk of Picketpost Mountain at 12 o'clock. (Nelson, 1966).
219.5	66.2	12 o'clock. View into Superior with Precambrian basement and sediments through Pennsylvanian Naco Limestone overlain by Tertiary dacite with Whitetail Conglomerate here and there between the limestone and dacite. Tertiary Earlier Volcanics underlie the dacite to the north.
221.0	67.7	Roadcuts with schist overlain by red ash (Olbreg beds of Blucher (Sell, 1968) overlain by dacite and water-lain tuffs. These tuffs are found on schist for the next several miles on both sides of the road.
221.2	67.9	Roadcut in Blue Basalt of Blucher (Sell, 1968).
221.7	68.4	Mined bench cuts of water-lain tuff (1 o'clock) near road was used for flagstone and building blocks around Superior. On left, in roadcut, Precambrian Pinal Schist overlain by 30- degree east dipping red ash beds overlain by blue basalt, then cut by a 70-degree west dipping fault; then, the schist-red ash-basalt sequence repeated. Last third of roadcut is all blue basalt cut by numerous vertical fault breccia zones. On the initial portion of the roadcut, in the right (south) wall, a unit of red ash is draped over a faulted schist block, which is repeated as on the north wall.
222.0	68.7	9 o'clock. View of jumbled volcanics in rift at distance. Next several roadcuts in Blue Basalt.
222.2	68.9	Queen Creek Bridge with Blue Basalt in creek. Next several road cuts in Blue Basalt.
223.1	69.8	Entrance on right to Boyce Thompson Arboretum. A nice family picnic and hiking stop-over. (University of Arizona pamphlets).
223.2	69.9	Partial roadcut on right has Whitetail Conglomerate resting on Pinal Schist. Cuts on left are lower units of air and water-lain tuffs from the Picketpost volcano (3 o'clock).

Mile Post	Cumulative Mileage	
223.5	70.2	Roadside marker (right side). *"Picketpost Mountain – A landmark and lookout point during Indian Wars, site of outpost of Camp Pinal which was located at head of Stoneman Grade to the east. Soldiers protected Pinal City and the Silver King Mine from Apache raiders. It was the home of Col. William Boyce Thompson, mining magnate and founder of the Southwest Arboretum at the foot of the mountain."* Col. Thompson's house (castle) is the tile roofed edifice at 2 o'clock. Thompson formed Newmont Corporation as his holding company for investments in Magma, Inspiration, Bingham Canyon, Inco, etc., at the turn of the century (Hagedorn, H., 1935).
224.1	70.8	Roadcut of Quaternary Gila Conglomerate.
224.5	71.2	Roadcut of inner-rift volcanics. **STOP 1 ahead on right.**
225.1	71.8	**STOP 1.** Superior Airport. Park along the fence adjacent to airport building at top of rise on right. The sloping runway needs pilot adjustment when landing or taking off. Figures 2 through 5 show maps with all of the STOPS.

References for district:

- Hammer and Peterson, 1968
- Paul and Knight, 1995
- Peterson, D.W., 1960, 1961, 1962, 1968, 1969
- Peterson, N.P., 1963
- Sell, 1995.

Figure 1 is the geologic column for the district.

We are standing in a basin filled by alluvium, Gila Conglomerate and inner-rift volcanics. Others have stopped here (Sheridan, M.F., 1968), however, you'll probably hear a somewhat different version.

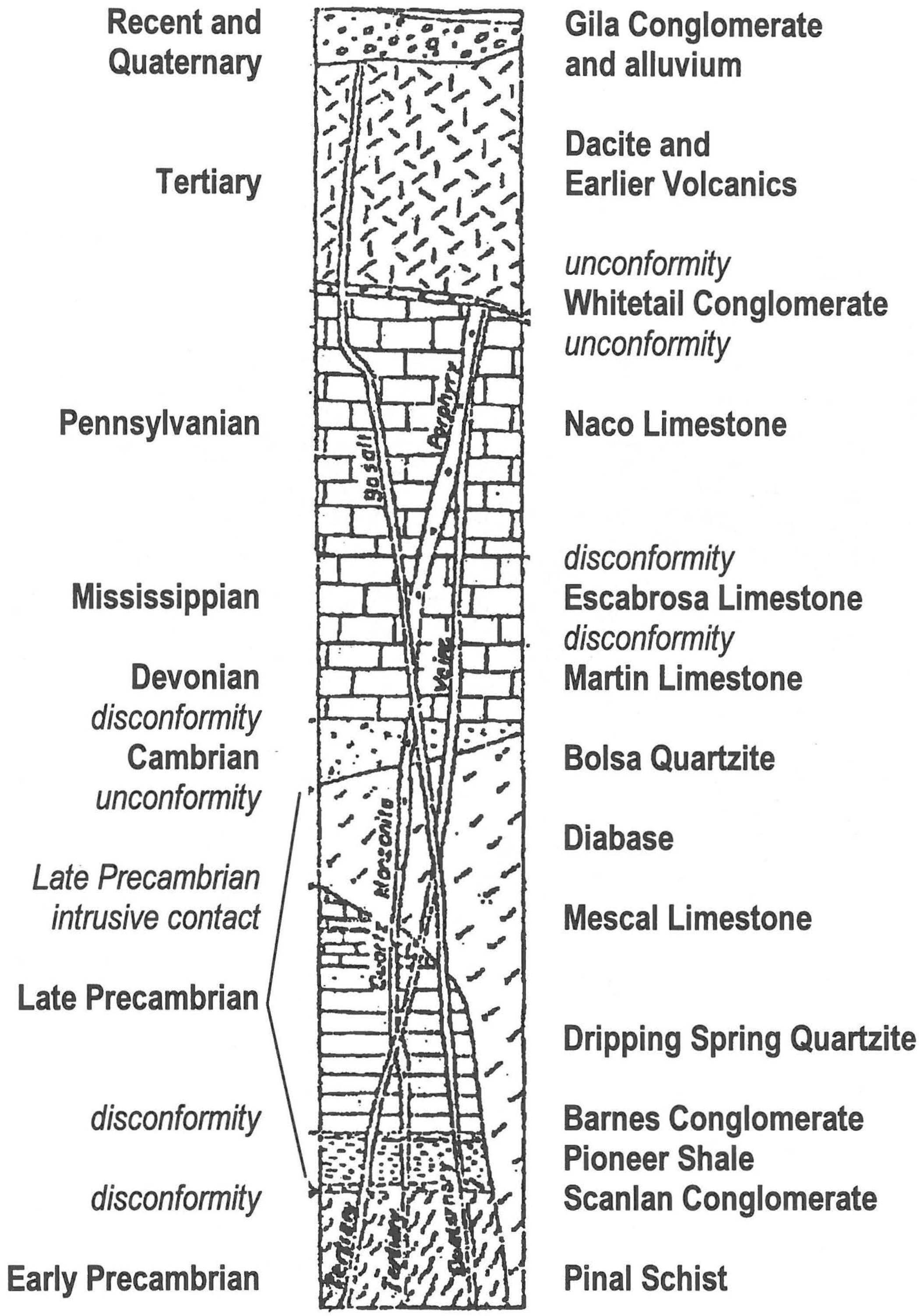

Figure 1.

Generalized geologic column in the vicinity of the Magma Mine.
(Revised from Figure 2 in AGS, 1981.)

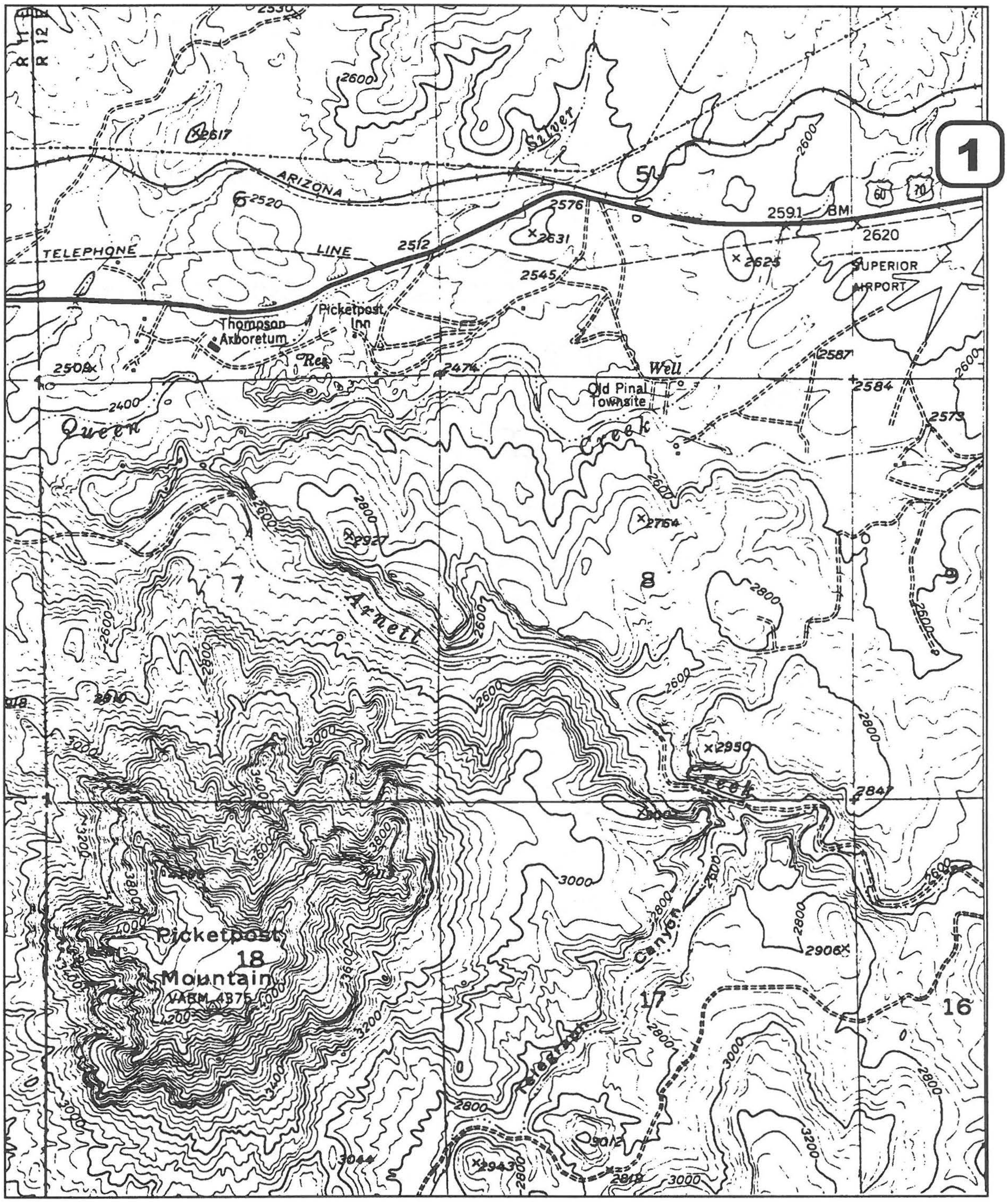

Figure 2.

Stop 1 is at the Superior Airport.

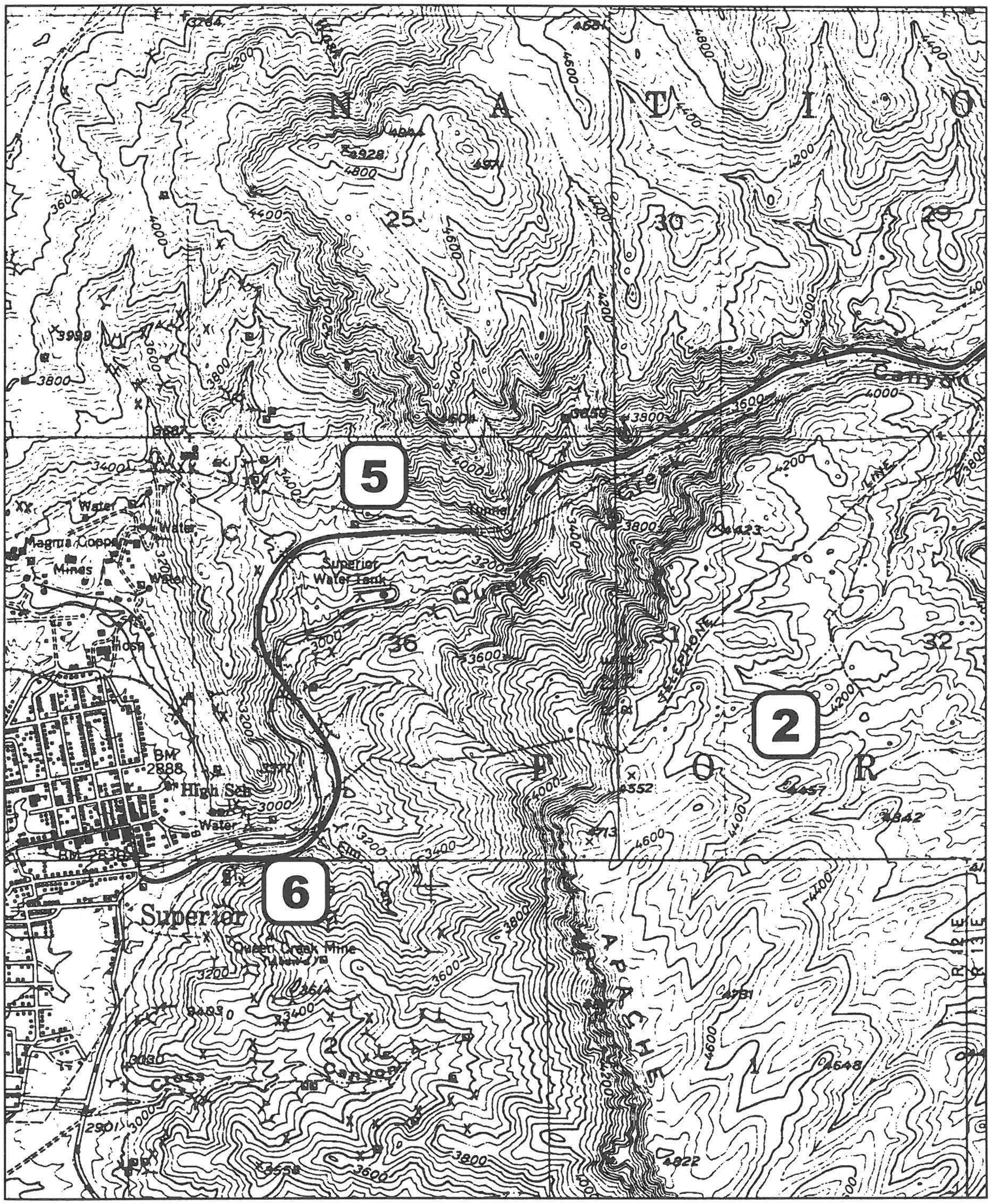

Figure 3.

Queen Creek Canyon and Stops 2, 5, and 6.

