Prepared for the Utah School and Institutional Trust Lands Administration

Mineral Potential of the Blawn Wash Alunite Area, Beaver County, Utah

by

Ken Krahulec

Blawn Wash Area B looking east at sunset.

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EXECUTIVE SUMMARY

The Blawn Wash alunite area is located in southwestern Beaver County, Utah approximately 29 miles southwest of Milford. The Blawn Wash alunite deposits consist of four discrete resistant ridges designated Area A in the south, Area B in the east, Area C in the north, and Area D at Blawn Mountain in the west. The land covering the Blawn Wash alunite deposits is currently controlled by the Utah School and Institutional Trust Lands Administration (SITLA).

The first mention of the Blawn Mountain mining district is a very brief note about iron mining. The Staats fluorite mine, on the south flank of Blawn Mountain, was first staked in 1931. The mid-1970s saw Anaconda, Western Nuclear, Phillips Petroleum, Brush Beryllium, Energy Fuels, and Exxon examine the district, primarily for uranium. In 1976, Phelps Dodge Corporation discovered the deep, Climax-type porphyry molybdenum deposit at Pine Grove. Also in the 1970s, Earth Sciences, Inc. (ESI) began to search for alunite deposits as a possible source of alumina. ESI subsequently formed the Alumet Joint Venture with National Steel Corporation (25%), and the Southwire Company (25%) to develop the de-posits. However, due to poor economics and high initial capital cost, the project lost momentum stalled, and was ultimately shelved.

The Blawn Wash alunite deposits lie in the eastern portion of the Basin and Range province. The more than three-mile-thick section of generally conformable Paleozoic miogeosynclinal sedimentary rocks that compose most of the Wah Wah Mountains north, west, and south of Blawn Mountain were folded about a northerly trending axis and thrust eastward during the Late Cretaceous Sevier orogeny.

Following a period of uplift and erosion, the Paleozoic sedimentary rocks were covered by a thick se-quence of Oligocene and Miocene volcanic rocks. Magmatism associated with east-west-trending mineral belts was predominantly calc-alkaline prior to about 24 Ma and bimodal afterward. The later Mio-cene bimodal suite (23-18 Ma) resulted in much smaller volumes of magmatism, predominantly po-tassic trachyandesite generally associated with slightly younger rhyolites. Several small, silicic-alkalic, rhyolite porphyry plugs are associated with the Blawn Wash alteration. The current topography is a result of Basin and Range extension and block faulting during the Miocene and Pliocene.

The Blawn Wash alunite deposits occur in a triangular-shaped area about 4.5 miles on a side. The chemical formula for alunite is $KAl_3(SO_4)_2(OH)_6$, giving a composition of about 11 weight percent K_2O, 37% Al_2O_3, 39% SO_3, and 13% H_2O. The Blawn Wash alteration was mapped at a scale of 1:12,000 and divided into six types of alteration of the volcanic rocks: low propylitic, high propylitic, hematite-clay, quartz-alunite, silica cap, and quartz-sericite-pyrite.

The Blawn Wash alunite deposits are believed to have resulted from the upwelling of hydrothermal fluids derived from a shallowly emplaced felsic intrusion associated with the Blawn Formation volcanism at about 22.5 Ma. As the low-salinity, about 300°C, H_2S-bearing fluids rose above the local water table, boiling ensued, H_2S was oxidized to H_2SO_4, and the sulfuric acid leached the host volcanic rocks forming broad areas of advanced argillic alteration. In the zones of strong hydrothermal upwelling, the alunite-rich alteration occurs as deeply rooted, downward tapering cones. Elsewhere, the alunite deposits are shallow, tabular zones consisting of steam-heated deposits above the regional paleo-ground-water table.

The global alunite resource delineated at Blawn Wash is approximately 738 million short tons averaging about 41% alunite. Within this, Alumet defined a “proven” resource of about 129 million tons averaging 38% alunite in Area C. In 1977, the final proposed alunite mine and processing plant anticipated a production of 500,000 tons per year of alumina with byproducts of 370,000 tons per year of potassium sulfate fertilizer, 1.7 million tons per year of superphosphate fertilizer, and 20,000 tons per year of aluminum fluoride. Based on current estimated prices of \$312/ton for alumina (Al_2O_3) and \$300/ton for potassium sulfate, the in-place value of these commodities in the Blawn Wash deposits is over \$50 billion. These prices also yield a value of \$65/ton for the primary resource in Area C.

The Blawn Wash alunite deposits are part of an advanced argillic alteration assemblage which could also constitute the lithocap above an undiscovered porphyry deposit at depth. The proximity to and similarities between Blawn Wash and the Climax-type deposit at Pine Grove suggest that molybdenum mineralization may lie beneath the mapped alunite alteration zones, possibly as shallow as 2000 feet. Likewise, there could be similar potential for less valuable mineral deposits such as Mo-W or Zn-Pb-Ag skarns and replacement deposits. Peripheral portions of the Blawn Wash alunite system to the southwest are being exploited for kaolinite.

INTRODUCTION

The Blawn Wash alunite area is located in southwestern Beaver County, Utah approximately 29 miles southwest of Milford (figure 1). Milford is a small (population 1450) Union Pacific railroad town about halfway between Salt Lake City and Las Vegas. The Blawn Wash alunite area lies on the east flank of the Wah Wah Mountains and is considered part of the Blawn Mountain mining district. The Blawn Wash property has been referred to by a variety of names including: Alunite, Alumet, Area C, Blawn Mountain, Cedar City Alunite, NG Alunite, Revenue prospect, and Wah Wah. The Blawn Wash area is located about seven miles southeast of the Pine Grove mining district, 3.5 miles northeast of the Staats mine area, and roughly 16 miles from the Union Pacific's main line to the southeast. Blawn Wash is reached by driving west on Utah State Highway 21 from Milford for 24 miles and then turning south on a network of county-maintained gravel and dirt roads for an additional 17 miles.

Because alunite is resistant to weathering, the deposits result in topographic highs. The Blawn Wash alunite deposits consist of four discrete resistant ridges designated Area A in the south, Area B in the east, Area C in the north, and Area D at Blawn Mountain in the west. The terrain varies from steep hills to small mountains with an elevation range from 8250 feet at the top of Blawn Mountain down to about 6400 feet in the bottom of the dry washes on the east edge of the area. Vegetation generally consists of juniper and pinyon pine covering slopes, sagebrush and grass on low hills, and rabbitbrush and grass out on the flats. Ponderosa pine is present locally above about 8000 feet on Blawn Mountain and in the wet bottom lands of Pine Grove.

The land covering the Blawn Wash alunite deposits is currently controlled by the Utah School and Institutional Trust Lands Administration (SITLA). These lands were acquired from the U.S. Bureau of Land Management (BLM) by trade. The mineral rights of a few pre-existing unpatented mining claims were transferred from the BLM to SITLA during the land exchange. Some of these are still valid claims and cover a portion of Area B. In addition, SITLA has granted some clay and metalliferous leases adjoining Area A.

The Blawn Wash area is known for its large alunite deposits which have been explored as potential sources of alumina and potassium sulfate fertilizer. These alunite deposits are part of an advanced argillic hydrothermal alteration zone which could be the lithocap to a porphyry molybdenum deposit. In addition, clay is being produced from just west of Blawn Mountain and a possible clay resource is held east of Area A.

District History

Early Exploration

The first mention of the Blawn Mountain mining district appears to be this very brief note in Butler and others (1920):

> The iron deposits in the eastern foothills of the Wah Wah Range near English Springs, about 20 miles south from Newhouse, were not examined, and no description of them has been found in the literature. Some ores from them were shipped to the Frisco smelters about 1880.

The Staats fluorite mine, on the south flank of Blawn Mountain, was staked as the Monarch claims in 1931 (Bullock, 1976) and subsequently purchased by Fred Staats and associates in 1938. The fluorite property was worked by a small open cut and also has an estimated 800 feet of underground workings. Some 4855 tons of fluorite was mined from 1935 to 1951. During the 1950s, uranium was discovered at the Staats mine and an additional 1994 tons of 0.258% U_3O_8 uranium ore were shipped. Similar mineralization occurs a half mile to the south at the Daisy, Producer, and Desert View #1 mines, although lesser amounts of fluorite and uranium ore have been produced from these mines (Bullock, 1976).

Mickey Robis (an old Industrial Workers of the World [Wobbly] underground contract miner) from Milford acquired the Staats mine area property in 1955, and held it into the 1980s. In the 1970s, exploration elsewhere in the Blawn Mountain district focused on molybdenum, clay, and uranium potential. In the early part of the decade, the J.M. Huber Corporation evaluated the potential of the kaolinite resources near the saddle in the ridge north of the Staats mine on the extreme west end of Blawn Mountain (Area D). They reportedly drilled a few dozen shallow holes (less than 500 feet deep) and delineated a kaolinite (+alunite?) clay resource near the saddle on the top of Blawn Mountain (unpublished data in Utah Geological Survey files).

The mid-1970s saw Anaconda, Western Nuclear (Phelps Dodge), Phillips Petroleum, Brush Beryllium, Energy Fuels, and Exxon examine the district, primarily for volcanic-hosted uranium (unpublished data in Utah Geological Survey files). Western Nuclear drilled thirty-eight rotary holes to depths of 80 to 460 feet and intersected weak uranium mineralization associated with fluorite in the tuff. Anaconda then joint ventured the property and probed these holes. The average uranium drill intersection was roughly a few feet of 0.02% estimated U_3O_8 with the best intercept being four feet averaging 0.23% estimated U_3O_8 (Nielson, 1976).

In 1976, Phelps Dodge Corporation discovered the deep, Climax-type porphyry molybdenum deposit at Pine Grove. The first hole hit low-grade molybdenum mineralization and three of the following holes hit high-grade molybdenum. The project was joint ventured with Getty Oil Company in 1978 and an additional 30 deep holes were completed totaling 107,953 feet (Staff, 1984). The deposit hosts about 124 million tons averaging about 0.36% MoS_2. No important work has been done on the property since 1983.

In the late 1970s and early 1980s, the Getty Oil Company, Amoco, and Amax all looked at the potential for a deep molybdenum porphyry deposit near the Staats mine (Pack, 1995). Amoco ran two north-south IP lines on the property in 1979, but apparently did no further work. Amax ended up drilling two shallow holes near the Staats mine. In 1980, they drilled a 313-foot core hole on top of the ridge, a half mile north of the Staats mine for assessment purposes. The following year, Amax drilled a second 808-foot rotary hole in the rhyolite about 4600 feet south-southeast of the Staats mine. Both the outcropping rhyolite (>2000 ppm F) and the rhyolite in the drill hole (>3000 ppm F) are anomalous in fluorine. This property was then joint ventured with Anaconda. Anaconda ran a single, long, north-northeast trending IP line across Blawn Mountain, but failed to turn up a significant anomaly (unpublished data in Utah Geological Survey files).

Figure 1. *Location of the Blawn Wash alunite area (red), Beaver County, Utah (railroads shown in dark green).*

Red beryl was found three miles east of Blawn Wash by Ted Harris of Delta in the mid-1970s. This deposit has been exploited for marketable gem-quality crystals at the Violet mine sporadically since 1976. Production figures from 1989 to 1993 total approximately $3.4 million. In 1994, Kennecott Exploration leased the mine in an unsuccessful attempt to define a large, economic, red beryl resource. The beryl is hosted in the upper Rhyolite member of the Miocene Blawn Formation (Keith and others, 1994). Rancho Equipment still retains a Utah Department of Oil, Gas and Mining (DOGM) large mine permit for the Violet mine property.