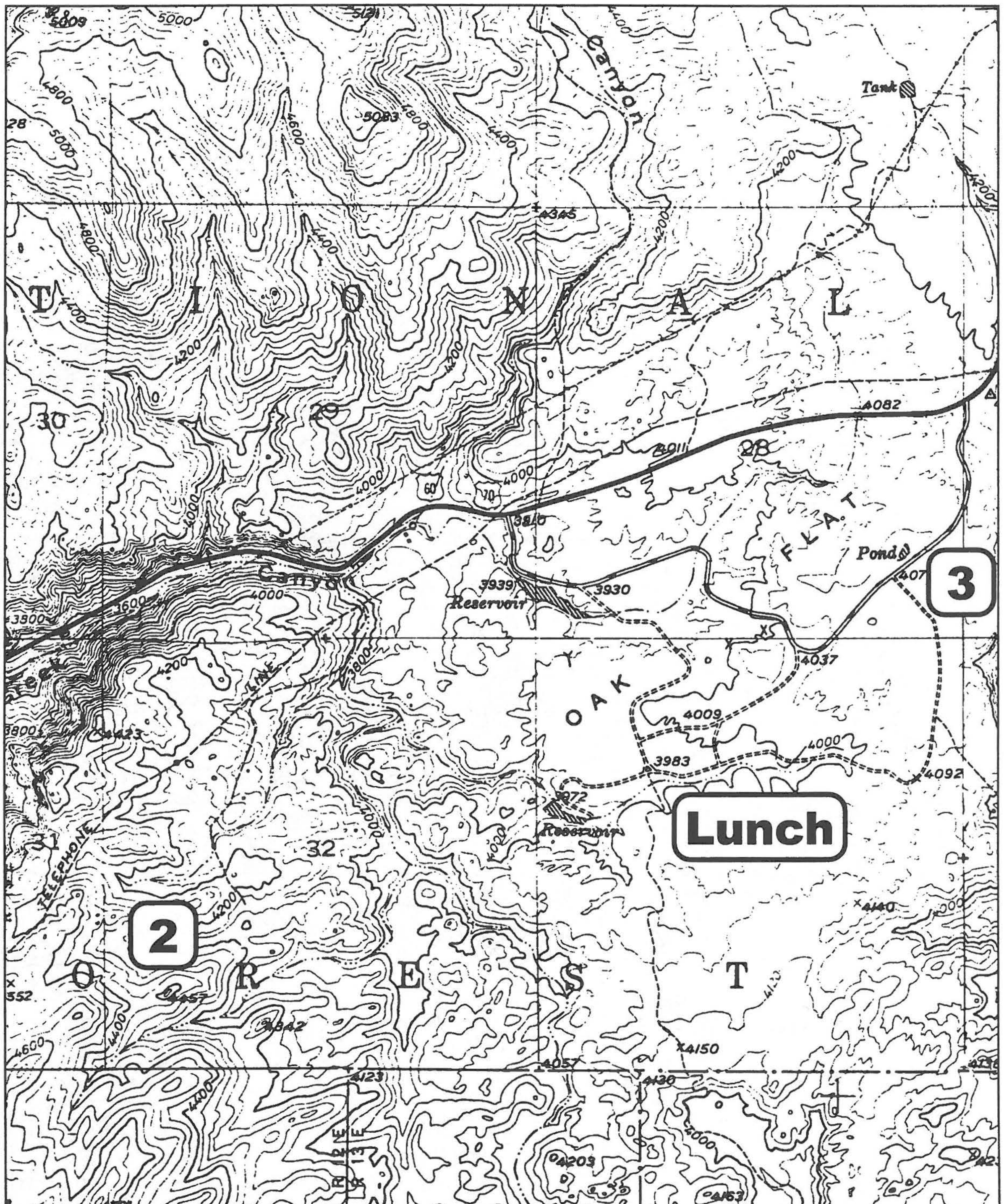

Figure 4.

The area over the Magma Mine and Stops 2, 3, and Lunch.

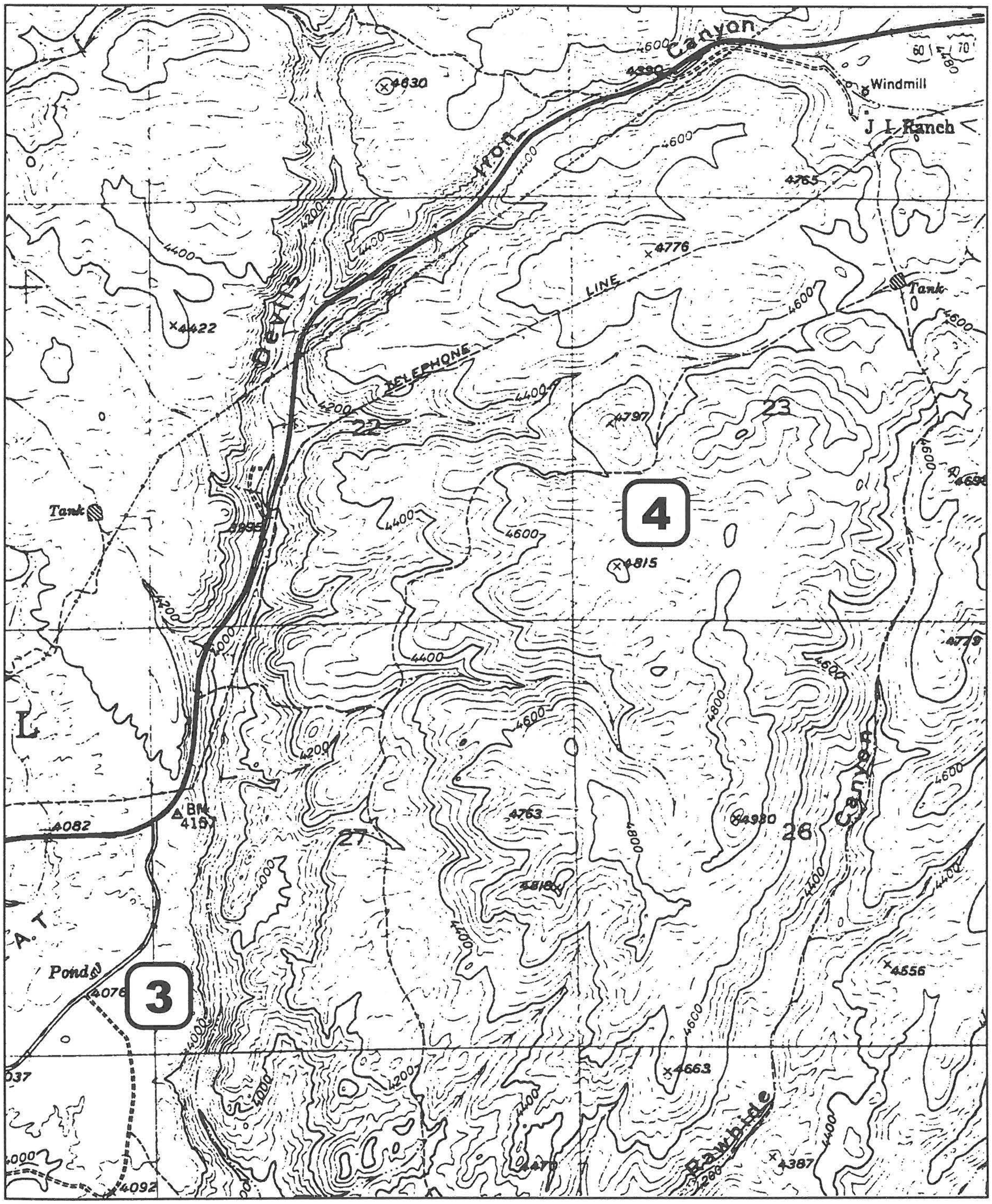

Figure 5.

The area of the Superior East project and Stops 3 and 4.

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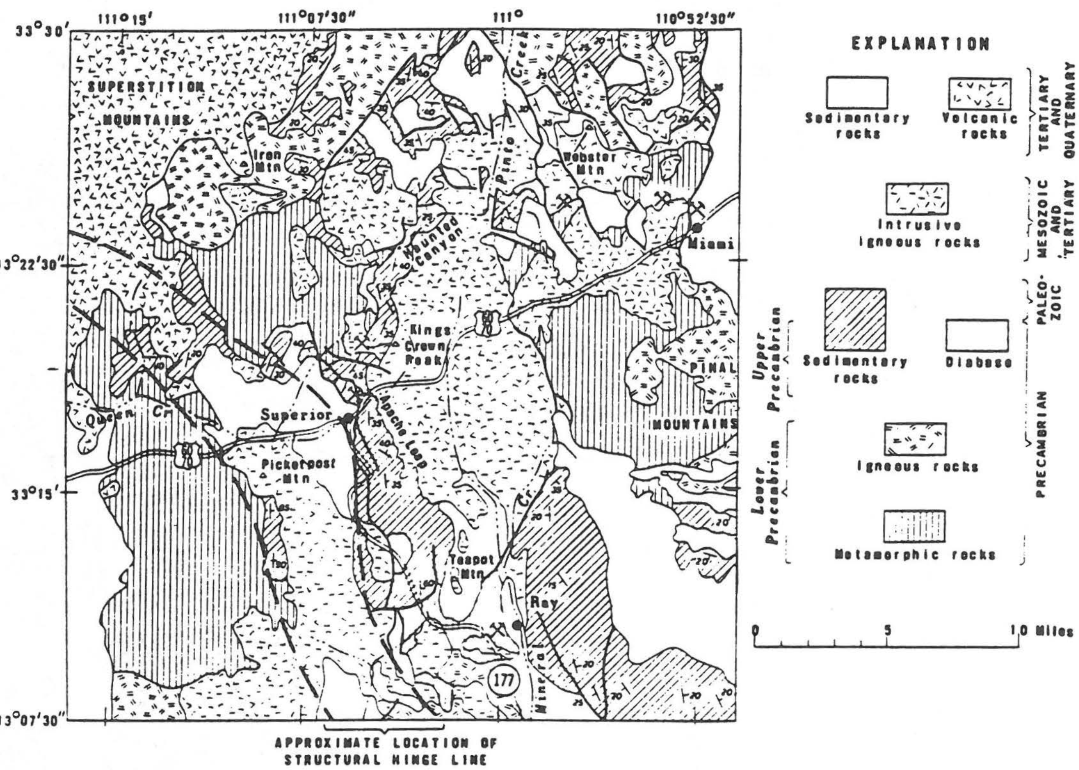


FIG. 1. *Geologic Map of the Region around the Magma Mine. Geology has been generalized, with modification, from the following maps and reports: F. L. Ransome (5), N. P. Peterson, (18), E. D. Wilson, et al. (11, 12), and D. W. Peterson (13, 17).*

Figure 6.

Geologic Map of the Region around the Magma Mine.
(Adapted from Hammer and Peterson, 1968)

We're inside the hinge zone of
Hammer and Peterson (1968) Figure 4,
and Keith (1986) Figure 5.

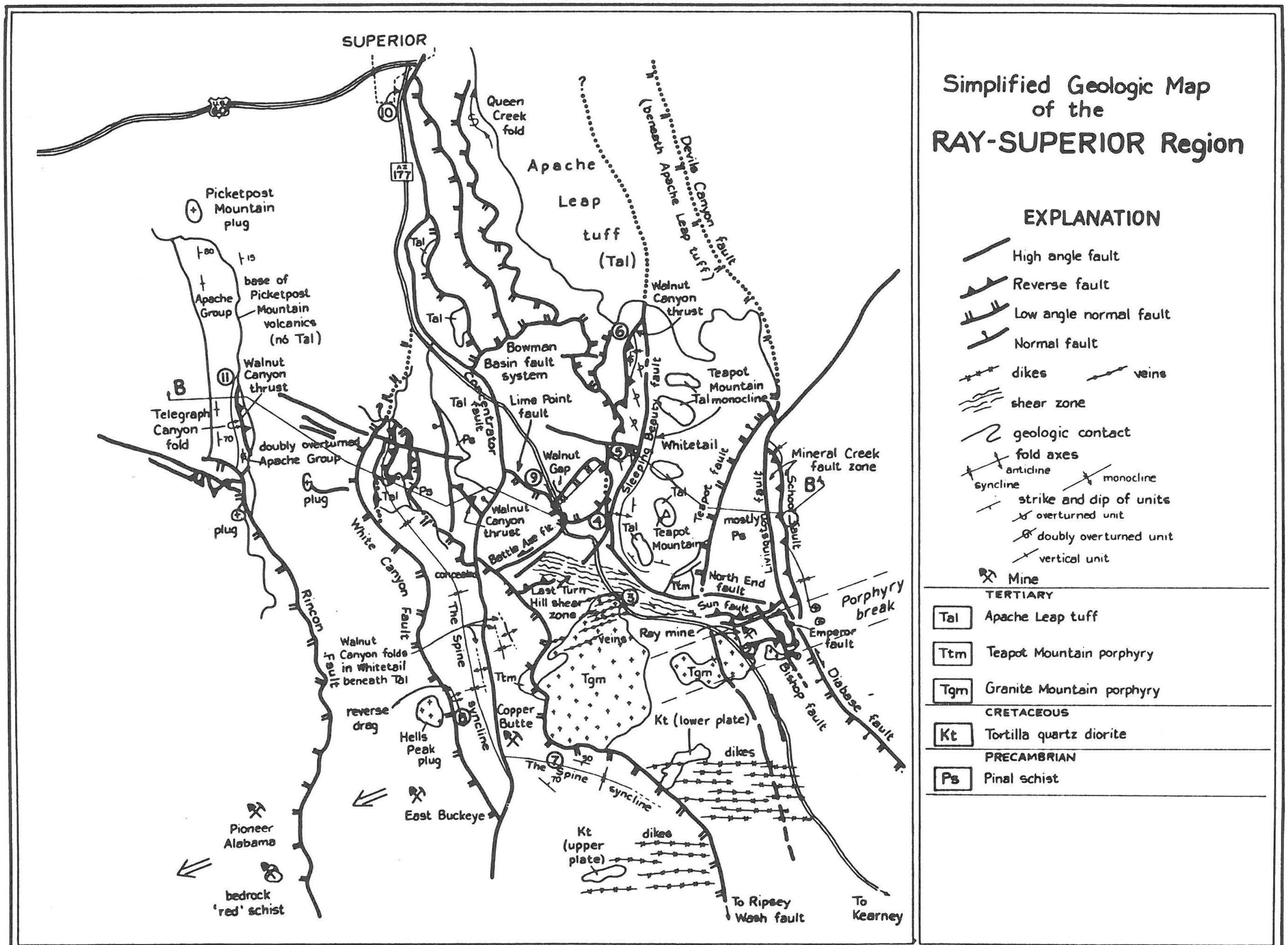


Figure 7. Simplified Geology of the Ray-Superior Region

Notes

At 12 o'clock (east), the massive Apache Leap cliffs of dacite are here and there underlain by patches of Whitetail Conglomerate, with both resting on Pennsylvania Naco Limestone (visible through the Queen Creek gap).

The near sub-skyline ridge is Mississippian Escabrosa Limestone and Devonian Martin Limestone. The reddish cliffs midway down with the mine dump, are Cambrian Bolsa Quartzite, underlying Apache Group, and diabase along the base.

At the base of the hills, the steep west-dipping Concentrator Fault separates the eastern sedimentary units from the volcanic rift units and Quaternary Gila Conglomerate on which we are standing.