Alunite Deposits

In the 1970s, Earth Sciences, Inc. (ESI) began to search for alunite deposits as a possible source of alumina. This program was driven by rapidly escalating aluminum prices from 25 cents per pound in 1972 to 76 cents per pound in 1980. There were fears, at that time, of the formation of an international aluminum cartel and the U.S. Bureau of Mines began an alumina mini-plant research and development project (1974-1981) to test possible nonbauxitic resources and metallurgical processes (Barclay, 1984). So ESI began to look for a domestic source of aluminum (Richard H. DeVoto, consulting geologist, verbal communication, 2006). ESI initially conducted reconnaissance exploration of reported hydrothermal alteration zones, westward along the Marysvale-Pioche mineral belt from the known alunite deposits near Marysvale. Follow-up work by Bill Walker led to the discovery of several alunite deposits in southwestern Beaver and northwestern Iron Counties, including the NG[1] (Blawn Wash) deposits (W.W. Walker, consulting geologist, verbal communication, 2006).

The following year, a Joint Venture (Alumet JV) was formed between ESI (50%), National Steel Corporation (25%), and the Southwire Company (25%) to develop the deposits, employing a staff of about ten in an office in Cedar City. At least eight alunite properties were located, mapped, sampled, and acquired through the staking of unpatented lode mining claims and the acquisition of federal potassium prospecting permits. The most favorable of these targets, primarily those at Blawn Wash, were then drill tested, bulk sampled, metallurgically tested, and had engineering designs completed. ESI also completed an Environmental Impact Assessment (Earth Science, Inc., 1974) and a "Survey of Community Attitudes" (Lewis and others, 1974). The survey found overwhelming local support and concluded: "It is hard to imagine any other issue of which one would obtain such a consensus." This was followed by a Final Environmental Statement by the BLM in 1977 (U.S. BLM, 1977). However, the project lost momentum due to its poor economics and very high initial capital cost, stalled, and was ultimately shelved. In the late 1970s, ESI battled the BLM in court over the costs of producing the Final Environmental Statement, and prevailed on appeal. Alumet assigned its Utah alunite interests back to ESI in December, 1986. ESI retained some of the mineral rights to the most promising property (Area C) through a 680-acre Federal Potassium Preference Right Lease until 1998 (SEC filing); however, ESI finally relinquished all the ground.

Canyon Resources Corporation[2] explored the Blawn Wash property for uranium, without success, in the 1980s. They also did some gold exploration on the property, which included analysis of some of the alunite drill core. Although the results are unavailable, Bill Walker reports that the samples were not anomalous in gold, but may have been weakly anomalous in some of the typical gold-associated trace elements (W.W. Walker, consulting geologist, verbal communication, 2006). Canyon Resources also supported a Colorado School of Mines master's thesis on Blawn Wash by Albert Hofstra (1984).

In the mid-1980s, Mel Pack and his company, JLP Exploration Company, acquired the ground over the Area B alunite zone primarily as a Goldfields-type gold target. He leased the property to Fire Clay Minerals Inc., who agreed to a deep drill test of the alteration. The reverse circulation hole reportedly drilled 610 feet of oxidized, argillized volcanics followed by propylitized volcanics with disseminated pyrite to 1425 feet, before bottoming at 1480 feet in strong propylitically altered volcanics with lesser pyrite and increasing hypogene specularite (Pack, 1995). Pack still retains a few unpatented mining claims on Area B.

Recent Work

In the 1980s, the exploration focus shifted to gold. Although little gold exploration actually took place on the Blawn Wash alunite zones, several companies did work, including drilling, peripherally, mostly in areas of Paleozoic carbonates. Freeport MacMoran Corporation (FMC) drilled an area of quartz-carbonate veins a few miles to the south, near the Seeps. FMC also looked at a prospect west of Blawn Wash near Lamerdorf Spring. Kennecott, Goldfields, Mark Dotson, and others have drilled auriferous jasperoids in the Blue Mountain district three to five miles southeast of the Blawn Wash alunite deposits (Pack, 1995).

During the 1990s, Mark Dotson of Milford also drilled a series of shallow holes (less than 500 feet deep) southeast of the Iron Mines, southwest of Area C. These holes bottomed in fresh limestone, no obvious mineralization was intersected, and the holes were not assayed. Dotson also drilled the crest of the Blue Mountain dome for base metals. None of these projects have resulted in metal production.

The Blawn Mountain mining district currently has two DOGM-permitted small "clay" operations. One called the "Mickey project," is a small kaolinite open pit about five miles west of the Blawn Wash alunite area. The other operation, Sandy Wash 4 (owned by Sandy Nell), is in the extreme southwest corner of the Blawn Wash, west of Area D, and is likely opened on a mixture of kaolinite, alunite, and dickite (appendix A, photograph 19). This deposit is believed to host about 5 to 7 million tons of clay resources.

REGIONAL GEOLOGIC SETTING

The Blawn Wash alunite deposits lie in the eastern portion of the Basin and Range province of western Beaver County, Utah. Blawn Wash lies within a broad, east-northeasterly trending zone of Tertiary magmatism known as the Pioche-Marysvale mineral belt (figure 2; Stewart and others, 1977). Within the Pioche-Marysvale belt of Beaver County, magmatism generally becomes younger to the south and east. The origin of the mineral belt and the associated lineaments is well described by Rowley and Dixon (2001).

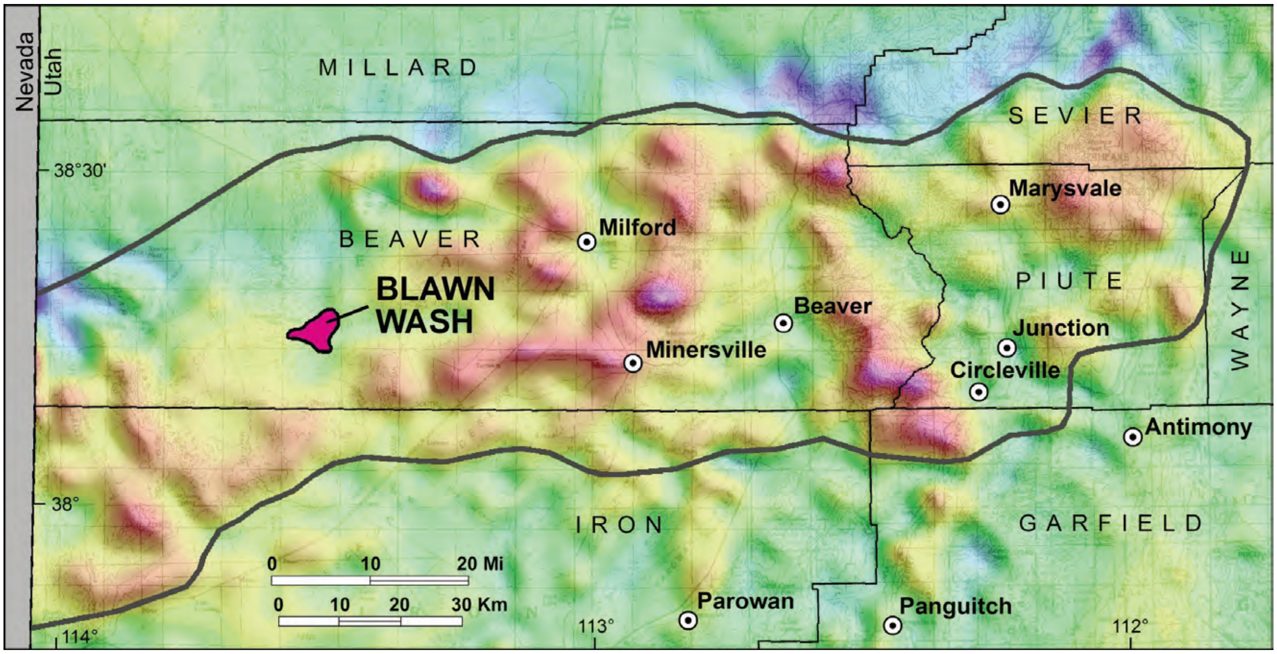


Figure 2. *Aeromagnetic map (highs in red, lows in blue) of the Utah portion of the Pioche-Marysvale mineral belt (outlined in black). The magmatic-hydrothermal mining districts in the belt generally become younger to the south and east, ranging in age from about 31 Ma down to less than 15 Ma. The pre-24 Ma mineralizing monzonite to granodiorite intrusive rocks are magnetic and show up as magnetic highs. In contrast, the post-24 Ma rhyolitic mineralizing intrusions are generally non-magnetic and do not show as pronounced a magnetic signature on this scale. Base aeromagnetic map from Raines and others, 1996).*

Magmatism associated with these belts was predominantly calc-alkaline prior to about 24 Ma and bimodal afterward. The earlier Oligocene magmatism produced great volumes of largely intermediate-composition plutonic and volcanic rocks, mostly monzonite and andesite. Large calderas formed with the eruption of these lavas. However, southwestern Utah was tectonically inactive and topographically flat during the late Oligocene so that by 26 Ma, the Isom Formation tuff "forms a thin sheet no more than a few tens of meters thick throughout most of the area" (Best and others, 1987).

The later Miocene bimodal magmatic suite (24-18 Ma) resulted in much smaller volumes of potassic trachyandesite and generally slightly younger rhyolites (Best and others, 1987; Rowley and others, 2002). Keith and others (1986) suggest that the nearby Pine Grove porphyry molybdenum deposit formed at about 23-22 Ma, soon after the switch from calc-alkaline to bimodal magmatism. They also note that Pine Grove has many of the characteristics of Climax-type deposits including a high-silica rhyolite porphyry plug, a lack of significant copper mineralization, and associated fluorite, topaz, and huebnerite ($MnWO_4$). Keith and others (1993) believe that the changeover from compressional to extensional tectonics may be important to the formation of giant porphyry molybdenum deposits.

Bimodal volcanism continued after a several million year hiatus, beginning again about 14 Ma. This volcanism again produced potassic basaltic rocks and high-silica, topaz-bearing rhyolites (Best and others, 1987). The Alunite Ridge deposits in the Mount Baldy district, near Marysvale, Utah formed at this time (Beaty and others, 1986).

The current topography is a result of Basin and Range extension by listric and block faulting during the Miocene and Pliocene (Best and others, 1987). The Wah Wah Mountains at Blawn Wash are a typical north-south trending range (figure 3). Cross-sections of the Wah Wah Mountains suggest that the range, like many others in the eastern Basin and Range, has been rotated eastward by 5 to 25 degrees since the early Miocene (Abbott and others, 1983), probably by major displacement on the west bounding fault.

LOCAL GEOLOGY

The conformable sequence of Paleozoic miogeosynclinal sedimentary rocks that compose most of the Wah Wah Mountains north, west, and south of Blawn Mountain were folded and thrust during the Late Cretaceous Sevier orogeny (figure 4). Approximately 10,000 feet of upper Proterozoic and overlying Cambrian strata are emplaced on the Wah Wah thrust over the estimated 7000 feet of Ordovician to Pennsylvanian strata (table 1). The upper plate of the thrust has been broadly folded into an open, upright, gently north-northeast-plunging syncline (Abbott and others, 1983). Additional, smaller, imbricate thrust faults occur deeper and emplace the middle and upper Paleozoic sedimentary rocks over Mesozoic clastic strata (Miller, 1966).

The concealed traces of the Tetons and Dry Canyon thrust faults and a northeast-trending anticlinal fold are projected to pass under the volcanic cover near the center of the Blawn Wash alteration system. The upper Teton thrust zone emplaces Ordovician and Silurian strata over Silurian and Devonian carbonates. The underlying Dry Canyon thrust emplaces the Silurian and Devonian carbonates over Pennsylvanian and Mississippian strata.