The Concentrator Fault extends from the far right, Figure 7, to the left and under the high school, where it splits. One segment curls northwest behind the smokestack and the low hills of Gila Conglomerate, and in front of the Apache Group sediments to the left of the smokestack, and crosses Silver King Wash to the north. The other split (Main Fault) continues north from the high school and goes behind the Apache Group hill before curling northwest to sub-parallel to the Concentrator Fault. They probably join together to the northwest.

Visible behind the smokestack are the smelter and mill remains, and the square sheetmetal cooling tower for the chilled water lines helping to cool off those going underground.

The gap in the main north-south Mississippian ridge behind the smokestack is the location of the Magma fault-vein (trending east-west) and the original No. 1 shaft. The glory hole scar is north of the vein and in Devonian limestone.

The ruffled skyline is Tertiary dacite with narrow strips of Tertiary Whitetail Conglomerate along the base. The 5500-foot elevation Kings Crown Peak, to the northeast, is dacite, but an Earlier Volcanic lies between the dacite and Whitetail there.

The Earlier Volcanics thicken to the north and pinch going south.

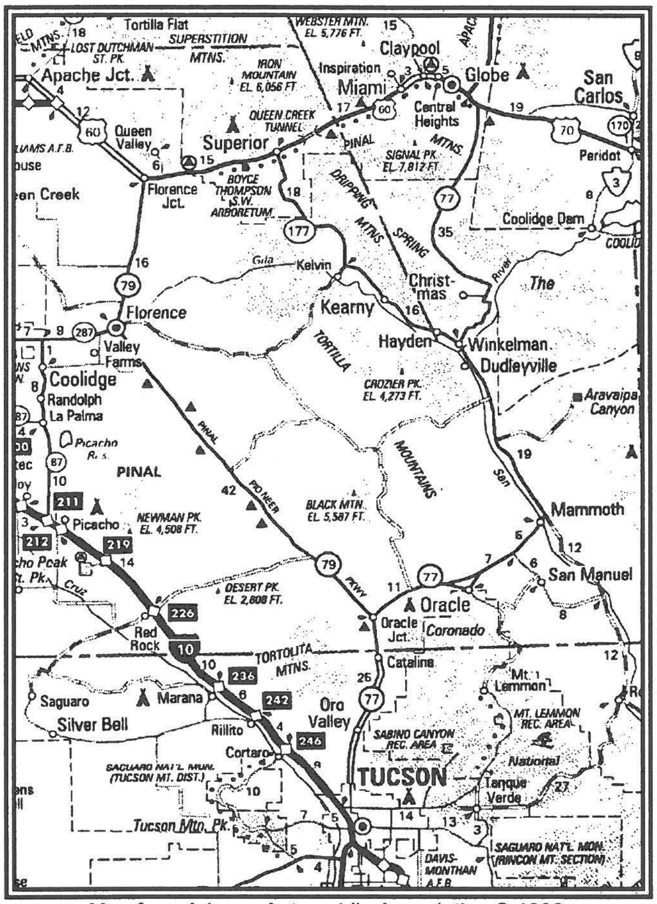
Mile Post	Cumulative Mileage	
		To the north are the perlite processing plants on the Gila Conglomerate and inner rift volcanics. Superior Oil drilled two holes here looking for the Magma Vein, as reported by Ted Eyde in AIME Preprint 73-I-48. They had taken a option from a group lead by Chuck Sewell (personal communications) who had also drilled a few holes earlier.
		Integration of the holes suggest that 5500-7000 feet of down displacement is west of the Concentrator Fault. Dripping Spring Quartzite and diabase were the first pre-mineral units found in most of the holes, but one block had a minor thickness of Mescal Limestone, Bolsa Quartzite, and Martin Limestone, all in an east-dipping homoclinal block, similar to the Paleozoic block east of the Concentrator fault.
		Above the pre-mineral bedrock units is a thick section of rift volcanics and Gila Conglomerate fill. Part of these inner-rift volcanics can be seen to the north in front of the Precambrian schist-metamorphic sequence on the skyline.
		Looking south (3 o'clock) to west, are the inner-rift volcanics with the perlite quarries. Picketpost (Nelson, 1966; Peterson, D.W., 1966) is an intrusive plug of rhyolite and associated units. On the south side of Picketpost, the intrusive came up alongside the vertical dipping Apache Group/Pinal Schist, Figure 7. This fault would be the western fault controlling this inner-rift basin we are standing on.
		On the north side of Picketpost, in Arnett Creek, is a small exposure of a quartz diorite porphyry (Nelson, 1966) which Balla (1972) dated at 71.8 my, and which is similar to the quartz diorite porphyry at Silver King to the north. Balla reports a number of these early Laramide diorites were intruded along the northwesterly "San Pedro hinge zone" extending from far south along the San Pedro and coming up here where this rift-zone is suggested. The zone trends on into the Superstition Mountain Wilderness to the northwest.
		Onward and up on Highway 60 East to the Magma #9 shaft for STOP 2.
225.7	78.7	Outcrop at 9 o'clock at junction has water-lain volcanic debris with fresh water ostracoda.

Mile Post	Cumulative Mileage	
226.0	79.0	Bridge under AZ Highway 177.
226.2	79.2	On right, at east end of offramp, are 6" and 10" water lines. This is the Concentrator Fault zone with Gila Conglomerate on the west and Precambrian diabase-Cambrian Bolsa on the east. WE'LL STOP AND SEE THE SECTION AFTER LUNCH AT STOP 6. See STOP NOTES 2 through 6 for information on these stops.
226.4	79.4	In the road cut, reddish Bolsa Quartzite is in contact with bleached replacement textured lower Devonian Martin Limestone units, dipping 30 degrees east.
226.5	79.5	On the right, we zipped by grey-yellow fissle shale at top of Devonian, and the dark middle "C-bed" replacement unit mined at Magma. The underground group will tell us all about the mineralization in this unit at lunch, if we ask. Looking quickly to the left (except for the drivers, please) you'll get a glimpse of the old concrete US 60 bridge low over Queen Creek, with the present classic steel arch bridge higher up. To the left across Queen Creek, you'll see the band of orange shale separating the Devonian-Mississippian beds as they jut up into the sky. On the right, you zipped over the east-west LS&A fault which shows up as the black manganese zone in the Escabrosa Limestone.
226.7	79.7	At the end of the railing on the right is a small parking area for a later time. At road level is the Maroon Shale marker bed. A karst development surface at the top of the Mississippian Escabrosa Limestone. To the east in the Naco Limestone are a few diorite porphyry dikes and pods along bedding. On up along the curve prior to the bridge, note the manganese encrusted east-west fault zone, and to the left, the open slices mined for manganese during WWII.
226.9	79.9	Queen Creek Bridge in Escabrosa Limestone.
227.2	80.2	On left, a short piece of Maroon Shale, and into Naco Limestone.

Mile Post	Cumulative Mileage	
227.5	80.5	Road cut in Pennsylvania Naco Limestone. In the afternoon we'll make Stop 5 in this wide area on the right and review the stratigraphy and replacement aspect. Much of this Naco section has numerous thin calcite-filled veinlets subparallel to the Magma Vein, 1,000 feet to the north. Some skarn-looking units, manganiferous, bleached beds, etc.
227.8	80.8	Queen Creek Tunnel–1952. At east end, on left (north), up drainage, is steel cover over Magma's No. 6 shaft. At highway level is major exhaust fan for eastern workings. We are over the A-bed (Devonian) replacement unit lying 2,500 feet below road level.
230.3	83.3	On curve, right side, north dipping fault surface in dacite. Probably part of the Conley Spring fault, or possibly an indication of the Magma Vein.
230.9	83.9	SLOW for turn-off south (right) to Magma Mine Shaft #9, at Stop 2, lunch at Oak Flat, and Stop 3 areas (See Stop Notes).
231.0	84.0	On north, top unit of dacite mass in road cut bank.
231.9	84.9	Going alongside Devils Canyon, and passing over bridge with same name.
232.7	85.7	SLOW. At start of passing lane, take the road right to Asarco's Superior East Project. Last guy in please CLOSE the GATE! Four-wheel drive will be required to continue. See Stop 4 Notes. Members going underground will have Stops 1, 2, lunch, 5, and 6. Members going on surface trip will have all Stops, except no underground visit. Field trip will terminate at the bridge of AZ 177 over US 60 East at Superior at end of Stop 6.

Three choices on return to Tucson:

1) Via AZ 177 to Ray, Winkleman, and Oracle Junction.
   See Addendum Road Log— Superior to Ray;
   then AGS Spring Field Trip, 1994 (John, E., *et al.*, 1994).
2) Via US 60 through Miami, Claypool, and Globe,
   then AZ 77 to Winkleman and Oracle Junction.
   (See Sheridan, *et al.*, 1968, and Peirce, 1967).
3) Back the way you came via Florence Junction.



Map from Arizona Automobile Association © 1986

**Safe journey,
and we look forward
to the next outing!**

Notes

Addendum Road Log

SUPERIOR to RAY MINE on Arizona Highway 177

Mile Post	Cumulative Mileage	(Note reverse milepost markers.)
167.6	0.0	From Superior Bridge over US 60 East on AZ Highway 177 going south.
		Gila Conglomerate on downdropped western side of Concentrator Fault.
167.0	0.6	Precambrian Mescal Limestone in roadcut bank.
166.0	1.6	Drill roads to east under dacite are in the Belmont Mine Area.
165.5	2.1	Good view of Picketpost Mountain at 2 o'clock, Weaver's Needle in Superstition Mountain Wilderness at 3:30 o'clock. Road cuts in Gila Conglomerate.
164.0	3.6	On left, next half mile up shallow saddle, Precambrian basalt, quartzite, and diabase, with Mississippian Escabrosa as saddle is approached. On right, inner-rift rhyolite, and tuffs (Creasey, *et al.*, 1983).
163.2	4.4	Saddle area, dacite.
162.6	5.0	Passing over Quaternary gravels and entering Quaternary basalt units with faulted complex to left involving Apache Group quartzite and limestone.
161.9	5.7	Passing over Apache Group units, diabase and quartzites, across fault and onto older Precambrian Madera Diorite basement in valley bottom, then climbing up slope through Apache Group sediments – Pioneer Shale, Dripping Spring Quartzite, diabase, more Dripping Spring, and Mescal Limestone at "Hump" summit.
160.4	7.2	"Hump" Summit. Very complex geology and interpretation. See Wilson, 1952, for early discussion, and Keith, 1985, 1986, for a later discussion of the tectonics of the region.
		Road on 10% downgrade with major fault on right side, dropping Naco Limestone against Apache Group. Note abundant travertine and brecciated masses; finally

Mile Post	Cumulative Mileage	
		crossing a fault (8.0) and into Pinal Schist on lower curve to Walnut Spring.
159.0	8.6	Crossing bridge at Walnut Canyon.
159.5	9.1	Looking at 3 o'clock (right) down Walnut Canyon to rhyolite plug at Hells Peak. (See Lamb, D.C., in Hammer, D.F., *et al.*, 1962).
159.0	9.6	Summit, stay straight ahead. Road right (3 o'clock) across Laramide quartz monzonite stock (Granite Mountain Porphyry) (some alongside of road) and down to Copper Butte mineralized area. To left are dacite-capped Whitetail Conglomerate knobs.
158.0	10.6	To left, view of Teapot Mountain with dacite capping a thick section of Whitetail Conglomerate resting on Pinal Schist.
157.0	11.6	Various views of the Asarco Ray Complex.
156.0	12.6	On left, road to Visitors View Point.
153.0	15.6	On left, Ray Mine Road. (See John, E., *et al.*, for field guidebook returning to Tucson.)

Stop Notes

STOP 1 — SUPERIOR AIRPORT

This will be our round-up stop after the trip from Tucson. We'll begin again when everyone has arrived.

STOP 2 — MAGMA MINE SHAFT # 9.

See Figure 4.

The Magma staff will give an overview to the group.

The Bootprints article by Paul and Knight (1995) is an excellent up-date of the replacement ores and is reproduced here for your reading. Mr. Kurt Friehauf is presently studying the replacement beds for his Ph.D. at Stanford, and his two recent abstracts follow the Paul and Knight paper.

Replacement Ores in the Magma Mine, Superior, Arizona

ALEXANDER H. PAUL *Magma Copper Co., Superior, Arizona*
MATTHEW J. KNIGHT *Magma Copper Co., Superior, Arizona*

ABSTRACT

The Magma Mine at Superior, Arizona, has produced over 25 million tons of high grade ore yielding more than 2 billion pounds of copper. Mining prior to 1960 focused on the Magma Vein. Commencing in 1949 mining gradually shifted to carbonate replacement orebodies east of the Magma Vein stopes. The mine currently produces 1,500 tons per day from underground.

Massive copper-iron replacement orebodies in the Magma Mine occur in favorable dolomitic horizons within the Devonian Martin, Mississippian Escabrosa, and Pennsylvanian Naco Formations. The favorable horizons are locally lettered A through E up section from the lower Martin Formation to the lower Naco Formation. The lower Martin A-bed is the most widely mineralized horizon and the lower Escabrosa C-bed is the thickest, most massive horizon.

Replacement bodies consist of chalcopyrite and bornite with hematite, pyrite, quartz, and carbonate gangue. These minerals completely replace dolostones in mantos that extend tongue-like down the dip of the beds as much as 4,400 continuous feet, along the strike of the beds as much as 900 feet, and across stratigraphic thicknesses as great as 150 feet.

The proposed genetic model for these replacement deposits involves premineralization faults that provided hydrothermal fluid channels in underlying silicic rocks and so directed solutions into favorable fault blocks. Ascending solutions then migrated out of these fluid channels up-dip into the overlying carbonate units, favoring horizons with pre-existing permeability. Early replacement of carbonate by hematite and pyrite further enhanced permeability. Subsequent copper-bearing solutions followed established plumbing and replaced early barren iron phases with minerals of progressively higher copper content.

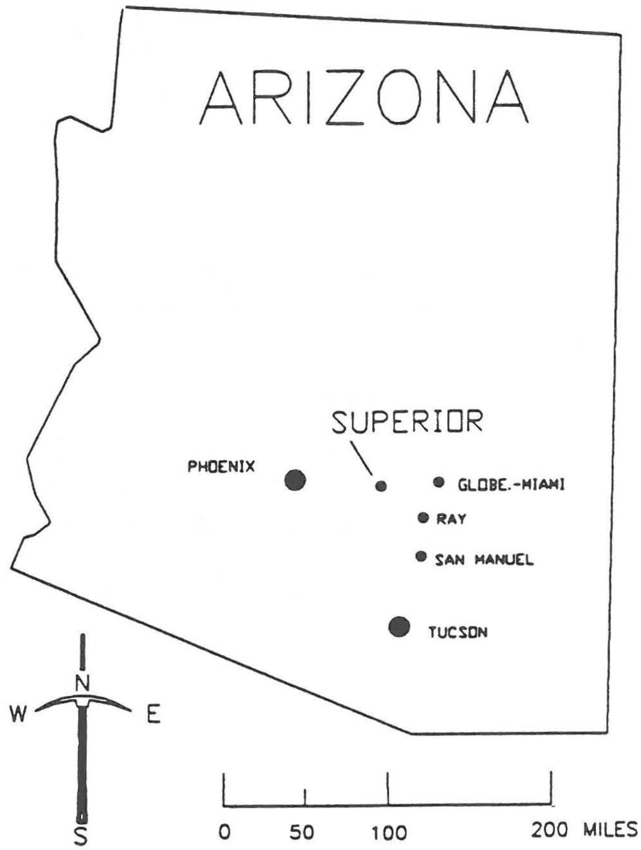


Figure 1. Index map of Arizona showing location of Magma Mine (SUPERIOR).