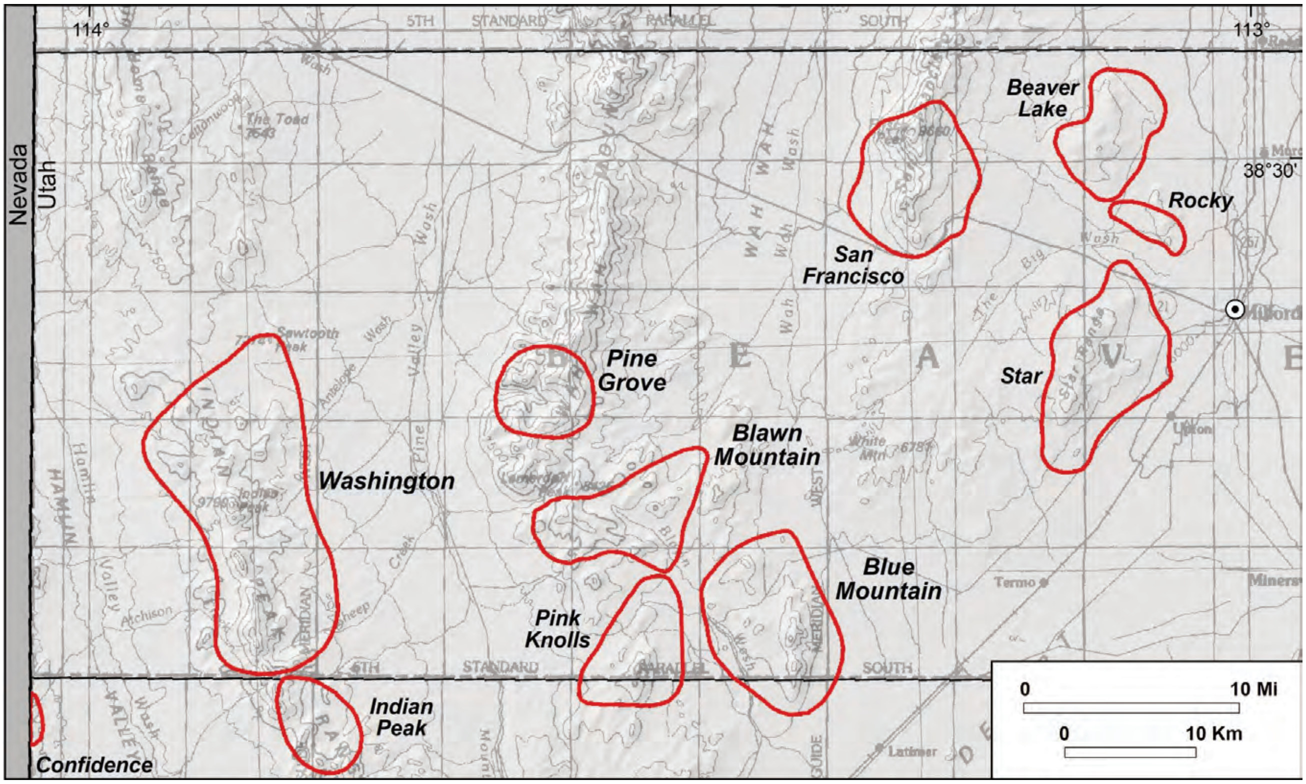


Figure 3. Location of geographic features and mining district boundaries in the southwestern portion of the area covered by the aeromagnetic map in figure 2.

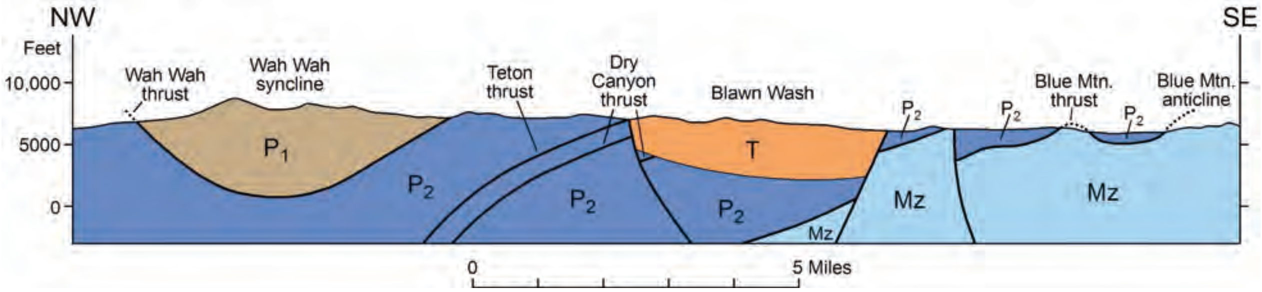


Figure 4. Diagrammatic northwest-southeast cross section through the Blawn Wash area, looking northeast. The section extends through the Wah Wah Mountains on the northwest, the Blawn Wash graben, and Blue Mountain on the southeast. Thrust faulting separates the major stratigraphic packages:

T = Tertiary volcanic rocks
Mz = Mesozoic block beneath the Blue Mountain thrust
P_2 = Upper Paleozoic block between the Blue Mountain and Wah Wah thrusts
P_1 = Lower Paleozoic block above the Wah Wah thrust

Modified from Abbott and others (1983) and Hintze and others (1994).

Table 1. Stratigraphy of the Blawn Wash Area

	Age	Group/Formation	Formation/Member	Age (Ma)
Tertiary	Quaternary	Alluvium and colluvium		
	Pliocene	Steamboat Mountain Formation	Basalt	13.0
	Miocene	Blawn Formation	Rhyolite member	20.0
	Miocene	Blawn Formation	Tuff member	23.0
	Miocene	Quichapa Group	Bauers Tuff member	
	Miocene	Blawn Formation	Mafic Flow member	24.0
	Miocene	Blawn Formation	Garnet tuff member	24.0
	Oligocene	Isom Formation	Bald Hills tuff member	26.0
	Oligocene	Bullion Canyon Volcanics	Three Creeks Tuff member	
	Oligocene	Needles Range Group	Lund Formation	27.9
	Oligocene	Needles Range Group	Wah Wah Springs Formation	29.5
	Oligocene	Needles Range Group	Cottonwood Wash Tuff	30.6
	Oligocene	Needles Range Group	Escalante Desert Formation	32.3
	Oligocene	Conglomerate		
Upper Plate of Wah Wah Thrust	Cambrian	Orr Formation		
	Cambrian	Wah Wah Summit Formation		
	Cambrian	Trippe Limestone		
	Cambrian	Pierson Cove Formation		
	Cambrian	Eye of Needle Limestone		
	Cambrian	Swasey Limestone		
	Cambrian	Whirlwind Formation		
	Cambrian	Dome Limestone		
	Cambrian	Peasley Limestone		
	Cambrian	Chisholm Shale		
	Cambrian	Howell Limestone		
	Cambrian	Pioche Formation		
	Cambrian	Prospect Mountain Quartzite		
	Proterozoic	Mutual Formation		
Lower Plate of Wah Wah Thrust	Pennsylvanian	Callville Limestone		
	Mississippian	Woodman Formation		
	Mississippian	Gardison Limestone		
	Devonian	Fitchville Formation		
	Devonian	Pinyon Peak Limestone		
	Devonian	Guilmette Formation		
	Devonian	Simonson Dolomite		
	Devonian	Sevy Dolomite		
	Silurian	Laketown Dolomite		
	Ordovician	Ely Springs Dolomite		
	Ordovician	Eureka Quartzite		
	Ordovician	Kanosh Shale		
	Ordovician	Juab Limestone		

Modified from Hofstra (1984) and Abbott and others (1983).

Following a period of uplift and erosion, the older sedimentary rocks were covered by a thick sequence of Oligocene and Miocene volcanic rocks. After this hiatus and deposition of a variable thickness of conglomerates, a thick sequence of about 3000 feet of Oligocene Needles Range Group moderately welded, quartz latitic tuffs were laid down between 32.3 to 27.9 Ma (table 1). This was followed by thin layers of tuffs belonging to the Bullion Canyon Volcanics and Isom Formation. The Isom is a 26 Ma, densely welded, vuggy, eutaxitic, latitic, and vitric ash-flow tuff. The Isom Formation is a cliff-former, less than 100 feet thick, and is used as a regional marker (Abbott and others, 1983).

Overlying this section are the Miocene Blawn Formation (24 to 18 Ma) volcanic rocks. The lowermost member is a 500-foot-thick, garnetiferous rhyolitic member, shown to be the stratigraphic equivalent of the vent facies of the East End pluton at Pine Grove (Keith, 1980; Keith and others, 1986). The garnets are deep red, <0.2 inch in diameter, yttrium-rich, almandine-spessartine, identical to those in the Pine Grove intrusive. The rhyolite is overlain by a 600-foot-thick trachyandesite flow member. Then a thin interval of Quichapa Group tuffs, a regional unit, was deposited. This is followed by another tongue of Blawn Formation latitic, welded ash-flow tuffs (600 feet) and porphyritic rhyolite plugs, domes, and flows (Abbott and others, 1983). Keith (1980) estimates an original volume of about 25 cubic kilometers of erupted material in the Blawn Formation.

Several small, silicic-alkalic, porphyry plugs are known to be associated with the Blawn Formation (figure 5). These include the Pine Grove porphyry, Staats rhyolite, and the Blawn Wash plugs. Keith and others (1986) report a 23-22 Ma date for the Pine Grove porphyry. The small topaz rhyolite plug adjacent to the fluorite-uranium mineralization at the Staats mine, just southwest of Area D (figure 5), was dated at 20.2 Ma (Mehnert and others, 1978).

Three mapped silicic-alkalic rhyolite plugs of the upper Blawn Formation, centrally located with respect to the Blawn Wash alunite alteration, are variably, but generally weakly argillically altered (appendix A; photograph 20 and 21). These mapped intrusives are oriented along a N. 55° W. trend. These small plugs have sparse feldspar and quartz phenocrysts with traces of biotite and are strongly flow-banded, especially along the margins. Flow banding in these small rhyolite plugs is generally sub-vertical and some intrusive breccias are present.

Abbott and others (1983) dated the Blawn Wash central rhyolite porphyry at 22.2 Ma and Hofstra (1984) reports an age of 22.5 Ma on the alunite in Area C. Alteration east of White Mountain was also dated as 22.5 Ma by Best and others (1987). Ages of alunite alteration at Marysvale are reported at 23 Ma and 17-14 Ma (Cunningham and others, 1984a).