INTRODUCTION

The Magma Mine is located at Superior, Arizona (fig. 1). The Magma Vein outcrop was discovered in 1875, but the mine's long history of production did not commence until 1911. Brief closures occurred in 1921 to 1923, 1932, and 1982 to 1990. Prior to 1960 most production came from the Magma Vein. Commencing in 1949 production gradually began shifting to the massive replacement ores in carbonate beds that extend at least 14,000 feet east of the Magma Vein discovery outcrop (fig. 4). The continuous high-tenor replacement orebodies are all blind and apex beneath the Apache Leap Tuff.

The 25,800,000 tons of ore produced from the mine to date is about equally divided between vein and replacement orebodies. Hammer (1989) summarized production through 1982 as consisting of 11,300,000 tons of 5.38 percent copper vein ore and 13,600,000 tons of 4.46 percent copper replacement ore. From its reopening in 1990 through 1993 the mine has produced some 924,000 tons grading 5.25 percent copper.

There are several published reports on the geology and mining of the Magma Vein. Gustafson (1961) described the Magma Vein in detail and proposed a spatial, temporal, and geochemical model for its formation. Hammer and Peterson (1968) presented the history, production, and geology of the Magma Mine to 1965; the reader is referred to that paper for descriptions of the surface geology and complete stratigraphic column. Sell (1961) described replacement orebodies in the lower Martin A-bed. This paper focuses on the character of the replacement ores exploited since 1965 and describes geologic relations observed during the course of underground mining.

REPLACEMENT BODY FORM

Replacement orebodies in the Magma Mine are associated with several stratigraphic horizons. Areally restricted but gener-

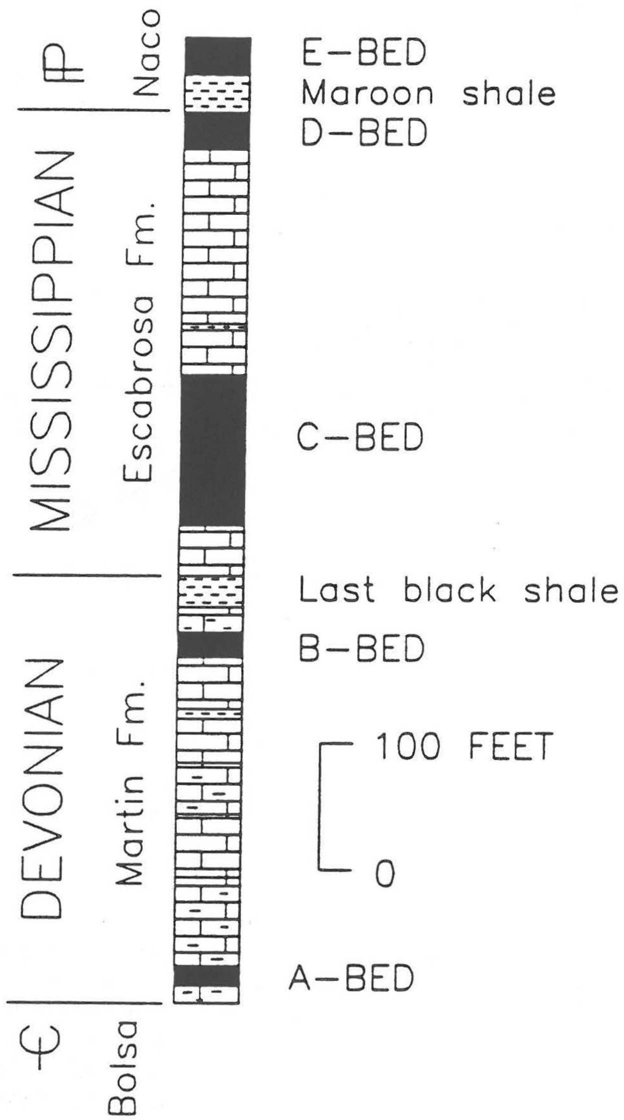


Figure 2. Generalized stratigraphic column of limestone units in the Magma Mine showing position and relative thickness of the A-, B-, C-, D-, and E-beds.

ally high-grade ore occurs in the Precambrian Mescal Limestone (Hammer, 1973). Favorable replacement horizons hosting more continuous orebodies in the Paleozoic carbonate formations overlying the Pinal Schist, Apache Group, and Precambrian diabase intrusions have been given alphabetical designations A through E (fig. 2). Each mineralized horizon has a particular stratigraphic position and distinct characteristics. The East Replacement Mineralized Area (fig. 4) contains the widest range of replaced horizons in the mine.

Massive replacements extend for great distances down the dip of favorable horizons. Replacement ore has been mined from the 2,000 level to the 4,000 level encompassing more than 4,400 feet of dip length and appear to separate into fingers up dip as they apex along east-trending faults. Drilling beneath the down-dip extension of the East Replacement C-bed Orebody indicates an abrupt and blunt termination (fig. 3), but the character of the down-dip termination of other favorable horizons is not as well documented.

Replacement orebodies generally occur as ribbon-like mantos with an easterly orientation. The thickness of individual mantos tends to be consistent, but some notable local variations occur. For example, the A-bed between the 3,000 and 3,200 levels thickens abruptly adjacent to the East Replacement Vein, giving the orebody the appearance of a manta ray in north-south section.

The A-bed replacement horizon near the base of the Martin Formation contains the greatest areal extent of mineral replacement. Five distinct east-trending mantos have been identified in the A-bed extending from the North Boundary Vein to north of the Magma Vein (fig. 4). The massive replacement zones are generally 15 feet thick; thicker sections occur adjacent to feeder veins and ore-control structures. Below the A-bed horizon some 15 to 20 feet of silty limestone overlies the clastic sediments of the Bolsa Formation.

The B-bed is located about 260 feet above the base of the Devonian Martin Formation and is intermittently replaced by massive, fine-grained pyrite in the East Replacement Area. Locally this replacement carries sufficient copper as chalcopyrite to constitute ore. Replacement bodies in the B-bed are restricted to short dip-segments of the upper Martin Formation.

A thinly laminated shaley limestone unit locally designated the "last black shale" delineates the top of the Martin Formation. The C-bed replacement horizon in the lower Escabrosa Formation starts some 30 feet above this shale and is the thickest of any of the replacement horizons, attaining a maximum thickness of 150 feet. Massive replacement in the C-bed extends an average of 300 feet and locally as much as 600 feet northward from the North Boundary Vein. The stratigraphic thickness of the replacement varies over the lateral extent of this orebody.

North of the North Boundary Vein, the C-bed tapers in wing-like fashion similar to that described above for the A-bed. Above the 3,400 level the C-bed Orebody departs from the North Boundary Vein and is centered on the East Replacement Vein. Between the 3,400 and 3,500 levels the C-bed Orebody thickens, forming nearly continuous replacement ore from the base to near the top of the Escabrosa Formation. This upward extension is locally called the C-C bed.

The D-bed occupies the top of the Escabrosa Limestone beneath the overlying "maroon shale." Its thickness is as much as 50 feet. Massive replacement extends through the entire Escabrosa Formation from the top of the "last black shale" into the base of the "maroon shale" marker beds in a few intensely mineralized zones.

The E-bed is approximately 30 feet thick and replaces the first carbonate beds above the maroon shale, the basal unit of the Naco Formation. Alternating limestone and shale units characterize the Naco Formation above the E-bed. Within the area of the mine no units of the Naco Formation above the E-bed are known to be mineralized.

STRUCTURE

There are two major structural elements recognized in the Magma Mine area (Hammer and Peterson, 1968): an east-trend-

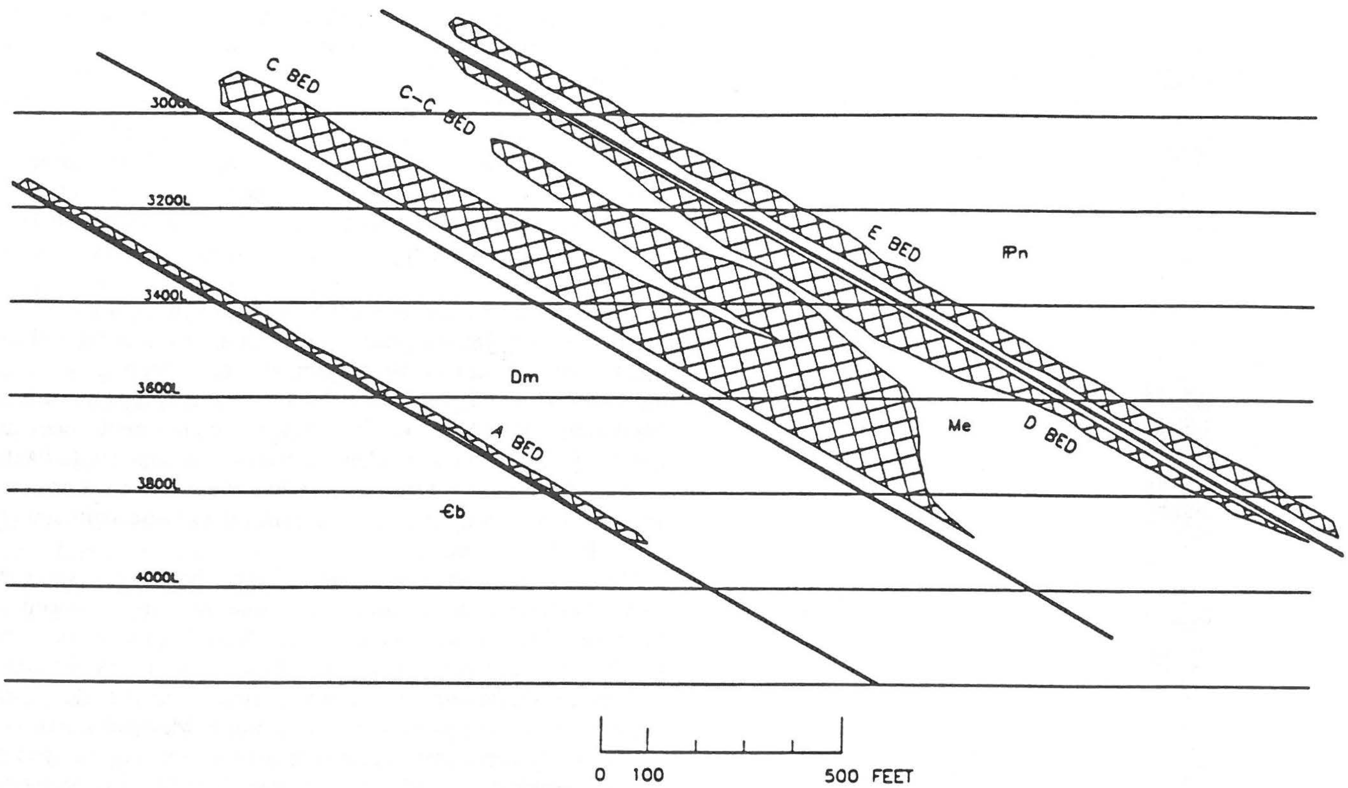


Figure 3. Generalized east-west cross section through East Replacement Orebodies, showing relative position of ore hosts and variations in replacement thickness. Mine levels are shown in feet below the collar of No. 1 Shaft.

ing premineralization set of veins and faults and a north-trending set of faults with significant post mineralization movement. The east-trending set is represented principally by the Magma and North Boundary Faults, mineralization along which has created the Magma and North Boundary Veins (fig. 4). In addition, several lesser east-trending faults such as the East Replacement (South Branch) Vein and the South Split of the Magma Vein cut the block of ground between the Magma and North Boundary Faults. Mineralization of these lesser faults has also led to vein formation.

Secondary east-trending faults break the ground between the Magma and North Boundary Veins into several tabular blocks that appear to be offset down to the south in a stair-like fashion. Although the exact direction of slip movement is not known, apparent dip displacement across the Magma Fault ranges from 350 to 450 feet increasing toward the east. For most of the secondary east-trending faults, apparent offset is in the order of 30 to 50 feet. Across the North Boundary Fault minimum apparent dip slip is greater than 2,000 feet.

Segments of the east-trending faults host ore minerals locally but these veins are generally subeconomic. In the vicinity of the replacement orebodies the mineralogy of the east-trending vein set is similar to that of the stoped parts of the Magma Vein, suggesting faults in the area were open during mineralization and acted as feeders for the replacement orebodies.

The north-trending post-ore fault set includes the Concentrator, Main, N-S5W, and numerous unnamed faults that strike north to northwest (fig. 4). This set of faults is characterized by predominantly down-to-the-west apparent movement. Correlative stratigraphic units have been dropped beyond limits reached by mining across the Concentrator Fault, suggesting minimum apparent dip slip of 2,000 feet. The Main Fault exhibits 1,400 feet of apparent left-lateral slip and a similar amount of apparent dip slip; the N-S5W Fault has 400 feet of apparent left lateral slip and 100 feet of apparent dip displacement (Gustafson, 1945).

Faults of the north-trending set are locally mineralized (Hammer, 1994, pers. commun.) but do not constitute ore. They offset both east-west vein and replacement orebodies. Latest movement on the north-trending structures appears to be associated with Basin and Range faulting during Cenozoic time.

The present dip of Paleozoic and older strata is approximately 30° to the east in the west end of the mine; dip flattens somewhat toward the east. Dips as steep as 40° east are, however, observed both at the surface and underground in certain fault-bounded blocks. A 15° angular unconformity exists between the Paleozoic formations in Queen Creek Canyon and the overlying Tertiary ashflow tuff, suggesting that at least half of the present tilt is the result of Cenozoic block-faulting and the remainder is inherited from tilting associated with Mesozoic uplift west of the mine area (Hammer and Peterson, 1968).

CHARACTER OF REPLACEMENT

Mapping has been done on the C, D, and E-beds from the 3,420 level down to the 3,788 level. Mapping shows that there are distinct mineral zones within the orebody that permit classi-

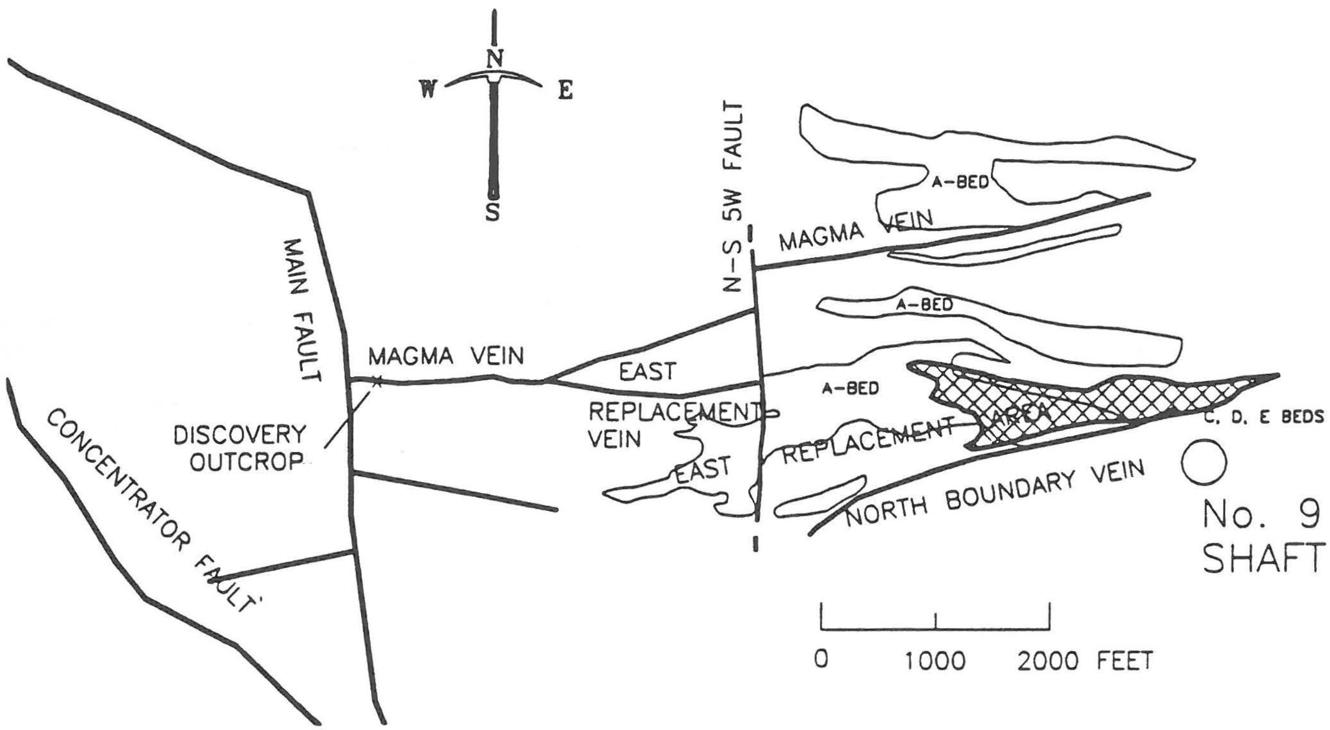


Figure 4. Map of the Superior area showing principal structures, extent of massive limestone replacement, and position of No. 9 mine shaft.

fication into four general mineral types: (1) specularite, (2) pyrite, (3) specularite-pyrite-chalcopyrite, and (4) pyrite-chalcopyrite-bornite. Within favorable horizons, tongues of higher tenor copper mineralization rich in chalcopyrite and bornite extend down dip adjacent to feeder veins, flexures in the beds, ore-control faults, and along replacement fringes. Oreshoots are flanked by lower tenor massive hematite-pyrite-chalcopyrite mineralization. Drilling below the 3,600 level penetrated an A-bed section where a central zone of massive specularite-pyrite-chalcopyrite was encased in coarse-grained dolomite which had replaced the hanging wall and footwall of the horizon. Copper grades depend primarily on the thickness and extent of the hematite-pyrite-chalcopyrite zone.

The ore mineralogy of the massive replacement orebodies is simple, consisting of the copper minerals chalcopyrite and bornite with rare chalcocite and tennantite. The copper minerals are accompanied by minor silica and carbonate gangue and replace and fill open spaces in earlier formed hematite and pyrite. Magnetite is present locally in the A-bed mineralized horizon. Contact relationships between hematite and pyrite bodies and cross-cutting copper-iron sulfide veins indicate hematite is the earliest of the massive replacement minerals and is followed by pyrite. Hematite is present throughout the orebodies but is more dominant up-dip and outward relative to pyrite in the A-bed and is the dominant gangue mineral in areas mined west of the N-S5W Fault (Hammer, 1994, pers. commun.). Hematite is present along the footwall of the bed and along the north fringe of the replaced horizon over the entire dip length of the C-bed Orebody. Hematite generally occurs in large masses of intergrown specularite blades and granular pods, but occurs as a soft red unctuous material wherever it has been stressed by post mineralization faulting, however slight.

Pyrite occurs in large, dense, massive, coarse-grained pods and as small blebs, veinlets, and thin bedding streaks in massive hematite. Pyrite occasionally forms euhedral crystals in a talc rind that surrounds the massive replacements at the limestone contact. Pyrite is commonly replaced by chalcopyrite and bornite. A large massive pod of pyrite at the south edge of the East Replacement C-bed Orebody is unreplaced by copper minerals and consequently nearly barren (less than 1 percent copper).

Chalcopyrite is the primary copper mineral in the replacement orebodies where it occurs as both euhedral octahedrons nested in open spaces between specularite blades and as small pods, thin veinlets, and bedding streaks in massive hematite-pyrite-chalcopyrite ores. Chalcopyrite forms massive pods within larger pyrite pods locally.

Bornite occurs as exsolution blebs within masses of chalcopyrite in high-grade ores and rarely as small granules intergrown between hematite blades and grains. More commonly bornite forms moderate sized tabular, vein-like masses within pyrite-chalcopyrite bodies or at the contacts between hematite and pyrite masses (Friehauf, 1993, oral commun.). In the East Replacement C-bed Orebody there are two root-like masses with a high proportion of bornite that extend down the dip of the beds.

Silica is present in the replacement ores but is volumetrically small compared with the massive hematite and the sulfide minerals. Chalcedonic quartz is common in the distal up-dip portions of the replacements that crop out. Chalcedony occurs rarely as isolated masses filling intergranular spaces in hematite and pyrite in the deeper parts of massive orebodies. Crystalline quartz commonly occurs with bornite veins and as vug fillings in massive pyrite.

Carbonate minerals are present as a gangue constituent of the massive replacements. Calcite occurs in coarse late stage crystals that fill intergranular spaces and vugs in massive hematite and pyrite. Ankerite and dolomite are also common as isolated intergranular masses. Granular recrystallized dolomite forms a thin hanging wall and footwall sheath encasing massive hematite-pyrite-chalcopyrite that replaces the center of the A-bed below 3,600 level.

Sphalerite and galena are rare within the massive replacements but do occur in sparse, thin veinlets and bedding streaks near the fringes of massive replacements. Microscopic grains of sphalerite fill open space in porous recrystallized dolostone along strike for a few feet beyond the limit of massive replacement in favorable horizons. Below 3,700 level considerable sphalerite is present in the hanging wall of the C-bed Orebody. Honey-brown crystalline barite has been reported (Hammer and Peterson, 1968) from large cavities at the up-dip terminations of some of the A-bed orebodies but is unknown in the deeper replacement orebodies.

Mapping is most detailed in the C-bed, where mining has focused since 1990. Massive specularite typically occurs on the northern and northwestern fringes of the C-bed Orebody near the limit of replacement (fig. 5); this phase carries less than 1 percent copper. Massive pyrite which also carries less than 1

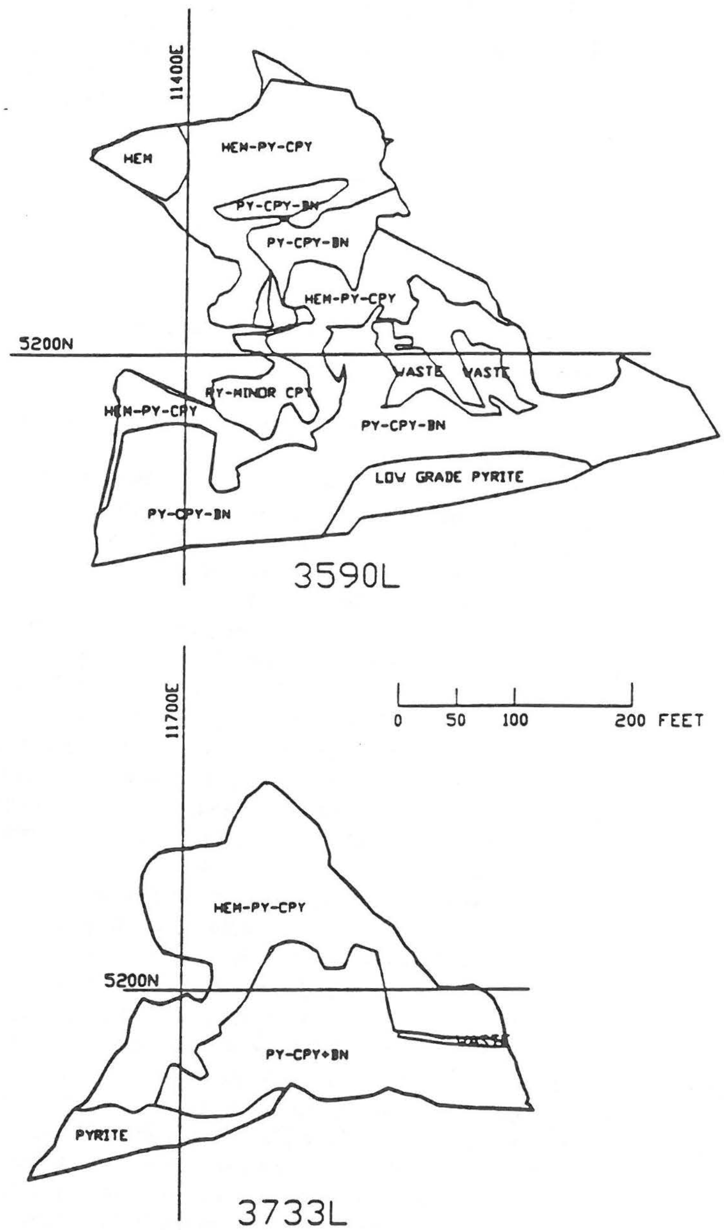


Figure 5. Horizontal slices through the East Replacement C-bed Orebody showing distribution of replacement mineral types. Waste refers to unreplaced carbonate pods within the orebody. Coordinate lines are Magma Mine survey system.

percent copper occurs only as a lens on the southern end of the C-bed Orebody from approximately the 3,570 level down to near the 3,800 level near the North Boundary Fault.

Specularite-pyrite-chalcopyrite ore typically consists of massive granular to bladed specularite with 10 to 30 percent pyrite-chalcopyrite. This type of ore is often quite porous and rarely has vugs which contain well crystallized specularite; copper grades range from 3 to 8 percent. Limited historical data suggest that the orebody above the 3,400 level consisted mainly of specularite-pyrite-chalcopyrite ore with occasional pods of high-grade pyrite-chalcopyrite-bornite ore. Below the 3,400 level the specularite-pyrite-chalcopyrite assemblage tends to occupy the northern portions of the orebody, while the pyrite-chalcopyrite-bornite assemblage dominates in the south. The specularite-pyrite-chalcopyrite assemblage persists to the termination of the orebody below the 3,800 level (fig. 5).

The pyrite-chalcopyrite-bornite assemblage comprises the high-grade roots mentioned earlier. Major bodies of these copper sulfide minerals persist from the 3,460 level to the downward termination of the C-bed Orebody. This copper sulfide phase is usually strongest in the southern portions of the orebody with a weaker root in the north central portion. Grades in the pyrite-chalcopyrite-bornite ore are typically quite high ranging from 5 percent to more than 20 percent copper. Rare large lenses of chalcopyrite-bornite yield stope sample grades over 25 percent copper.

Within the C-bed Orebody replacement of host rock is virtually complete but there are occasional horsts of unreplaced carbonate within the ore (fig. 5). These horsts may be limestone or dolomite and typically show little evidence of replacement. Commonly these blocks have haloes of very high-grade pyrite-chalcopyrite-bornite ore surrounding them. Replacement contacts are quite sharp with virtually no gradation from massive replacement to unreplaced limestone or dolomite.

Vein/fault structures within the C-bed Orebody are difficult to recognize, but there do seem to be persistent breccia zones crossing from west to east. These breccia zones likely correlate with the horst bounding faults that form the "notch" on the west side of the C-bed (fig. 5).

The mixed hematite-pyrite-chalcopyrite ore type is characteristic of the D-bed. Numerous high-grade pyrite-chalcopyrite-bornite pods are present, but they are smaller and more irregular than those of the C-bed.

The E-bed is generally replaced by mixed hematite-pyrite-chalcopyrite material. High-grade pyrite-chalcopyrite-bornite pods are less common than in the D-bed, thus the E-bed has a lower overall grade. Contacts between replaced beds and unmineralized sedimentary rocks are very sharp in the E-bed as in the other mantos. Replacement also appears to be more closely controlled by bedding in the D-bed, with the different mineral types appearing as ribbons parallel to beds rather than as large pods such as are seen in the C-bed.

ALTERATION

Alteration of carbonate wallrocks surrounding replacement orebodies consists of inconspicuous dolomitization and talc formation. The relation between wallrock alteration and replacement bodies is not well known.

Certain primary dolostones and non-magnesian limestones in the carbonate section have been recrystallized and affected by magnesian metasomatism (Hammer, 1994, pers. commun.) to form favorable replacement horizons. These recrystallized rocks are characterized by a dark- to light-gray color, megascopically fine-grained texture, and vitreous luster.

Spherical and ovoid masses of white crystalline calcite a few inches across are locally present in the gray dolostones of the C-bed. These calcite balls are rimmed with talc within approximately 100 feet of the massive replacement bodies. Closer to massive replacement bodies white talc replaces spherical, ovoid, and lens-like spots within host carbonates. Talc alteration is intense in the interval between the C and D horizons.

GENETIC MODEL

Formation of replacement orebodies at Superior followed development of the east-trending fault system. A stair step down-to-the-south pattern of fault-bounded blocks developed in a north-south tensional environment. Some of the tensional structures filled with intrusive dike material prior to mineralization.

Host sedimentary units dipped gently to the east at the time of mineralization. The broad distribution of mineralized and altered rock in and along the east-west veins and faults indicates

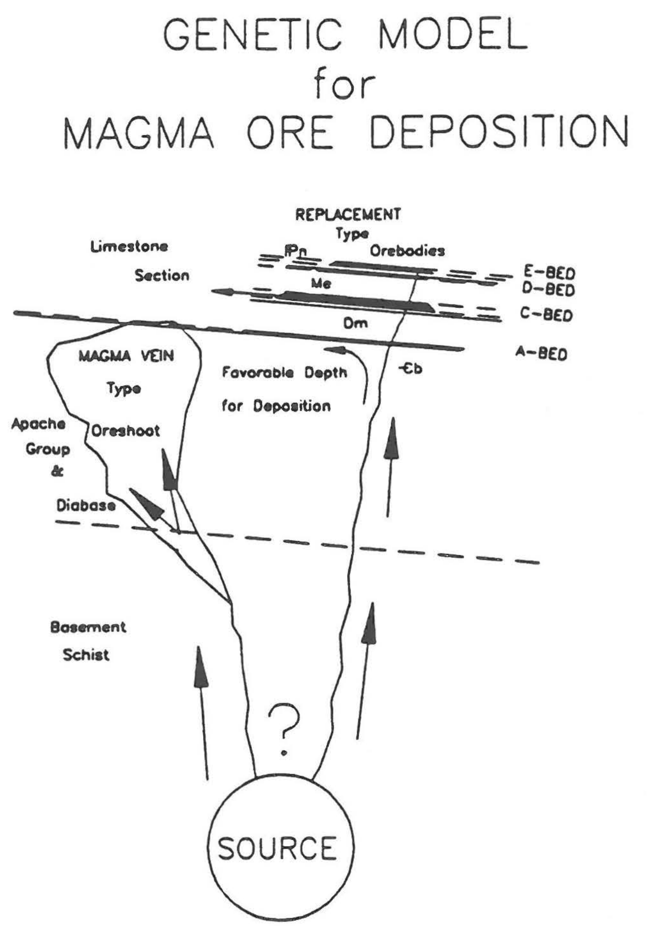


Figure 6. Schematic diagram of hydrothermal system which produced vein and replacement orebodies in the Magma Mine.

that source solutions ascended from a deep level affecting a wide area and that plumbing features played an important role in localizing orebodies. Some intersections and deflections were open and enhanced rock permeability, while other structural bearing surfaces and specific rock types impeded solution flow.