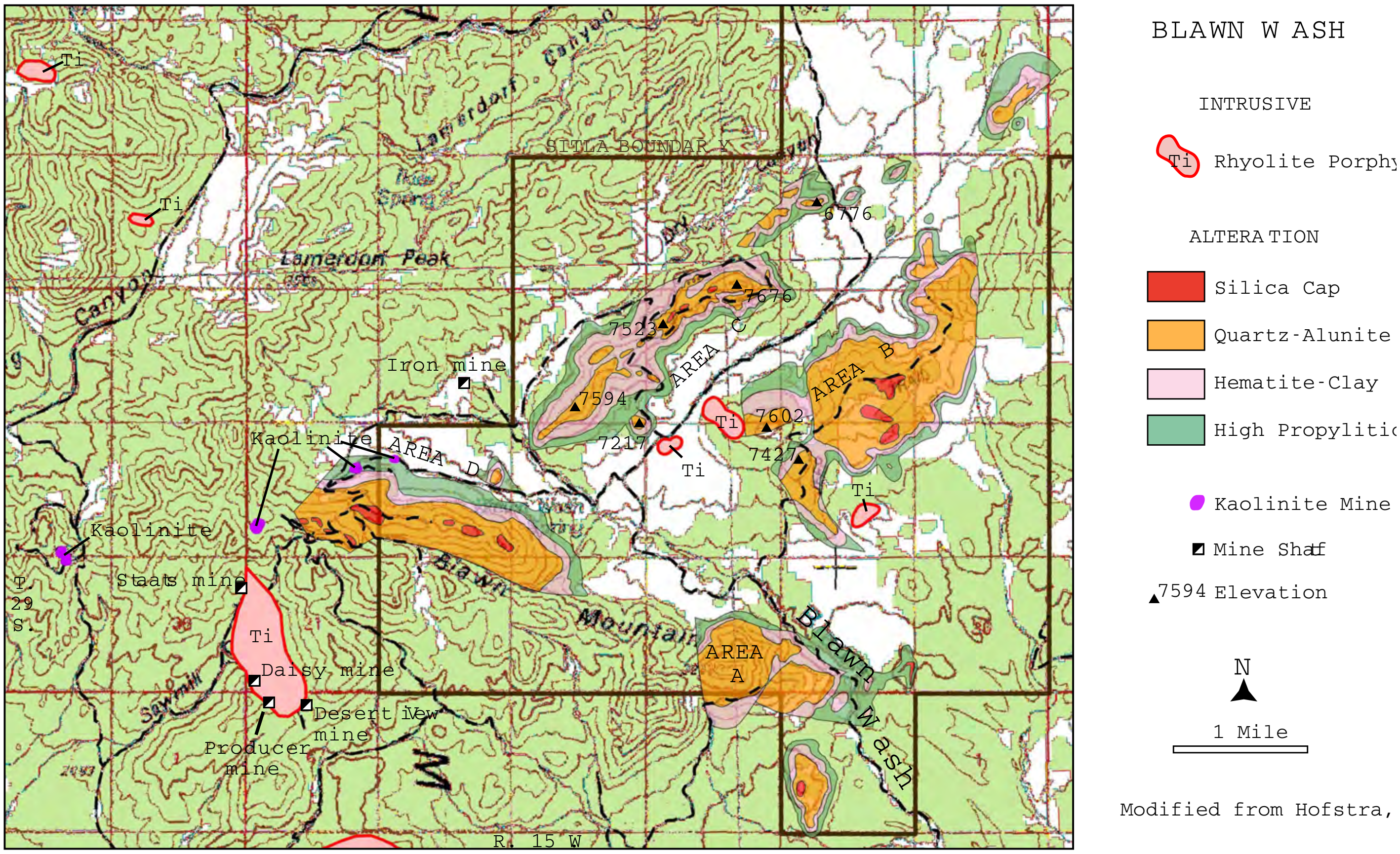


Figure 5. *Blawn Wash's four principal alunite zones along with some smaller outlying altered areas are shown along with the generalized Miocene rhyolitic porphyries (red), primary access roads (black, dashed), and SITLA property boundary on a USGS 1:100,000 topographic base.*

A small, isolated, alunitized knob on the southeast flank of Area C (SE¼SE¼SE¼ section 21) locally has large, abundant quartz eyes and could represent a pervasively altered intrusive. This knob also features strong iron-oxide coatings on fractures, possibly the weathering products of sulfide minerals.

Attitudes of flow foliation and bedding within the Tertiary volcanic section at Blawn Wash typically dip moderately (15 to 50 degrees) to the east or southeast. Faults mapped in the area show four dominant trends: west-northwest, northeast, northwest, and north-south. The west-northwest trending faults are typically normal faults down-thrown to the north. This is also the trend of surficial base metal mineralization at Pine Grove. The northeast set is dominantly a set of normal faults down-thrown to the southeast. There are also some northwest-trending faults conjugate to the northeast faults (Abbott and others, 1983). The final Blawn Wash area fault set trends north-south (Basin and Range), is generally normal, and has down to the east displacement.

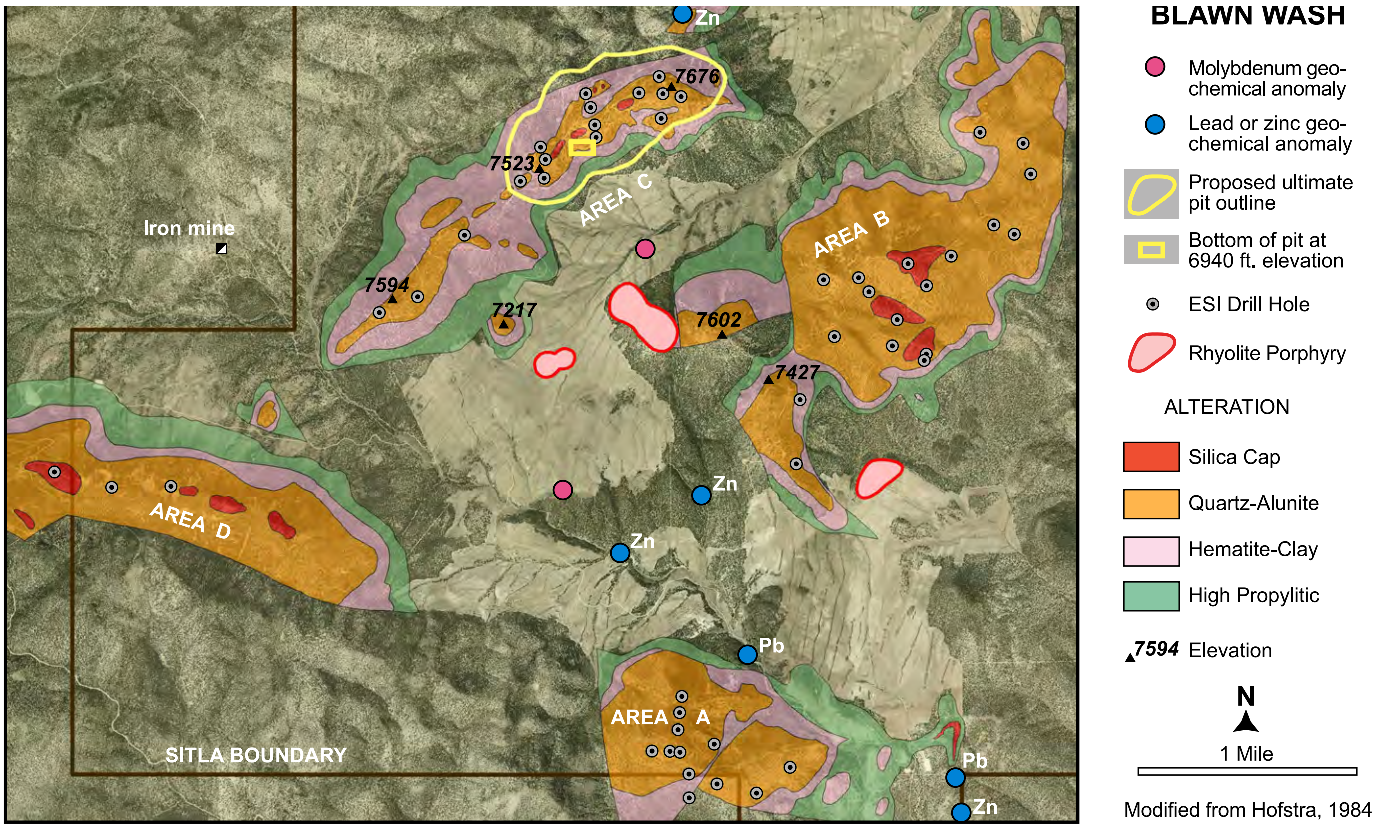
The west-northwest, northeast, and northwest fault sets appear to be pre- or syn-alteration. The west-northwest and northeast faults form an angular graben, or possible caldron, which largely contains the Blawn Wash alunitic alteration. Hofstra (1984) suggests there is an intrusive at depth beneath this area based on domal or homoclinal surface dips.

The volcanism in the Blawn Wash area resumed briefly after a 5 million year hiatus, with an additional 500 feet of mid-Miocene basaltic andesite (13 Ma), which occur mostly east of Blawn Wash and are entirely post-mineralization (Abbott and others, 1983).

While the depth to the bottom of the Tertiary volcanic rocks at Blawn Wash is unknown, it is probably in the range of 2000 to 3000 feet based on cross sections through the alteration zones (Abbott and others, 1983; Hofstra, 1984).

Hydrothermal Alteration

The Blawn Wash deposits occur in a triangular shaped area about 4.5 miles on a side (figure 6). The alunite deposits, as defined by ESI, form four resistant ridges designated Area A (appendix A, photograph 1) in the south, Area B (appendix A, photographs 2 to 7) in the east, Area C (appendix A, photographs 8 to 17) in the north, and Area D (appendix A, photograph 18) at Blawn Mountain in the west. These four ridges consist of pervasive, texturally destructive hydrothermal alteration. The alunitic alteration is developed wholly within the Oligocene-Miocene volcanic and volcaniclastic rocks, however, due to the intensity of the alteration, individual host rock formations have not been differentiated in drilling. On the surface, the altered rocks are predominantly Blawn Formation and the underlying Needles Range Group; the intervening Isom Formation, a strongly welded tuff, is not as susceptible to alteration. The most intensely altered rocks are the porous rocks of the upper part of the Lund Formation of the Needles Range Group and the poorly consolidated tuffs and tuffaceous sediments of the Blawn



Modified from Hofstra, 1984

Figure 6. *Detailed map of the Blawn Wash alunite areas, drill holes, Miocene rhyolitic plugs, lithogeochemical Mo anomalies, SITLA, and proposed location of the ESI open pit alunite mine draped on U.S. Department of Agriculture National Agriculture Imagery Program (NAIP) air photo base.*

Formation. Felt (1981) notes that the Needles Range Group is also the most easily altered unit in the southern San Francisco Mountains, to the east of Blawn Wash. He also suggests that it may still be acting as an aquifer today based on the location of springs in that area.

Hofstra (1984) mapped the Blawn Wash alteration at a scale of 1:12,000 and came up with six types of alteration in the volcanic rocks. From weakest to strongest these are:

Low Propylitic	Chlorite-calcite, ±epidote, ±quartz With textural preservation
High Propylitic	Chlorite-epidote-montmorillonite-sericite, ±pyrite, ±kaolinite, ±quartz, ±calcite, ±illite With textural preservation
Hematite-Clay	Hematite-kaolinite-chlorite-montmorillonite, ±alunite, ±sericite With textural preservation
Quartz-Alunite	Quartz-alunite, ±kaolinite, ±pyrophyllite, ±cristobolite, ±hematite Original rock textures largely destroyed
Silica Cap	Quartz, ±opal, ±cristobolite, ±tridymite Original rock textures destroyed
Quartz-Sericite-Pyrite	Quartz-sericite-pyrite, ±alunite Original rock textures destroyed

The Silica Cap is a zone of intense silicification believed to be the near-surface manifestation of the hydrothermal channelways. The silica is typically buff, dense, and massive, but may be quite porous and vuggy locally and resemble a siliceous sinter (appendix A, photograph 13).

On the surface the Quartz-Alunite alteration zones are composed of white to cream to buff to gray to pink, generally fine-grained, punky to dense, intermixed alunite and silica with only minor amounts of other impurities, mainly iron (appendix A, photograph 14). Alunite also occurs locally as coarse (>0.5 inch), lathy, typically pink crystals in veins (appendix A, photograph 15-17). Kaolinite becomes increasingly important, at the expense of alunite, in the Quartz-Alunite zone near the boundary with the Hematite-Clay zones and also where the Quartz-Alunite zones are cut by faults (Walker, 1972). Dickite (a high-temperature member of the kaolinite group) is reported by Whelan (1965) and Thompson (1991) in the Quartz-Alunite zones.

Quartz-Alunite alteration is equivalent to advan-ced argillic alteration. Alunite, with quartz and kaolinite, is the critical mineral assemblage for defining advanced argillic or acid-sulfate alteration. Other minerals which may be found in advanced argillic alteration, in order of typically decreasing temperature of formation, include pyrophyllite, diaspore, and dickite. Advanced argillic mineral assemblages may also be found in some extreme supergene-weathering environments. The deposits at Blawn Wash are of hypogene origin, there being insufficient sulfides present to have formed the alunite by supergene processes.