Mineralizing solutions ascended from depth through a thick sequence of siliceous rocks. That schists of the Pinal Formation, siliceous sediments of the Apache Group, and thick diabase sills all supported open fractures sufficiently to allow mineralizing solutions to ascend to moderate depths is indicated by the mesothermal character of the vein and replacement ores. Oreshoots developed along faults to form veins where physical conditions of temperature and pressure were favorable and enclosing wallrocks were siliceous (Hammer and Peterson, 1968).

Some porous beds within the carbonate sequence above the siliceous rocks were less restrictive to upward fluid flow than the feeding faults. Recrystallization of certain dolomitic horizons further enhanced permeability, and dissolution of the host rocks increased porosity and directed even greater amounts of fluid into favorable hosts once flow was established.

Access to higher carbonate beds was established through specific plumbing channels at favorable intersections and deflections. Intersections of the east-trending veins and faults with major east-northeast-trending veins and faults appear to have been particularly strong channelways.

Metallic mineral deposition commenced with replacement of recrystallized dolostone by massive bodies of intergrown bladed specularite crystals and porous granular hematite aggregates. Porosity within these hematite bodies was high, allowing solutions to continue to pass through in great volumes.

As ore formation continued, earlier-formed hematite was replaced by pyrite, often along relict bedding planes. Solutions may have spent their sulfur while ascending: The deposit is crudely zoned, with hematite dominant up dip and sulfide minerals more common down dip.

Early pyrite was subsequently replaced by chalcopyrite. Where greater volumes of solution ascended through distinctly established channels, further copper enrichment led to formation of the bornite-rich "roots," pods, and veins.

The near total replacement of host rocks within the orebodies make original structures within the orebodies difficult to observe. Features such as the high grade "roots" in the C-bed and abnormal thickening of the A-bed to a manta ray-like form may indicate intersections of steep vein-like structures with favorable beds. Commonly such ore features align with faint fractures and veins in unmineralized limestone. Breccia zones within the massive sulfide replacement of the C-bed appear to be associated with east-trending structures.

Solutions made very little penetration into the surrounding limestone country rock beyond the limits of the orebodies resulting in only narrow alteration envelopes of talc, sphalerite, and rare galena.

The top portion of the Magma Vein and the up-dip portion of some of the replacement orebodies have been exposed to oxidation near a paleosurface. Mine records suggest the occurrence of oxidation and supergene enrichment in the vein deposits. Oxidation was recorded in some of the upper levels of the replacement orebodies, but enrichment of replacement ores is less well documented and some chalcocite in upper levels may be supergene.

The mineralized area was covered by a thick sequence of fluvial sediments and an ashflow tuff unit prior to being faulted and tilted by north- to northwest-trending basin-and-range faults. Only a short segment of the Magma Vein has been exposed by erosion, and this outcrop led to discovery of the system. All of the continuous massive replacement orebodies are blind, apexing deep beneath the postmineralization cover.

ACKNOWLEDGMENTS

The authors would like to thank Magma Copper Company for its support in producing this paper and allowing it to be published. Don Hammer has contributed to developing the geologic concepts presented here and shared his historical knowledge of the district, and Kurt Friehauf has shared his recent observations and thoughts about the geology of the replacement orebodies.

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Carbonate-replacement Cu-(Au) deposits associated with a high-sulfidation state Butte-type vein system, Superior District, AZ

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Copper veins in the Superior district closely resemble quartz monzonite-hosted "Main stage veins" at Butte (MT), Tintic (UT), Yauricocha (Peru), and Chuquicamata (Chile) in vein filling mineralogy and associated alteration. Carbonate-hosted ores in the Superior district are similar to the carbonate-hosted ores of Bisbee (AZ) and Yauricocha (Peru). The association of Butte, Yauricocha, Chuquicamata, and Bisbee with porphyry copper systems suggests Superior is related to an as-yet undiscovered porphyry copper system.

East-dipping Paleozoic carbonates host the stratabound massive specularite-copper sulfide and Pb-Zn sulfide replacement ("manto") ores where E-W-striking, enargite-bearing veins (e.g. Magma vein) intersect favorable carbonate strata. Favorable strata occur near the base of the Devonian Martin Formation (5 m thick "A-bed" dolostone), the lower part of the Mississippian Escabrosa Limestone (< 60 m thick dolomitic and calcitic "C-bed"), and below and above the shale at the base of the Pennsylvanian Naco Limestone (5 m thick "D-" and E-bed"). "Nonfavorable" limestone and dolostone beds that lie between the favorable horizons show little visible evidence of fluid-rock interaction more than a meter from the feeder veins.

Footwall contacts of mantos are locally discordant (on the order of a meter), but hanging wall contacts are discordant by up to tens of meters. Portions of mantos tend to be either specularite- or sulfide-dominant with sharp (< 25 cm) contacts between zones. Early replacement of carbonates by massive specular hematite with 5-15% disseminated pyrite and chalcopyrite was followed by the formation of massive pyrite-chalcopyrite ± bornite replacement veins and mantos *within* the specularite body. The time-integrated mineral association zoning is from central bornite+chalcopyrite+pyrite+quartz outward to pyrite-chalcopyrite-quartz to specularite+pyrite+chalcopyrite. Small, isolated massive galena-sphalerite-pyrite-quartz pods within limestones/dolostones occur peripheral to copper orebodies.

Wall-rock alteration adjacent to specularite-copper sulfide mantos is characterized by mm-scale white dolomite or calcite veinlets ± quartz-specularite veinlets with bleached halos within meters of the contact. At one locality, a latite porphyry dike in contact with a manto is pervasively altered to sericite-pyrite and chlorite and is cut by quartz-sericite-pyrite, specularite, and quartz-adularia ± chlorite veins. XRD analyses of siliceous sulfide breccias in the central zone of the C-bed orebody indicate the presence of dickite and zunyite -- minerals typical of hypogene advanced argillic alteration in quartzofeldspathic rocks in other Butte-type systems -- suggesting manto ores at Superior represent the carbonate-hosted analogues of advanced argillic alteration.

Skarn and Cu-(Au)-rich massive sulfide/specularite carbonate-replacement deposits of the Superior District, AZ

Kurt C. Friehauf. Dept. of Geological and Environmental Sciences, Stanford University, Stanford CA 94305-2115

The presence of pre-mineral porphyry dikes, skarn followed by high-sulfidation, enargite-bearing Cu-Au veins and pebble breccias suggest the manto ores of the Superior district are similar to the carbonate-hosted ores of Tintic (UT), Bisbee (AZ), Yauricocha (Peru), Morococha (Peru), and Cananea (Sonora) and the carbonate-hosted analogues of high-sulfidation base metal lode veins such as at Butte (MT), Bor (Yugoslavia), Recsk (Hungary), Srednegorje (Bulgaria), Chuquicamata (Chile), Lepanto (Philippines), and Nena (Papua New Guinea).

East-dipping Paleozoic carbonates in the Superior District (26 Mt 4.7% Cu, 1 ppm Au, 45 ppm Ag, Matt Knight, Pers. Comm., 1994)) host garnet, amphibole, and talc skarn and stratabound massive specularite-copper sulfide and Pb-Zn sulfide replacement ("manto") ores where E-W-striking, enargite-bearing veins (e.g. Magma vein) intersect favorable carbonate lithologies. Favorable strata occur near the base of the Devonian Martin Formation (5 m thick "A-bed" dolostone), the lower part of the Mississippian Escabrosa Limestone (< 60 m thick dolomitic and calcitic "C-bed"), and below and above the shale at the base of the Pennsylvanian Naco Limestone (5 m thick "D-" and E-bed"). Hydrothermal fluids did not react visibly with "non-favorable" carbonate strata.

Garnet-amphibole-pyrite-(sphalerite) skarn, followed by rhythmically-layered sphalerite-magnetite-talc bodies, pre-date specularite-copper sulfide manto formation. Garnet-bearing skarn occurs predominantly as east-striking veins (i.e. the same fracture set occupied by copper ores and pre-mineral porphyry dikes) with small mantos flaring out in favorable members of the "D-bed". Amphibole-bearing skarn consists of an early, forest green, fine-grained (2-3 mm grains) variety growing on and cutting compositionally-zoned garnet grains which is in turn cut by light green coarse-grained (10-15 mm) amphibole veins. No copper minerals precipitated during skarn formation. Garnet is weakly altered to soft, tan-colored clay and locally specularite where cut by pyrite-bornite ± specularite-calcite veinlets. Skarn amphiboles have been altered to talc. Rhythmically-banded talc-magnetite skarn replaces dolomitic units and locally contains talc-altered coarse-grained amphibole veins.

Massive galena-pyrite-sphalerite-quartz mantos (< 1m thick) and replacement veins lacking associated talc alteration occur as separate bodies from the main specularite-copper-sulfide mantos. No magnetite or specularite and only traces of chalcopyrite precipitated with galena-bearing massive sulfide. Sphalerite displays chalcopyrite disease and pyrite is locally platy (a la Leadville, CO).

Massive specularite-sulfide mantos (5-60 m thick, < 90 m wide, and < 300 m down the dip) post-date skarn and consist of coarse-grained specular hematite, pyrite, chalcopyrite, bornite, minor chalcocite, and < 5% quartz. Rock types tend to be either specularite- or sulfide-dominant (>80:<20) with sharp (< 25 cm) chalcopyrite-rich contacts between types. Sulfide-dominant (2-4 mm granular pyrite-chalcopyrite (85:15) ± bornite) bodies occur as coalescing elongate pods (typically 6-25 m) within a "sea" of specularite-dominant (80-95% 1-5 mm specularite + 5-10% 2-5 mm pyrite + <10% chalcopyrite) rock that generally extends to the sharp (<10 cm wide) contact with wall-rock carbonate. Specularite-dominant rock predominates in shallower levels, along the footwall, and along the northern margin of the manto, but sulfide pods predominate at intermediate levels. WNW-elongate sulfide pods (i.e. similar orientation to veins in the district) widen at some stratigraphic levels within the specularite-dominant zone of the C-bed orebody, possibly reflecting stratigraphic control on a late sulfidizing fluid flow into favorable replacement horizons within earlier specularite. NW and NNE-striking, irregular bornite-chalcopyrite and bornite-pyrite replacement veins and bornite-matrix pyrite-bornite- + pyrite-chalcopyrite-fragment breccias are the locus of high-grade Cu-Au ore within the sulfide pods. Bornite veins commonly have rhythmically-banded bornite-pyrite or nebulous bornite-chalcopyrite/chalcopyrite-pyrite selvages. Paragenetic relations suggest an early stage of specularite + minor pyrite-chalcopyrite replacement of carbonate followed by formation of sulfide-dominant zones by sulfidation of specularite to replacement veins and masses of pyrite, chalcopyrite and bornite. Even, nearly continuous 0.1 - 0.5 cm specular hematite rinds on small (<30 cm thick) massive pyrite >> chalcopyrite mantos in limestone, suggest specularite also precipitated as a peripheral mineral zone during introduction of Cu-Fe sulfides.

Wall-rock alteration peripheral to specularite-copper sulfide mantos is characterized by mm-scale white dolomite or calcite veinlets ± specularite veinlets with bleached halos, and white talc spots (2-40 mm diam.) in dolomite within meters of the contact. Small (< 1 m) pyrite-chalcopyrite mantos do not visibly alter limestone. A 20-foot thick, quartz-eye-poor, hornblende-rich "latite" porphyry dike, where cut by massive sulfide/specularite mantos, is pervasively altered to sericite-pyrite and chlorite and cut by quartz-sericite-pyrite, specularite, and quartz-adularia ± chlorite veins. Hornblende sites were locally replaced by specularite.

STOP 3 — OVERLOOK TO DRILL HOLE A-4

On Figure 8, Stop 3 is near the "T" in the word "**OAK FLAT**" near Devils Canyon.

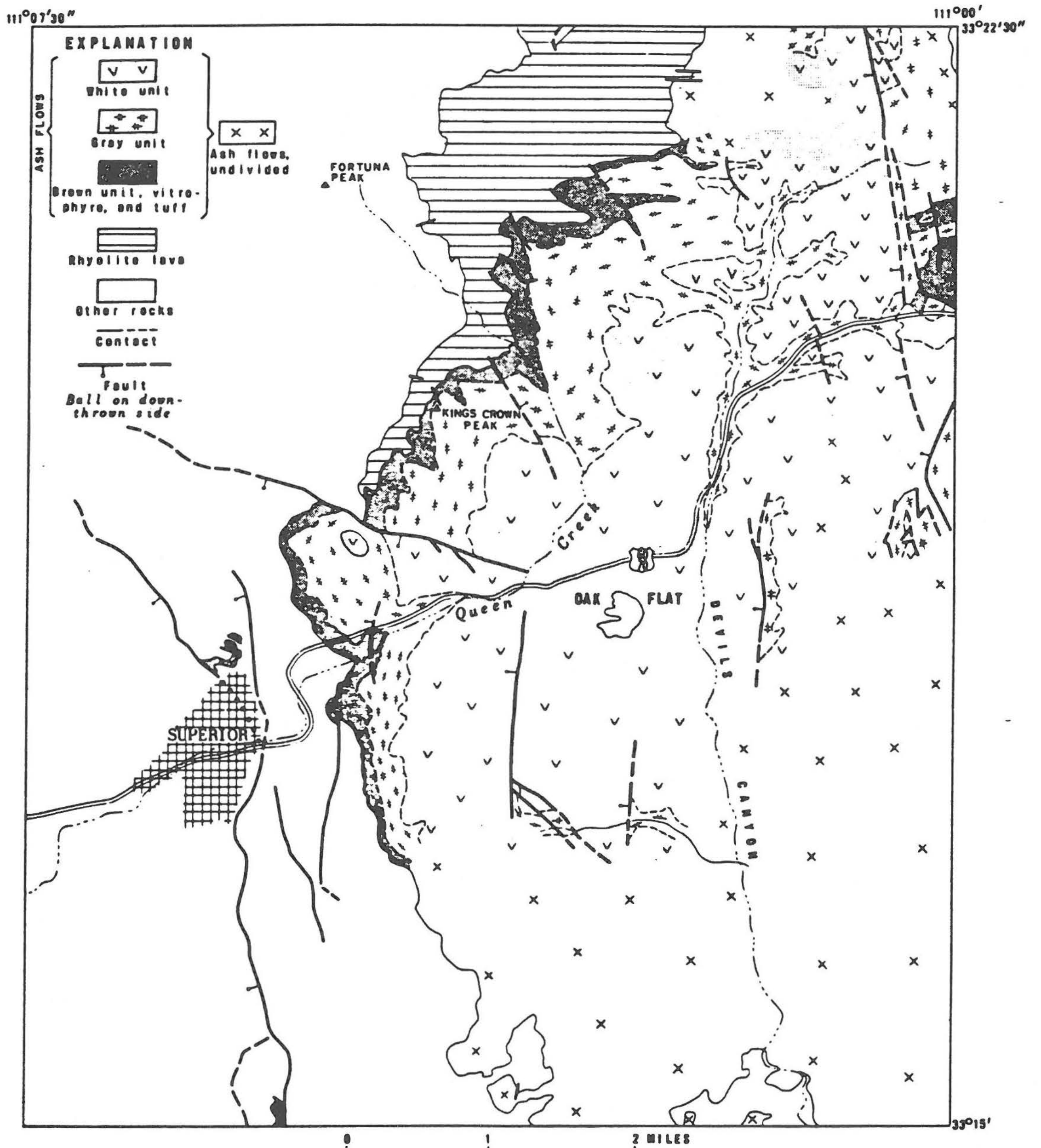

Figure 3 – Generalized geologic map of the Superior quadrangle, showing the distribution of recognized field units within the ash flow sheet. Recognition of the units has permitted identification of several faults within the sheet.