The cross-sectional geometry of the Quartz-Alunite zones is important to understanding of the genesis of the hydrothermal alteration system at Blawn Wash. There are two profoundly differently shaped zones: (1) deeply rooted, funnel- or cone-shaped zones and (2) tabular, sub-horizontal, shallow, flat-bottomed zones. The cone-shaped (narrow end at the base) zones are interpreted as the primary area of strong hydrothermal upwelling (figure 7) and the adjoining flat-bottomed zones are recognized as permeability-controlled areas above the paleo-ground-water table where steam-heated H_2S was oxidized to H_2SO_4. Only the central portion of Area C at Blawn Wash is clearly a funnel-shaped zone. The other flat-bottomed alunite zones are strongly controlled by higher porosity and permeability of the host volcanic rocks, while the hydrothermal cones are largely independent of these factors (Hofstra, 1984):

> The best example of the control of porosity on alteration intensity is at the north end of Area C. At this location, the upper weakly welded portion of the Lund Member of the Needles Range Formation is only weakly altered, while overlying tuff breccia of the Formation of Blawn Wash and the underlying, more strongly welded part of the Lund are intensely altered to quartz and alunite. The control of permeability on the degree of alteration intensity is most important near the margins of Quartz-Alunite altered zones. In the centers of Areas A, B, C, and D alteration is pervasive and unaffected by variations in the permeability of the host rocks.

Another important feature in differentiating the flat-bottomed alunitic alteration zones from the deeply rooted cones is the vertical alteration assemblages present in them. The flat-bottomed zones are only a few hundred feet thick and underlain by progressively weaker hydrothermal alteration grading downward from Hematite-Clay, to High Propylitic, and finally down into Weak Propylitic.

In contrast, the deeply rooted, alunitic cones channel downward into increasing grades of alteration with Quartz-Sericite-Alunite-Pyrite at depths of 800 to 1000 feet. It should be noted here that the alunite ridges themselves are 700 to over 1000 feet high so that quartz-sericite occurs at an elevation of about 6500 feet. Although not reported by ESI, and possibly not detected, the alteration in the cones probably grades downward through accessory dickite, diaspore, and possibly pyrophyllite above the Quartz-Sericite-Alunite-Pyrite zones. Limited deep drilling has shown that only a small portion of the widespread alunitic alteration on the surface is underlain by the deeply-rooted alteration cones (Hofstra, 1984).

The lower grade alteration types, Hematite-Clay, High Propylitic, and Weak Propylitic, are more easily eroded and generally less well exposed. The Hematite-Clay zone forms red soils, typically on steep slopes adjacent to and topographically below the Quartz-Alunite ridges. Earthy red hematite occurs with locally fresh biotite and K-spar (Hofstra, 1984). The High Propylitic zone is poorly exposed and topographically below the Hematite-Clay zones. Clay zoning in the Hematite-Clay and High Propylitic alteration zones may change from higher temperature kaolinite to illite to montmorillonite, distally (Rockwell and others, 2006). The Weakly Propylitized rocks occupy the flat areas between the

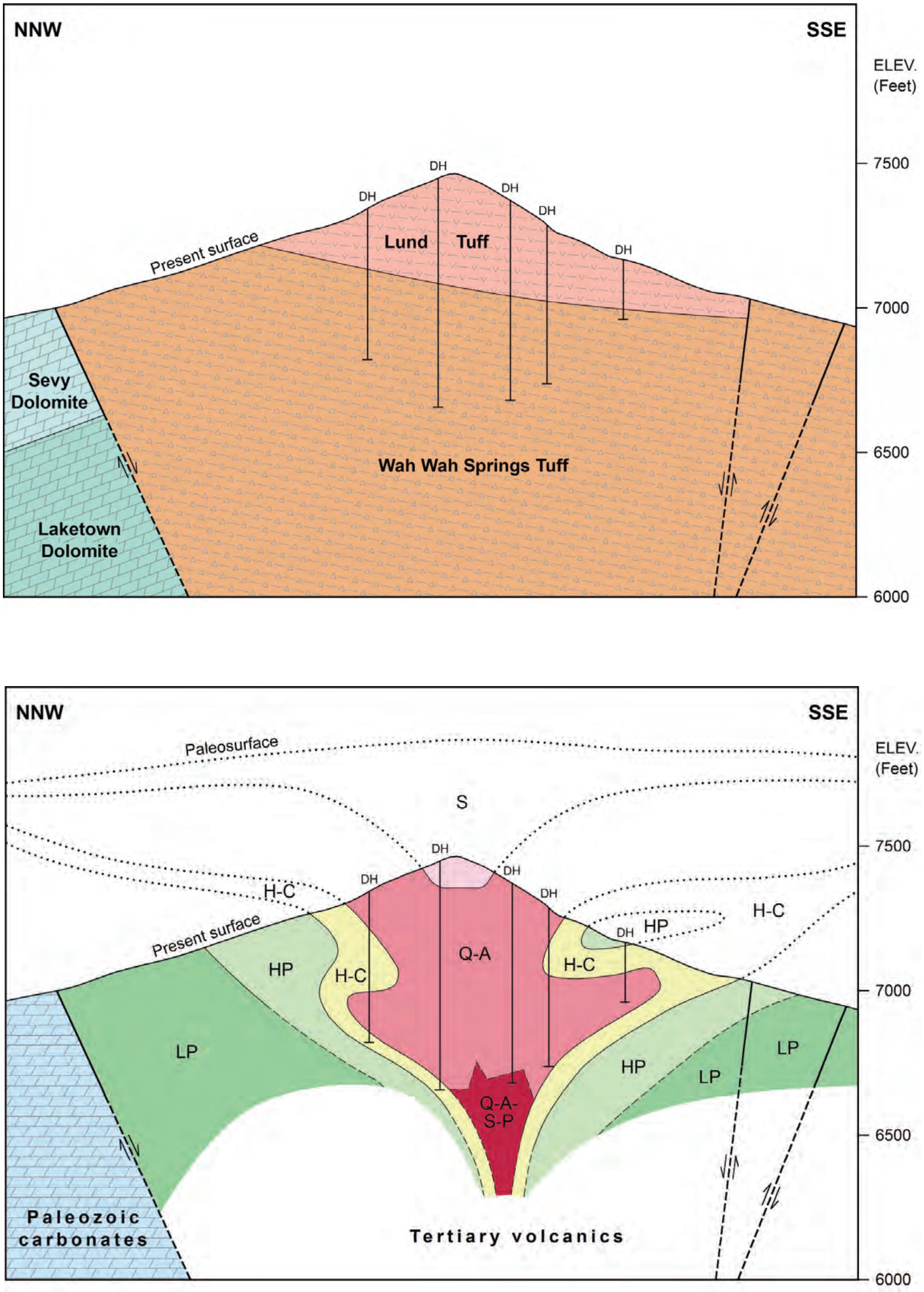


Figure 7. *Diagrammatic cross sections of geology and alteration through alunite Area C across the proposed open pit, no vertical exaggeration, modified from Hofstra (1984).*

Q-A-S-P: Quartz-alunite-sericite-pyrite zone
Q-A: Quartz-alunite zone
S: Silica zone
H-C: Hematite-clay zone
HP: High propylitic zone
LP: Low propylitic zone

Quartz-Alunite topped ridges. Isolated exposures of nearly fresh volcanic rocks occur scattered in the Weak Propylitic zone.

Veins

Hofstra (1984) recognized, mapped, and studied a series of veins on the surface at Blawn Wash. He defined a paragenesis of early calcite veins followed and replaced by quartz veins. Quartz veins with clear pseudomorphs after platy calcite are locally common, especially centrally located with respect to the alunite zones. The early quartz veins were followed by quartz-sericite-pyrite veins in the volcanic rocks and jasperoids in carbonate host rocks prior to the main stage of pervasive alunitic alteration. The quartz-sericite-pyrite veins on the surface are either associated with the Quartz-Alunite zones or centrally located between them at a lower topographic level. The massive iron oxide deposits were formed in Paleozoic carbonate rocks during or after the alunitic alteration.

Known Metallic Mineralization

Very little metallic mineralization has been recognized at the surface in the Blawn Mountain mining district. The history of these minor operations is briefly described in the "District History" section in the Introduction. Generally, there are small iron and manganese occurrences in the carbonate rocks west of alunite Area C and small fluorite and uranium prospects southwest of alunite Area D. Hofstra (1984) notes that the massive pods of black iron oxides adjacent to the west side of Area C are suspected of containing weak uranium mineralization as indicated by slightly elevated scintillometer readings. The iron and manganese occur as magnetite, goethite, and pyrolusite. Fluorite occurs as lenses and pods from a few inches to 10 feet wide and 30 to 200 feet in length (Bullock, 1970).

The mineralization at the Staats mine (figure 5) is described as small, discontinuous veins/bodies of fluorite with clay alteration and minor uranium. The fluorite, which occurs without quartz, varies from dark purple through blue and green to white. The mineralization occurs near the rhyolite porphyry and dolomite contact. The rhyolite is gray to pink, porphyritic, and has a dense, very fine-grained groundmass. Phenocrysts are beta quartz (clear to smoky), sanidine, and minor biotite. The margins of the rhyolite porphyry are often strongly flow-banded or brecciated with some clay alteration and minor pyrite. Alteration in the rhyolite is strongest in the area of the Staats mine at the north end of the porphyry. The rhyolite intrusions at the Tetons, a mile to the south of the Staats porphyry, are similar to those at the Staats, but fresher. The fluorite ore zones, grading approximately 75 to 90% CaF2, are typically a few feet in width, a few tens to 110 feet in length, and occur near the rhyolite contact. The autunite ($Ca(UO_2)_2(PO_4)_2\cdot 2\text{-}6(H_2O)$) and uranophane ($Ca(UO_2)_2SiO_3(OH)_2\cdot 5(H_2O)$) after uraninite ($UO_2$) occur as small flakes and coatings in gouge zones adjacent to the fluorite with grades of less than 0.2% U_3O_8 (Whelan, 1965; Bullock, 1976). Lindsey and Osmonson (1978) note the occurrence of very low-level geochemical anomalies for tin, molybdenum, and beryllium associated with the rhyolite stock. Lindsey (retired USGS, written communication, July, 2007) notes the occurrence of good crystalline cassiterite in a fluorspar breccia near the Staats mine.

Quartz-carbonate veins occur along a prominent northeast-trending fault about 3.75 miles south of the center of the Blawn Wash alunite zone. The fault extends southwest from near The Seeps (east of the Tetons) with a steeply dipping quartz-carbonate-adularia-sulfide vein along it for roughly a mile (Best and others, 1987; Ken Puchlik, consulting geologist, personal communication, 2007). These low-sulfidation veins reportedly have assayed 1 ppm gold and 10 ppm silver or more (Pack, 1995).

Trace Element Geochemistry

Hofstra (1984) presents the trace element analytical results of 100 surface litho-geochemical samples in the Blawn Wash alunite area (plate 4 and appendix B). All of the samples were analyzed for Au, Ag, Cu, Pb, Zn, and Mo with select samples analyzed for As, Sb, Mo, Sn, W, and F. In general, the results show very low trace element concentrations with only isolated, single-sample anomalies. However, it is interesting to note that the two strongly anomalous Mo samples (66 and 393 ppm) are located (figure 6) near the small rhyolite porphyry plugs, central to the four alunite zones (figure 6). In contrast, the strongly anomalous Pb (168 and 650 ppm) and Zn (400, 420, 440, and 1650 ppm) samples are generally near the outer margins of the alunite zones (figure 6). The anomalous Pb samples are located along Blawn Wash east of Area A and the Zn anomalies are located near hill 6776 north of Area C.

Other lithogeochemical surveys of the Blawn Wash alunite area showed similar results. The U.S. Geological Survey (USGS) National Geochemical Data Base (NGDB) samples yielded generally low level results. FMC reportedly ran 150 geochemical samples of the Blawn Wash alunite area in the 1980s and although no gold anomalies were detected, some arsenic and antimony anomalies were found (Pack, 1995). Thompson (1991) in very limited sampling, found no geochemical anomalies. In a rock-chip geochemical sampling program at Blawn Mountain proper, Getty defined an area on top of the ridge, starting at and extending a half mile east from the 8250 elevation peak, with consistently anomalous tungsten analyses of greater than 20 ppm, averaging nearly 60 ppm (Gloyn, 1978). This anomaly covers a portion of the west end of Area D, but is not replicated in the detailed Amax lithogeochemistry (unpublished data in Utah Geological Survey files).

Fluid Inclusions and Sulfur Isotopes

Hofstra (1984) performed microthermometric analysis of fluid inclusions from calcite and quartz veins on the Blawn Wash property. Liquid-dominant inclusions containing a vapor bubble taking up less than 30 volume percent of the inclusion volume are the most common. Hofstra found a horizontal temperature gradient in these samples ranging from a low of 175-225° C in the peripheral Low Propylitic alteration to 275-325° C in the Silica zone. All of the samples show salinities of less than 2 equivalent weight percent.

Hofstra (1984) also observed fluid inclusions in alunite veins on the Blawn Wash property as well. The alunite vein inclusions were very small and vapor-dominant, however, he was unable to observe homogenization temperatures on these inclusions. Hofstra interpreted these inclusions as indicative of having formed at shallow depths (less than 500 feet) in a vapor-dominated environment over a boiling zone above the upwelling hydrothermal fluids. This suggests the alunite zones were produced as a result of the oxidation of H_2S released on boiling, generating H_2SO_4, which leached the enclosing volcanic rocks.

Charles (Skip) Cunningham of the USGS obtained a sample of fine-grained replacement alunite from the Alumet bulk-sample metallurgical test pit in Area C and had the sample analyzed for 34S and 32S (Hofstra, 1984). The results were a $^{34}S/^{32}S$ ratio of +1.45 per mil. Hofstra (1984) interprets this ratio, in the absence of sulfide minerals and with the likely high oxygen fugacity environment of formation, as suggestive of having been derived from a magmatic source. Hofstra calculates that a total of approximately 30 million metric tonnes of elemental sulfur have been added to the rocks at Blawn Wash to make alunite.

Origin of the Alunite Deposits

The Blawn Wash alunite deposits are believed to have resulted from the localized upwelling of hydrothermal fluids derived from a shallowly emplaced felsic intrusion associated with the Blawn Formation volcanism at about 22.5 Ma (Hofstra, 1984). As the 300°C, low-salinity, H_2S-bearing fluids rose above the local water table, boiling ensued, H_2S was oxidized to H_2SO_4 resulting in the acid leaching of the volcanic rocks to form broad areas of advanced argillic alteration. In the localized zones of stronger upwelling, the alunite-rich alteration occur as deeply rooted cones, elsewhere the alunite deposits are shallow, tabular zones formed as steam-heated deposits above the regional paleo-ground-water table.

MINERAL POTENTIAL

Alunite Deposits

Alunite Mineralogy and Uses

The mineral alunite is generally a product of epithermal, acidic, alteration of intermediate to felsic igneous rocks. Alunite is typically yellow-gray to light pink to off white, moderately hard (<4), and commonly occurs as earthy to massive-granular or more rarely, lathy crystals in cockscomb veins. The theoretical chemical formula for alunite is $KAl_3(SO_4)_2(OH)_6$ giving a composition (in weight percent) of about 11% K_2O, 37% Al_2O_3, 39% SO_3, and 13% H_2O. However, Na commonly substitutes for K and Fe for Al. The Na-Al end-member of the series is natroalunite. The K-Fe end-member of the alunite group is jarosite and natrojarosite is the Na-Fe end-member. Other elemental substitutions are possible, but rarer.

The unique composition of alunite has resulted in abortive attempts to exploit exceptionally pure veins of alunite on Mount Brigham in the Mount Baldy mining district southwest of Marysvale, Utah, both for potash fertilizer during World War I and for alumina during World War II (Hall, 1978). In the 1940s, 10,800 tons of high-grade vein alunite from Alunite Ridge on Deer Trail Mountain was processed in a 50-ton per day pilot plant in Salt Lake City using the Kalunite process. The effort was abandoned at the end of the war due to processing difficulties, especially in the reduction roasting step (Barclay, 1984). The Kalunite process utilizes a 600°C initial dehydration roast followed by a 1000°C final calcination (reduction roast) to produce alumina, potassium sulfate fertilizer, and sulfuric acid. In Australia during World War II, alunite was roasted to 600°C and converted into alumina and potassium sulfate fertilizer, however, this was mainly utilized as a source of fertilizer. Similarly, Japan also attempted to recover alumina and potash fertilizer from alunite deposits during World War II (Hall, 1978).

Alunite, probably due to its unique chemical composition, was also touted as a potential soil additive to improve the efficiency of fertilizers and retard nutrient leaching. However, in testing on alfalfa no positive evidence was recognized after four crop cycles (Christensen, 1977).

Although the vein deposits offer the highest alunite grade, up to 88% alunite, these deposits are far too small for commercial exploitation and the much larger replacement-alteration deposits are believed to offer a better chance of economic viability by bulk mining and processing methods (figure 8 and appendix D). In Hall's (1978) list of U.S. alunite resources, Blawn Wash (NG Alunite) is the largest reported resource at 695 million tons of greater than 30% alunite.

Alunite Resources and Previous Mine Planning

Previous exploration/development work on the four Blawn Wash alunite deposits was completed by the Alumet JV operated by ESI in the 1970s. Ten rotary holes totaling 2650 feet were drilled in Phase I and a further 10,400 feet were completed in 38 holes in Phase II (Walker, 1972). By 1975, a total of 51,627 feet of rotary and air-track drilling had been completed in 241 holes on Area C alone (Couzens, 1975). A 1998 filing to the SEC reported a total of 239 drill holes totaling 52,200 feet in Area C on approximately a 300- by 500-foot grid. The initial predevelopment work at Blawn Wash suggested that the alunite resource in Area C was the most favorable and should be developed first. A 3000-ton bulk sample was taken from the top of Area C for metallurgical testing performed at the JV's own Alunite Metallurgical Center (Alumet) in Golden, Colorado.

The alunite and alumina resources for all four deposits in the Blawn Wash area are tabulated below (table 2). The nomenclature, terminology, and definition of the type of mineral inventory has changed over time and despite the use of the term "reserves" for several of the deposits, probably none of the deposits would meet the current more rigid standard for use of the term reserves. Most of the better defined deposits would, most likely, be categorized as "indicated resources" by today's standards (Society for Mining, Metallurgy and Exploration, Inc., 2005).

A modified Bayer process, which had apparently been successfully used on alunite during the 1960s in the Soviet Union (Azerbaijan), was proposed for the project (Hall, 1978). In the Bayer process (which is the standard treatment of bauxite), the ore is digested in a sodium hydroxide solution producing a soluble aluminate, filtered, aluminum hydroxide is precipitated, and then the precipitate is calcined

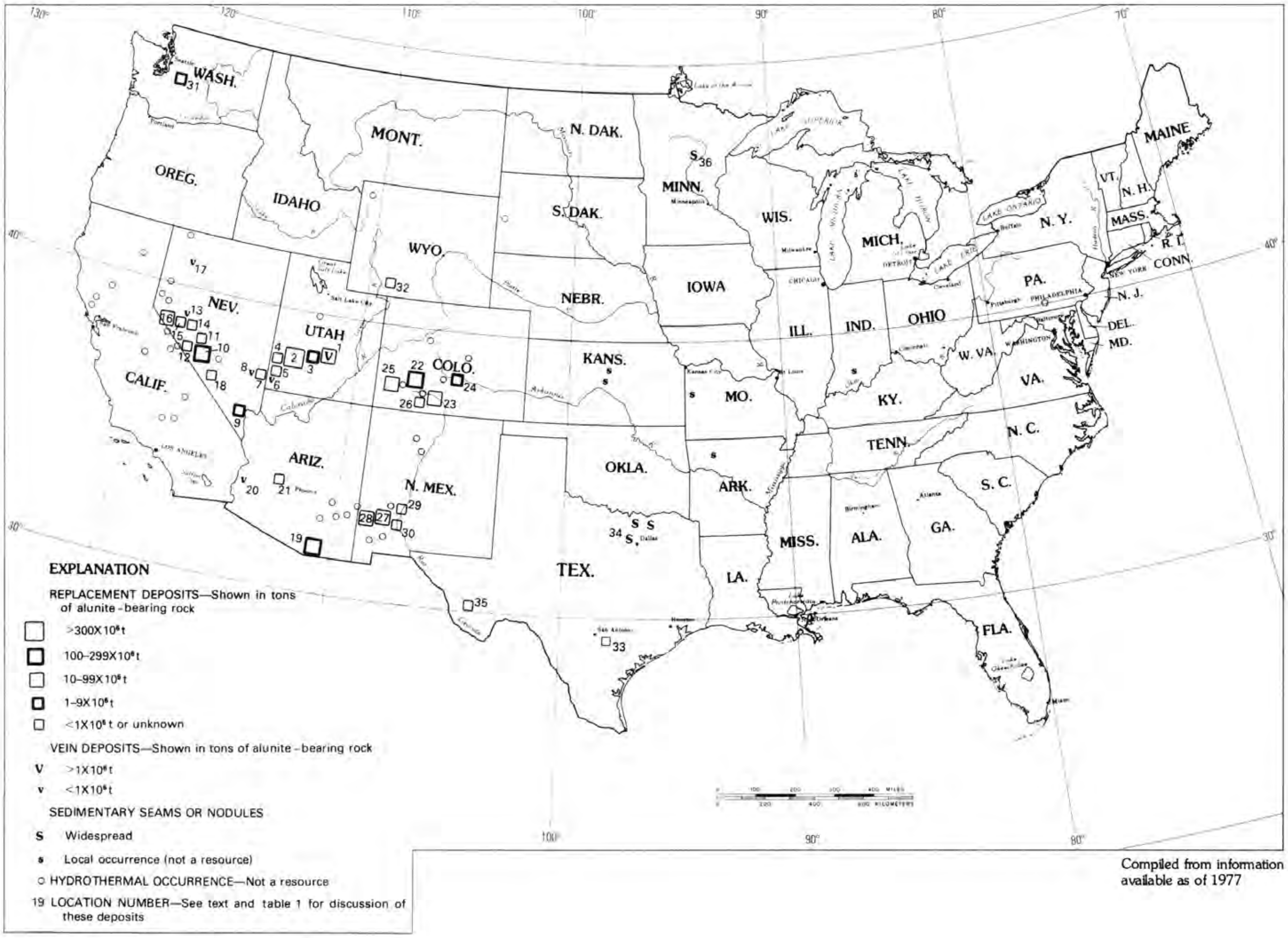


Figure 8. *Alunite deposits of the U.S. (from Hall, 1978). The Blawn Wash alunite area is designated by the number 2 in southwestern Utah; a listing of all of the property names and resources is shown in Appendix C.*

(heated to drive off volatiles) to alumina (Al_2O_3). In using this process on alunite, seven tons of alunite ore will yield about one ton of alumina, a half ton of potassium sulfate (K_2SO_4) fertilizer, and one ton of sulfuric acid [H_2SO_4] byproduct. In contrast, two tons of typical bauxite ore yield one ton of alumina.

The pit design called for a roughly oval-shaped open pit about 5000 feet long, 2600 feet wide, and 700 feet deep (Couzens, 1975). The ultimate pit would have been centered slightly east of the geographic center of the Area C alunite deposit in the center of the NW¼ section 22, T. 29 S., R. 15 W. (figure 6). Area C was chosen over the other alunite zones because it had fewer objectionable impurities, particularly iron-oxides and soluble clays which could result in excessive iron or silica, respectively, in the final alumina product. In addition, the larger Area D had more abundant kaolinite, large zones of silicification, and may have had conflicting lode claims held by other companies on its western extension (W.W. Walker, consulting geologist, written communication, 2007). Interestingly, the proposed pit was centered near the only known deep cone of alunite.