Figure 8. (adapted from Peterson, D.W., 1968)

The hole A-4 was a 1971 penetration and was rotary drilled to 3,593 feet, then cored to completion at 6664 feet (Sell, 1995). Probably a slim-hole record at the time.

The dacite is 1,975 feet thick with an additional 158 feet of Earlier Volcanics.

A very thick sequence of Whitetail Conglomerate was rotaried and cored, 4,206 feet worth, before a slide block of 109 feet of Escabrosa Limestone was encountered. A 36-foot section of Whitetail underlies the Escabrosa slide block and confirms its moved aspect. More Escabrosa, 87 feet, was boxed, at which point a steeply dipping fault was cut. This fault is undoubtedly the Devils Canyon Fault. Under the fault, Pinal Schist is intruded by a dark porphyry (biotite quartz monzonite), both of which had traces of pyrite, chalcopyrite, and moly. A K-Ar date of 62.6 my was returned on this intrusive.

A piece of the Devils Canyon Fault was mapped by Don Peterson, 1968, Figure 8, bringing the gray unit of dacite against the white unit, on the east side of Devils Canyon.

Asarco drilling on both sides of the canyon indicates 500-600 feet of west-side-down displacement of the Earlier Volcanic base across the Devils Canyon Fault. The increased thickness of Whitetail across the fault here is around 1,400 feet. As no Paleozoics exist east of the Devils Canyon Fault under the dacite, the entire Precambrian sedimentary section, the diabase, and the Paleozoics must have been stripped off, plus an unknown amount of Pinal Schist. This amounts to 6,800 feet of section at Magma. If the Escabrosa is near the base, as in drill hole A-4, this suggests a minimum of 5,200 feet of displacement from schist to schist across the Devils Canyon Fault.

At Ray to the south, the Diabase Fault separates Precambrian on the east from schist on the west, and a minimum of 2,000 feet of displacement has been suggested (Fountain, 1981; Cornwall, *et al.*, 1971).

Aerial photos suggest the fault continues west of the Pinto Valley Mine and is lost in the vicinity of Roosevelt Lake. Displacement probably decreases in offset to the north, however, no good marker beds are available for control.

The plus-5,000 feet of displacement along part of the Devils Canyon Fault is similar to the 5,500-7,000 feet of displacement on the Concentrator Fault at Superior, and suggests the Devils Canyon Fault is a "failed rift" split from the main rift to the south. The homoclinal result and sag in the area of drill hole A-4 resulted in the thick deposition of Whitetail Conglomerate. It is the thickest known section of Whitetail in the region.

Figure 9 is a plan map showing the known drill holes on the Plateau (Sell, 1995).

We'll now return to US 60 East and continue the road log to the gate to Superior East.

STOP 4

Four wheel-drive will be required to continue off the AZ 60 East. Last guy, please CLOSE the GATE!

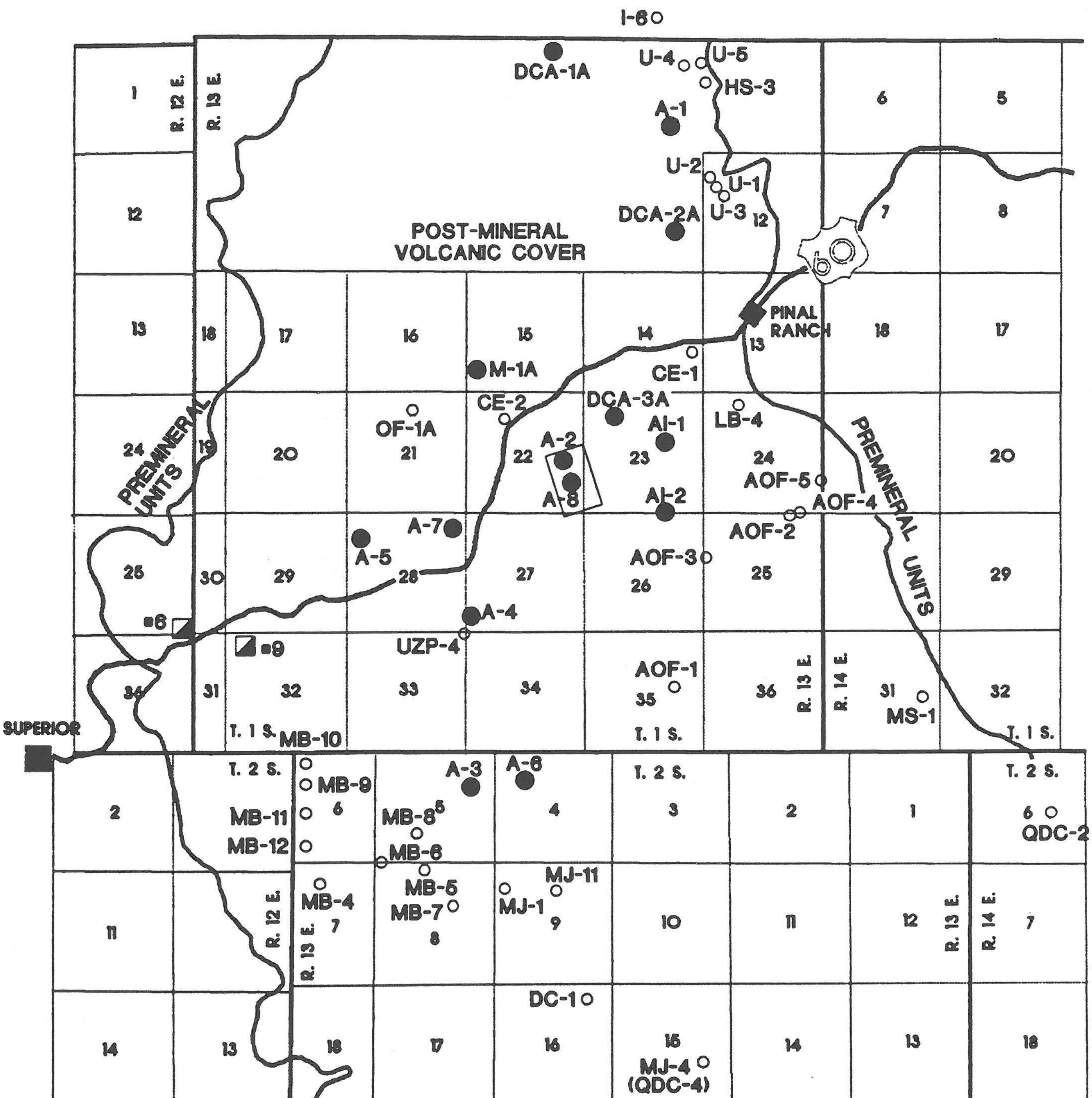

Figure 9. (adapted from Sell, 1995)

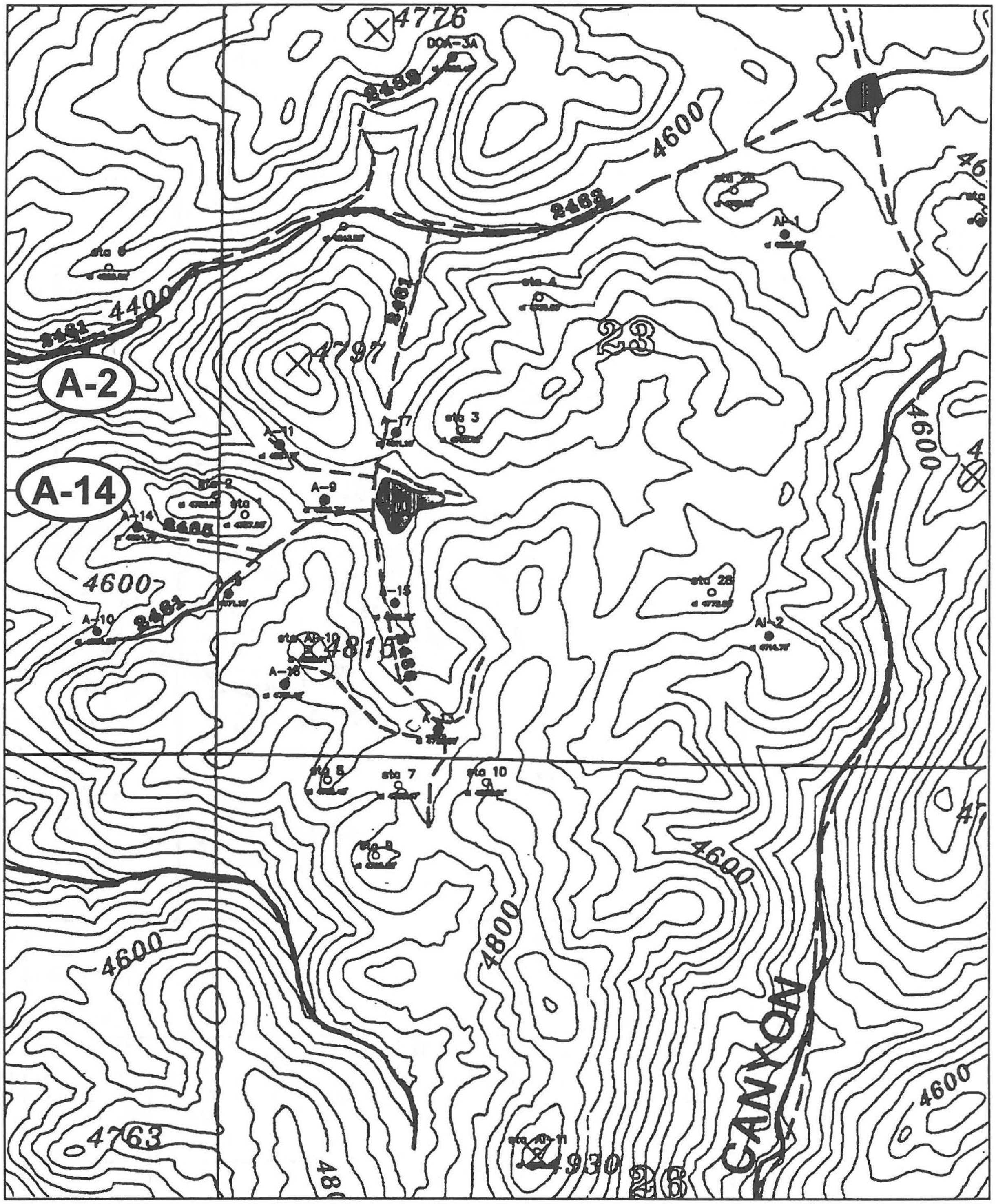

Figure 10. Drill hole detail at Superior East project.

We will go by hole A-2, then on up to the parking area at the big pond (about 1½ miles) and then walk on up to hole A-14 for an overview of the Superior East project. The abstract and exploration concept is reprinted here from the Bootprints article by Sell, 1995.

Discovery of a Deep (3500 feet) Unexposed Porphyry Copper Deposit at Superior East, Pinal County, Arizona

JAMES D. SELL *ASARCO Incorporated, Tucson, Arizona*

ABSTRACT

In 1970 ASARCO Incorporated initiated a search for porphyry copper mineralization postulated to lie under post-mineralization rocks between Superior and Miami in Pinal County, Arizona. An early drill hole penetrated 2,133 feet of volcanics and 4,351 feet of conglomerate for a total of 6,484 feet of post-mineralization cover rocks. Below the cover rocks the drill hole intercepted Laramide biotite quartz monzonite intruding Precambrian Pinal Schist which contained trace amounts of copper and molybdenum and displayed alteration and mineralization characteristic of porphyry copper deposits. Four drill holes later, the "discovery" hole penetrated 3,226 feet of post-mineralization rocks before intercepting the leached capping of a porphyry system. Below the leached capping, 646 feet of core assayed 1.57 percent copper. The intercept also averaged 31 ppm molybdenum, 0.22 ounces per ton silver, and trace gold.

Sulfide minerals at Superior East are chalcocite, bornite, chalcopyrite, and minor pyrite. Mineralization is disseminated and vein-controlled within Precambrian Pinal Schist intruded by several Laramide porphyries. Drilling in the deposit suggests a minimum geologic resource of 200 million tons with a grade of 0.90 percent copper including a high-grade core of 100 million tons at 1.1 percent copper.

Figure 1. Location of Superior East Project, eastern Pinal County, Arizona

INTRODUCTION

The Superior East Project is located between Superior and Pinal Ranch west of Miami in eastern Pinal County, Arizona (fig. 1). U.S. Highway 60 bisects the area from east to west; Devils Canyon bisects the area from north to south.

The initial report (Sell, 1970) proposing exploration for a major porphyry copper deposit hidden beneath volcanic cover rocks between Superior and Pinal Ranch was accepted by ASARCO International's New York corporate office, and an initial appropriation of funds was advanced in 1970.

EXPLORATION CONCEPT

Mineral exploration trend

N.P. Peterson (1962) summarized the geology of the Globe-Miami-Superior Mineral Belt, a six-mile wide, thirty-mile long northeast-trending mineralized zone (fig. 2). He noted that nearly half the area between the Old Dominion Mine (Globe) to the northeast and the Magma Mine (Superior) to the southwest is covered by thick blankets of post-mineralization volcanics and basin-fill deposits.

Following Mayo (1958), Balla (1972) labeled the northeast-trending zone from Globe to Magma the Jemez Zone and noted that intrusive activity along this trend was evident at 1,420 Ma with renewed activity at 840 Ma. Between 70 Ma and 60 Ma a number of intrusives including the Schultze Granite dated from 62 to 58 Ma were emplaced along the zone. Intrusive activity resumed at 20 Ma with the emplacement of the Wood Camp Canyon Quartz Monzonite north of Superior.