A conventional open-pit mining plan was developed to produce about 500,000 tons per year alumina, by mining 16,500 tons of combined ore and waste mined per day at a 1:1.5 ore to waste stripping ratio. Sufficient reserves were delineated at a 10% alumina cutoff in Area C for a 40 year mine life at the planned rate. The proposed mill was to be located in flatter terrain a few miles northeast of the mine. Products would have been shipped via a 23-mile railroad spur, to the Union Pacific mainline and then to existing U.S. aluminum smelters. In 1977, the capital cost for the proposed operation was $500 million ($1.7 billion in 2007 dollars) and the project was expected to employ about 1000 workers. By 1980, the anticipated capital cost had risen to an estimated $550 million ($1.4 billion in 2007 dollars).

ESI's alumina and alunite grade calculations for the Blawn Wash alunite area are based on five-inch diameter, vertical, air rotary holes. Two-pound representative samples were split from the drill cuttings and analyzed for sulfate. The alumina content was then back-calculated based on the formula of alunite. Alternate samples were analyzed directly for acid soluble alumina, potassium, and sodium for comparison. Cross-sections were used to calculate the volume of alunitic material and a tonnage factor of 12.8 cubic feet per ton was applied to calculate the tons of ore. The cutoff grade was a minimum 10% alumina (27% alunite) over a 40-foot bench height. ESI estimated a minimum target for economic bulk-mining was 100 million tons of open-pitable, "good grade" alunite ore (Walker, 1972). A later Pincock, Allen & Holt computer block model based on 20-foot benches, calculated a mining rate of about 13,000 tons per day, showed a stripping ratio of 1:1.5 (ore:waste), and assumed mill recovery was 90 percent (Couzens, 1975).

The Final Environmental Impact Statement (U.S. BLM, 1977) for the proposed alunite mine and processing plant anticipated a production of 500,000 tons per year of alumina with byproducts of 370,000 tons per year of potassium sulfate fertilizer, 1.7 million tons per year of superphosphate fertilizer , and 20,000 tons per year of aluminum fluoride.

Alunite Value

To calculate an in-place value for the Blawn Wash alunite resources, an accepted value for alumina needs to be calculated. Historical prices for alumina (Al_2O_3) are difficult to locate, but historical alumina prices since 2000 are available through the USGS (E. Lee Bray, USGS, personal communication, 2007). Based on these data, the average price for a ton of alumina is estimated at approximately $312/ton.

The other major product of alunite processing is potassium sulfate (fertilizer). While it is even more difficult to get a good handle on the price for this product, it currently appears to run around $300/ton. Although the actual grade of the deposits in relation to potassium sulfate production is not known, the Final Environmental Impact Statement (U.S. BLM, 1977) reported a production rate of 37 tons of potassium sulfate for every 50 tons of alumina. This ratio was used to calculate a byproduct output of potassium sulfate (table 3). It should be noted that this ratio was calculated based on the alunite mineralization in Area C. Other areas could potentially have different ratios based on the ratio of K-alunite to Na-alunite.

Using the above assumptions, an estimated in-place value of the Blawn Wash alunite deposits is calculated in table 3, although no correction has been applied for metallurgical recovery, which was estimated at 90% by Couzens (1975). Also, no value has been given in the calculations for the projected production of phosphate fertilizer and aluminum fluoride which are outside the scope of this study. The results show an in-place value of over $12 billion for the "proven" alunite resource in Area C alone and over $59 billion for the total recognized indicated and inferred resources in the four Blawn Wash alunite areas combined.

The proven alunite resource in Area C is valued at nearly $77 per ton. While overall mine, mill, transportation, and other costs are unknown, the direct mining costs are reported by Couzens (1975). These costs; broken down by drilling, blasting, loading, hauling, and other direct mining costs, are reported as $0.385 per ton or approximately $1.50 per ton escalated into 2007 dollars.

Looking at it another way, using the anticipated annual production rate of 500,000 tons of alumina and 370,000 tons of potassium sulfate (U.S. BLM, 1977), the projected value of the annual production is roughly $230 million. Assuming the expected 1000 employees earn the estimated average of $56,000 per year for the mining industry in Utah and including a 45% over ride for benefits yields $81,000 per year per employee or a total of $81 million annually in salaries and benefits. Or, on a per ton basis, the ore is valued at $65 per ton and total labor costs are estimated at about $23 per ton.

Porphyry Molybdenum Potential

Due to its origin in advanced argillic alteration zones, alunite often occurs in the lithocap above copper or molybdenum systems. Especially noteworthy on Hall's (1978) list of alunite deposits (appendix C) is the presence of several, then little known, porphyry copper and/or molybdenum systems. Prominent on the list are (1) Red Mountain, near Patagonia, Arizona [#19], now a drilled out porphyry copper deposit, and (2) Red Mountain, near Lake City, Colorado [#22], now a recognized porphyry molybdenum system (Bove and others, 1990), (3) Summitville, Colorado [#23] a gold-rich porphyry copper lithocap, (4) Deer Trail Mountain [#1], a suspected porphyry molybdenum deposit, and (5) Enumclaw, Washington [#31] another suspected porphyry copper lithocap (John and others, 2003). Also listed is Goldfield, Nevada, which is a high-sulfidation, epithermal gold district and has been speculated on as having a porphyry copper system at depth. Hall's list also includes several other known, deep porphyry targets. Another area in Utah with extensively alunitized rocks mentioned by Hall (1978) is the Big Hill area of the East Tintic district.

The Blawn Wash alunite deposits are part of an advanced argillic alteration assemblage which could constitute the lithocap above an undiscovered porphyry deposit at depth (figure 9). Hofstra (1984) shows that the alunite deposits resulted from an ascending, low-salinity, H_2S-bearing fluid that boiled in the shallow subsurface at about 300° C causing H_2S to be oxidized to H_2SO_4 and resulting in the acid leaching of the host volcanic rocks. He further infers that the hydrothermal fluids were derived from a shallowly emplaced, 22.5 Ma stock associated with the small, Blawn Formation rhyolite porphyries seen at Blawn Wash (Hofstra, 1984).

The nearby Pine Grove porphyry molybdenum deposit is a Climax-type system (USGS model 16; Stoeser and Heran, 2000). Climax-type porphyry molybdenum deposits are typically associated with high-silica rhyolite or granite porphyries, generally enriched in potassium, fluorine, and incompatible lithophile trace elements, such as tungsten[5], uranium, tin, beryllium, rubidium, thorium, and niobium. Conversely, the Climax-type deposits are typically low in compatible trace elements like strontium, titanium, and magnesium. According to Keith and others (1993) the evidence that Pine Grove is a Climax-type porphyry molybdenum deposit primarily includes:

1. Multiple intrusions of high-silica rhyolite
2. Large tonnage of high-grade ore – about 124 M tons averaging about 0.36% MoS2
3. Accessory fluorite, topaz, and huebnerite in the ore zone
4. Lack of appreciable copper in the system
5. Accessory monazite, xenotime, and ilmenorutile in the intrusive phases

The other commonly cited type of porphyry molybdenum deposit is the low-fluorine, calc-alkaline, quartz monzonite systems (USGS model 21b; Stoeser and Heran, 2000) which are typically lower grade (typically less than 0.17% MoS_2), have substantial, but not ore-grade copper, and are

Table 2. Southwest Utah Alunite Resource Estimates

Deposit	County	Ore Thousand Short Tons	Alunite Grade %	Alumina Grade %[1]	Alumina Thousand Short Tons[2]	Inventory Classification	Reference
Blawn Wash	Beaver						
Area A	Beaver	51,700	36.5	13.5	6,980	Indicated	Walker, 1972
Area A	Beaver	49,200	38.0	14.1	6,937	Inferred	Walker, 1972
Area A	Beaver	100,900	37.0	13.8	13,924	Total	Walker, 1972
Area B	Beaver	54,400	38.5	14.3	7,779	Indicated	Walker, 1972
Area B	Beaver	124,900	39.5	14.6	18,235	Inferred	Walker, 1972
Area B	Beaver	25,900	41.5	15.3	3,963	High-Grade Ind.	Walker, 1972
Area B	Beaver	179,300	39.0	14.5	25,999	Total	Walker, 1972
Area C	Beaver	129,400	38.3	14.0	18,155	Proven	Couzens, 1975
Area C	Beaver	17,770	40.3	14.8	2,625	Probable	Couzens, 1975
Area C	Beaver	18,015	46.7	17.1	3,079	Inferred	Couzens, 1975
Area C	Beaver	165,185	39.4	14.5	23,869	Total	Couzens, 1975
Area D	Beaver	11,600	44.0	16.2	1,879	Indicated	Walker, 1972
Area D	Beaver	281,400	44.0	16.2	45,587	Inferred	Walker, 1972
Area D	Beaver	7,300	47.0	17.3	1,263	High-Grade Ind.	Walker, 1972
Area D	Beaver	293,000	44.0	16.2	47,466	Total	Walker, 1972
Total	**Beaver**	**738,385**	**41.1**	**15.1**	**111,175**	**Grand Total**	
White Mountain	Beaver	1,500		11.6		Mineral Inventory	Walker, 1971
SX Area (West Area)	Beaver	24,500	37.5	13.9		Reserve	Green and Bauer, 1974
PV Area	Iron	19,500	33.5	12.4		Reserve	Bauer, 1974
PV Area	Iron	63,200				Resource	Bauer, 1974
Sheeprock	Beaver	2,000	30.0			Reserve	Hall, 1978
Big Pinto Spring	Beaver						Hall, 1978
Modena	Iron						Hall, 1978
Beauty Knoll	Washington	450	80.0			Reserve	Hall, 1978
Marysvale	Piute						
Vein	Piute	1,380	88.0			Reserve	Hall, 1978
Vein	Piute	740	79.0			Resource	Hall, 1978
Replacement	Piute	7,360	43.0			Reserve	Hall, 1978
Replacement	Piute	33,260	23.0			Resource	Hall, 1978

[1] Alunite is 37% Al_2O_3

[2] Thousand short tons of alumina (Al_2O_3)

Table 3. Blawn Wash Alunite Resource Estimates

Deposit	Ore Thousand Short Tons	Alumina[1] Grade %	Alumina[1] Thousand Short Tons	K_2SO_4[2] Thousand Short Tons	Alumina Value Million[3]	K_2SO_4 Value Million[4]	Total Value Million	Value $/st	Inventory Classification	Reference
Area A	51,700	13.5	6,980	5,165	$ 2,199	$ 1,549	$ 3,748	$ 72.50	Indicated	Walker, 1972
Area A	49,200	14.1	6,937	5,134	$ 2,185	$ 1,540	$ 3,725	$ 75.72	Inferred	Walker, 1972
Area A	100,900	13.8	13,924	10,304	$ 4,386	$ 3,091	$ 7,477	$ 74.11	Total	Walker, 1972
Area B	54,400	14.3	7,779	5,757	$ 2,450	$ 1,727	$ 4,177	$ 76.79	Indicated	Walker, 1972
Area B	124,900	14.6	18,235	13,494	$ 5,744	$ 4,048	$ 9,792	$ 78.40	Inferred	Walker, 1972
Area B	179,300	14.5	25,999	19,239	$ 8,190	$ 5,772	$ 13,961	$ 77.87	Total	Walker, 1972
Area C	129,400	14.0	18,155	13,435	$ 5,719	$ 4,030	$ 9,749	$ 75.34	Proven	Couzens, 1975
Area C	17,770	14.8	2,625	1,942	$ 827	$ 583	$ 1,409	$ 79.31	Probable	Couzens, 1975
Area C	18,015	17.1	3,079	2,278	$ 970	$ 683	$ 1,653	$ 91.77	Inferred	Couzens, 1975
Area C	165,185	14.5	23,869	17,663	$ 7,519	$ 5,299	$ 12,818	$ 77.60	Total	Couzens, 1975
Area D	11,600	16.2	1,879	1,391	$ 592	$ 417	$ 1,009	$ 86.99	Indicated	Walker, 1972
Area D	281,400	16.2	45,587	33,734	$ 14,360	$ 10,120	$ 24,480	$ 86.99	Inferred	Walker, 1972
Area D	293,000	16.2	47,466	35,125	$ 14,952	$ 10,537	$ 25,489	$ 86.99	Total	Walker, 1972
Grand Total	**738,385**	**15.1**	**111,175**	**16,739**	**$ 35,020**	**$ 24,681**	**$ 59,701**	**$ 80.85**	**Grand Total**	