The intrusive and structural histories of the region are summarized by Billingsley and Locke (1941), Gay (1972), Graybeal (1972), Hammer and Peterson (1968), Landwehr (1967), Lindgren

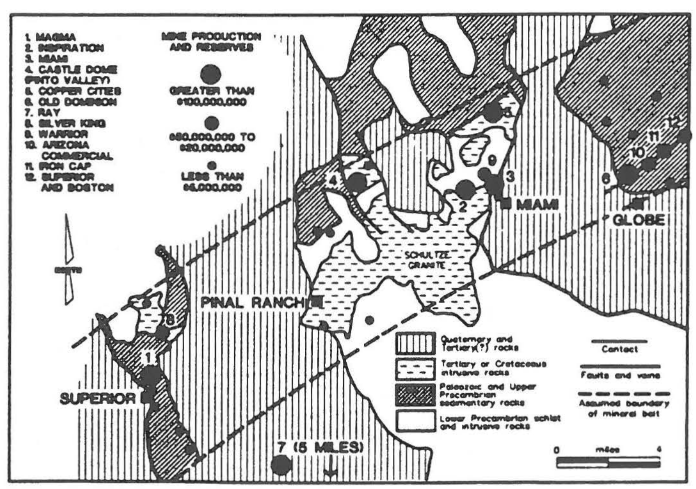

Figure 2. Index map of Pioneer (Superior) and Miami-Globe Districts with indicated limit of mineral belt and location of productive deposits (modified from N.P. Peterson, 1962).

(1915), Mayo (1958), Ransome (1915), Rehrig and Heidrick (1972), Schmitt (1933), and Wertz (1968). They also noted the alignment of intrusives and fracture trends related to porphyry copper deposits. This alignment and orientation is especially graphic on the geologic map of Arizona (Wilson and others, 1969).

The major pluton of the Superior East project area is the Schultze Granite (Peterson, N.P., 1962), which is elongated to the northeast. Castle Dome (Pinto Valley) and Copper Cities are along their own secondary northeast-trending alignment and are associated with smaller stocks of older (62-63 Ma, Balla, 1972) Lost Gulch Quartz Monzonite.

A large number of mineral deposits are associated with northeast elongation of plutons in the Arizona-New Mexico porphyry province. Deposits on northeast noses of such plutons include Poston Butte off the buried portion of the Three Peaks Granite (Balla, 1972), the Copper Creek Deposit (Hausen and Kerr, 1971, Balla, 1972), the Miami-Inspiration deposits off the Schultze Granite (Peterson, N.P., 1962; Olmstead and Johnson, 1966; Balla, 1972), the San Manuel Deposit (Creasey 1965; Thomas, 1966), the Johnson Camp, I-10, Dragoon, and Strong and Harris Deposits off the Texas Canyon Pluton (Cooper and Silver, 1964), the Metcalf-King Deposits in the Morenci District (Lindgren, 1905; Moolick and Durek, 1966), the Safford (Lone Star) Deposit (Cook and Robinson, 1962), and the Tyrone Deposit in New Mexico, (Paige, 1922).

Only the Sacaton Deposit north of Casa Grande is suggested to be off the southwest nose of the Three Peaks Monzonite (Balla, 1972). The location of twelve or so major mines off northeast noses and only one off a southwest nose of major northeast-trending plutons suggested an important question: What was the likelihood of a mineral deposit off the southwest nose of the northeast-elongate Schultze Granite under the volcanic cover between Pinal Ranch and Superior?

Drill hole A-8 was the discovery hole in that from 3,879 to 4,525 feet, the 646-foot section averaged 1.57% copper, with chalcopyrite-bornite mineralization.

This deep target has been drilled, Figure 10, for 3,000 feet northwest by 2,500 feet northeast. The mineralization has been cut by several northeast-trending faults which downdrop the zone to the northwest. Depth to sulfides average 4,010 feet below the surface on the south, 4,070 feet in the middle, and 4,480 feet to the northwest.

The deposit is open in plan, however, present interpretations suggest the drilled portion is part of a ring structure with a barren central core, similar to that suggested for the Ray deposit (Phillips, 1974).

O.K., let's return to the Oak Flat campground and have lunch while trading tales with the underground group.

Don't forget — LAST GUY, PLEASE CLOSE the GATE!

STOP 5

When you leave the campground, please spread out going back toward Superior.

Immediately after going through the Queen Creek Tunnel, turn left across traffic, when permissible, and pull into the wide parking area. Uphill traffic may be tight at times and will cause some problem going left—thus, we need space between vehicles so as to not stop in the right hand lane and cause more problems here!

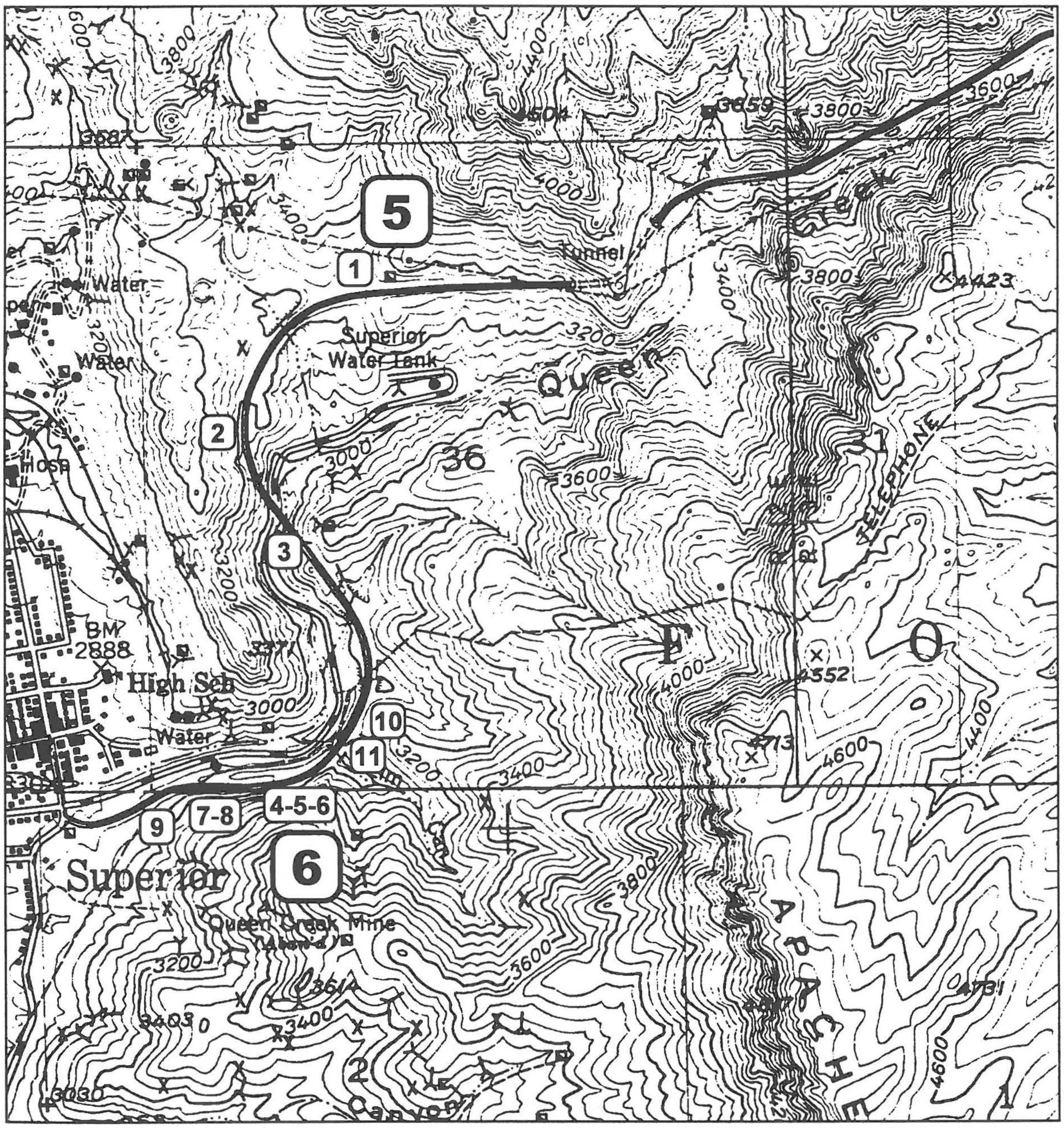

Figure 11. Stops 5 and 6 with the 11 geochemical sampling sites.

Unit	Sample	Footage	ppm						ppb
			Cu	Mo	Pb	Zn	Mn	Ag	Hg
Naco Limestone Middle Replacement	1	6	200	5	700	1500	53,000	50	105
Escabrosa Limestone Upper Replacement	2	10	200	30	2000	5000	130,000	100	220
	3	6	500	100	5000	5000	65,000	100	—
	A-4-1	10	3000	*	100	3000	3000	—	—
	A-4-2	10	5000	*	50	2000	3000	—	—
Escabrosa Limestone Middle Replacement	4	50	70	30	3000	1000	200,000	50	—
	5	1	500	20	1000	7000	2000	1	—
	6	50	20	*	100	200	1500	1	45
	A-4-3	10	500	15	*	2000	100	—	—
Martin Limestone Lower Replacement O'Carroll bed	7	5	300	10	1000	2000	1000	*	—
	8	12	50	*	50	200	2000	1	45
Bolsa Quartzite	9	50	50	*	*	*	300	*	135
LS&A Vein	10	20	20	2	50	200	10000	10	65
	11	100	200	15	2000	10,000	25,000	100	125

Unit	Sample	percent				Remarks
		Fe	Ca	Mg	SiO_2	
Naco Limestone Middle Replacement	1	2.0	3.0	0.03	76.0	mineralized replacement textures
Escabrosa Limestone Upper Replacement	2	2.0	7.0	0.02	37.7	mineralized replacement textures
	3	2.0	15.0	0.20	11.8	struc. w/lateral lms. repl. text.
	A-4-1	1.0	—	—	12.8	lms., bx., w/sec. CuOx
	A-4-2	1.0	—	—	20.5	lms., bx., w/sec. CuOx
Escabrosa Limestone Middle Replacement	4	3.0	5.0	0.02	24.5	struc. w/lateral lms. repl. text.
	5	33.3	5.0	0.10	4.0	total Fe repl. bed.
	6	1.0	23.2	5.00	1.8	repl. text. beds on both sides of sample 5
	A-4-3	37.3	—	—	36.9	total Fe repl. bed.
Martin Limestone Lower Replacement O'Carroll bed	7	33.0	1.5	0.20	37.9	total Fe repl. bed.
	8	1.0	26.0	5.00	1.7	repl text adj to sample 7
Bolsa Quartzite	9	5.0	0.10	0.05	90.0	weakly mineralized
LS&A Vein	10	1.0	24.0	0.10	—	in Naco, minor fract., above shale
	11	1.0	0.2	0.05	—	in Upper Escabrosa, mushroom, below shale

NOTE: mineralization is oxidized.
Dash (—) indicates no results for this sample.
Asterisk (*) signifies results reported were less than 2 ppm Mo; 25 ppm Pb; 200 ppm Zn; or 1 ppm Ag

Table 1. Geochemical data of samples from sites 1 through 11.

The site 1 in Stop 5 area is 2,500 feet vertically above the Devonian A-bed mineralization, west of the NS5W fault (the fifth north-south fault named). We are in the Pennsylvanian Naco Limestone section. It has numerous bleached beds in both the limestone and shale units. Numerous calcite veins subparallel to the east-west Magma Vein, located 1,000 feet north of the road, are in the units. On the south bank are several weak skarn-looking units. Iron and manganese have been added to some of the units.

Table 1 contains geochemical data for the sites 1 through 11.

At the east end of the parking area is a view point. Looking south over the water tank is the thin-bedded Naco, and at its upper contact, semi-saddle, is a yellowish zone of Whitetail Conglomerate, about 80 feet thick. This is the thickest section peeking out along the western front of the dacite. Dacite cliffs and the "Apache Leap" portion is along the south above the Whitetail.

Looking back to the west, past the new Queen Creek bridge, the workings left by the manganese miners are evident. Far out the gap of Queen Creek is the younger basin-filling volcanics.

The sample 1, taken in the north wall of the cut, is 3,500 feet up-dip from the "blind" Naco ore zone which has been mined. The zinc-manganese-silica values are indicative of the mineral fringes (especially up-dip) of the massive replacement deposits at Superior. Note also the anomalous silver value.

For those walking on down to the upper replacement zones of the Escabrosa Limestone, just below the Maroon Shale marker bed, the Samples 2 and 3 were collected four to five thousand feet up-dip (westward) from the "blind" Escabrosa C-C" bed. Note the lead-zinc-manganese-silver values and the moly in Sample 3. The A-4 drill hole samples reflect the silica addition and lower, but appreciable, lead-zinc-manganese. The higher copper values in the A-4 samples are the result of secondary copper oxides.

The vehicles should now move on down the hill. Take the off-ramp into Superior and turn hard right onto the parking of the old Highway 60.

STOP 6

Refer to Figure 11 for the sites to be discussed, and Table 1 for the geochemical data.

We will walk south, up AZ 177 on the bridge over US 60 East. The rock in the cut is Gila Conglomerate. Walk on down the on-ramp to Globe, and at the end of the east-bound on-ramp, two water pipes can be seen on the south bank.

The steep west-dipping, Concentrator Fault strikes north-south here and separates Quaternary Gila Conglomerate from Precambrian diabase.

Be careful walking east alongside the highway, and from diabase you'll pass by the red-stained Cambrian Bolsa Quartzite (Sample 9). The iron-stained and altered quartzite has an anomalous value of mercury and the high iron.

On ahead, just past the quartzite contact, is the lower Devonian ore bed (A-bed, O'Carroll bed) with samples 7 and 8. The O'Carroll stratigraphic horizon is one of the most persistent replacement horizons in Central Arizona, and generally reflects any nearby mineralization source for a longer distance than any other stratigraphic unit. The samples 7 and 8 show strong lead-zinc-manganese-silica additions over other Martin Limestone horizons (not listed here).

Moving up traffic, the main C-bed Escabrosa unit has three samples (4, 5, and 6). The entire range of values are elevated, including the sample from A-4. The dusky, replacement texture of this outcrop is typical of the better developed zones outside of ore.

The upper Escabrosa replacement horizon is not found in this section of outcrop, but was seen by those who walked down the road from STOP 5, and looked at points 2 and 3.

The section of outcrop along which we have just walked is between two east-west trending faults—the LS&A on the north along the creek and up ahead, and the Queen Creek Mine Fault to the south. When they built the new road, they broke into the Queen Creek Mine workings and did some back filling to stabilize the road. Thus, we cannot say that these values are indicative of the C-bed which is plus 5,000 feet east of here, however, they are indicative of the type found associated with mineralization.

Continue up along the curve to the manganiferous zone of the LS&A Fault. Climbing the hill, you'll see the Maroon Shale marker bed. Sample 11 was collected from the mushroomed manganese below the shale, while sample 10 was taken above the shale in the Naco Limestone. It is obvious that the shale acted as a trap for the mineralization at this point. When you return to your library, you may be interested in reading Hausen (178), p.4 and 5, where he discusses the early work by Newmont on the Superior stratiform replacement (manto) deposits.

While you are up on the slope, you might look for the small outcrops of porphyry among the Naco bedding (Peterson, D.W., 1962).

As the sun is setting behind Picketpost Mountain, Thank You for the Outing at Superior, and Thanks to Magma Copper Company!

Have a
safe journey
home.

Notes

🕮 Things To Read!

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