[1] Alunite is 37% alumina (Al_2O_3)

[2] Calculated based on a ratio of 1:0.74 with short tons of alumina

[3] Calculated based on $312/ton

[4] Calculated based on $300/ton

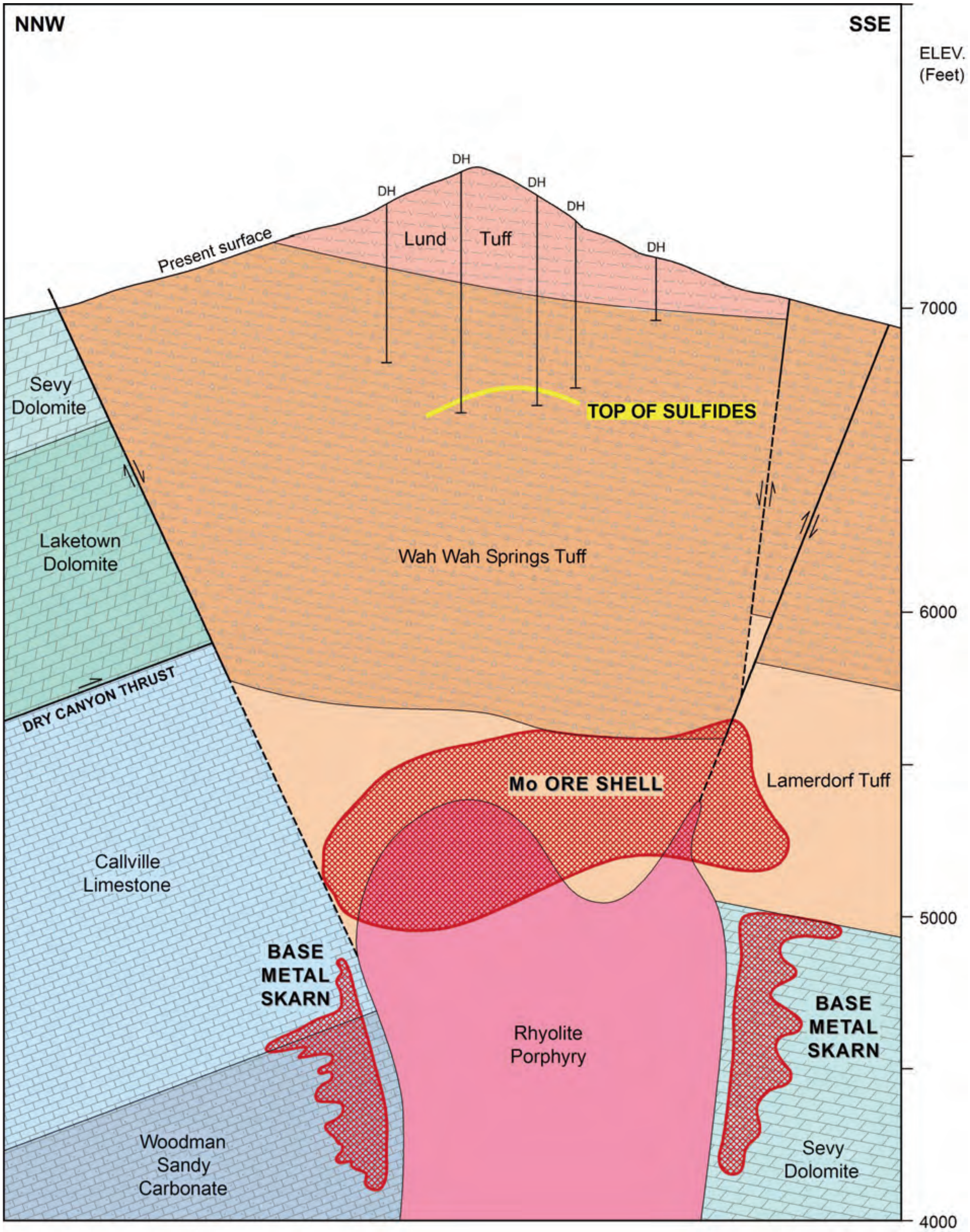


Figure 9. *Cross section showing a hypothetical porphyry molybdenum deposit at depth under an alunite zone at Blawn Wash, no vertical exaggeration. Speculative Mo-W and/or Pb-Zn skarns are shown adjoining the porphyry in the carbonate host rocks.*

generally similar to porphyry copper-molybdenum deposits (USGS model 21a; Stoeser and Heran, 2000). Another occasionally mentioned class of porphyry molybdenum deposit is the transitional or sub-Climax-type which is a hybrid between the Climax-type and the quartz monzonite systems (Wallace, 1995).

An important feature typical of porphyry molybdenum deposits, particularly Climax-type, is the occurrence of repeated cupola and molybdenum ore shell formation. Individual productive intrusions are typically 500 to 1500 feet in diameter (Wallace, 1995). Each ore deposit or shell is generally a dome shaped stockwork of quartz-molybdenite±fluorite veinlets centered on and commonly overlapping the apex of an intrusive cupola. The intrusives are small, steep-walled plugs of silicic (74-79% $Si0_2$), aluminous (10-13% Al_2O_3), alkali-rich (4-7% K_20), rhyolite porphyry. Common accessory minerals in Climax-type porphyry molybdenum intrusive rocks are fluorite, topaz, spessartine, uraninite, monazite, and ilmenorutile (White and others, 1981).

Only the Climax-type deposits produce "giant" molybdenum deposits both in terms of tons of ore and grade. The prototypical Climax-type molybdenum deposits are the Climax and Henderson deposits in Colorado. These two deposits are unique in having both grades in excess of 0.25% MoS2 and tonnages over 500 million tons of ore (Keith and others, 1993). The tectonic settings of the Climax-type deposits is frequently referred to as back-arc or rift-related. Sillitoe (1980) noted the importance of a shift from a compressional to an extensional tectonic setting during the formation of this type of deposit. It is worthy of note that both Blawn Wash and Pine Grove formed during the changeover from a more compressional setting in the Oligocene to the onset of Basin and Range extension in the earliest Miocene.

The strong geologic similarities between Blawn Wash and the nearby Pine Grove porphyry molybdenum deposit suggest that the causative intrusive at Blawn Wash is comparable to the rhyolite porphyry at Pine Grove. In addition to their close proximity, both areas are cored by earliest Miocene felsic intrusive rocks. The Pine Grove system is tied to a 23-22 Ma dacite-rhyolite event (Keith and others, 1986) and the Blawn Wash deposits are associated with a 22.5 Ma rhyolite (Hofstra, 1984). One of the differences between the two is that there is less evidence of volcanic venting at Blawn Wash – which could potentially result in more effectively trapping of evolved magmatic-hydrothermal fluids than at Pine Grove.

Another large alunitic resource in a porphyry lithocap is at Red Mountain near Lake City, Colorado (Hall, 1978). At Red Mountain, the advanced argillic alteration is underlain by a sub-economic, moderately high-fluorine, dacite (granodiorite) porphyry molybdenum deposit (Bove and others, 1990). Molybdenum mineralization is associated with typical phyllic and potassic porphyry alteration assemblages. The Red Mountain deposit is probably a hybrid between the Climax- and the quartz monzonite type system or a sub-Climax-type porphyry molybdenum system (Dana J. Bove, USGS, written personal communication, 2007). However, the Blawn Wash system is associated with a Climax-like, high-silica, alkali-rhyolite (about 75% SiO_2 and 5.8% K_2O) unlike the dacitic intrusive rocks (about 64% SiO_2 and 4.4% K_2O) at Red Mountain.

Depth of deposit formation for porphyry molybdenum deposits ranges from about 1900 to 12,000 feet (Mutschler and others, 1981) and the estimated depth of formation for Pine Grove is 7900 feet. The depth to the molybdenum zone at Red Mountain, Colorado is about 1400 feet below the current erosional surface. Hofstra (1984) estimates that approximately 500 feet have been eroded from the top of the Blawn Wash system. Based on structural considerations and analogous advanced argillic alteration assemblages to Red Mountain, it is thought that molybdenum, if present, could be encountered at a depth as shallow as about 2000 feet at Blawn Wash. This depth is also compatible with depth from the top of quartz-sericite-pyrite alteration in Area C and the analogous distance from the top of the quartz-sericite alteration down to ore at Henderson, Colorado (Seedorff and Einaudi, 2004).

In addition, the presence of carbonate rocks to the northwest and possibly southeast of the proposed intrusive suggests the potential for Mo-W or Zn-Pb skarn or replacement mineralization adjacent to the inferred rhyolite plug. If present, these skarn and replacement deposits are likely to have associated fluorite.

With an estimated $25 billion in molybdenum (at current metal prices) sitting just seven miles away at Pine Grove, what is the mineral exploration potential that similar Climax-type porphyry molybdenum mineralization at Blawn Wash is stronger, shallower, or both and perhaps economic?

Other Commodities

Kaolinite is currently being mined from a small open pit just west of the top of Blawn Mountain (appendix A, photograph 19). This occurrence appears to be developed on a small, isolated, hydrothermal breccia pipe. This kaolinite is currently being shipped to the Leamington cement plant. Another purported kaolinite resource is leased (Jack L. Kettler - State of Utah Clay Lease #39145) east of Area A, although production has apparently not commenced. In addition, kaolinite is reported as a peripheral alteration mineral to the Quartz-Alunite alteration zones. Whether either of these latter two kaolinite occurrences has economic potential is unknown.

A U.S. Bureau of Mines report (Barclay, 1984) on non-bauxitic resources mentions in passing that there may be a potential for recovering "small, but valuable, amounts of vanadium and gallium" in the alunite deposits. This aspect of the alunite operation was not mentioned in the available ESI reports and is not considered further here. There is no recognized potential for iron, gold, or uranium on the Blawn Wash property.

RECCOMMENDATIONS

As far as the alunite resource is concerned, little additional work is required. The resource estimates for the deposits should be published so that the interested parties may be made aware of its availability. Also, all of the existing data on the deposits needs be archived for future use.

In regard to the potential for porphyry molybdenum mineralization at depth beneath the Blawn Wash alunite zones several relatively inexpensive exploration methods are recommended prior to target definition and drill testing. Probably the most useful technique would be to run an induced polarization (IP) geophysical survey of the entire Blawn Wash area. This survey would readily indicate zones of disseminated sulfides at depth. An aeromagnetic survey of the area may be useful; however, no mention is made in the UGS Pine Grove files of a magnetic survey being successfully utilized there. Hofstra's (1984) detailed geologic and alteration mapping at a scale of 1:12,000 is considered adequate. PIMA (portable infra-red mineral analyzer) spectrometer mapping of the clay minerals in the alunite zones could well be useful to indicate temperature gradients through mineral zoning. Geochemical sampling and analysis do not appear to have been productive in the past at Blawn Wash and extensive surveys are not initially recommended, although analysis of select samples may be useful.

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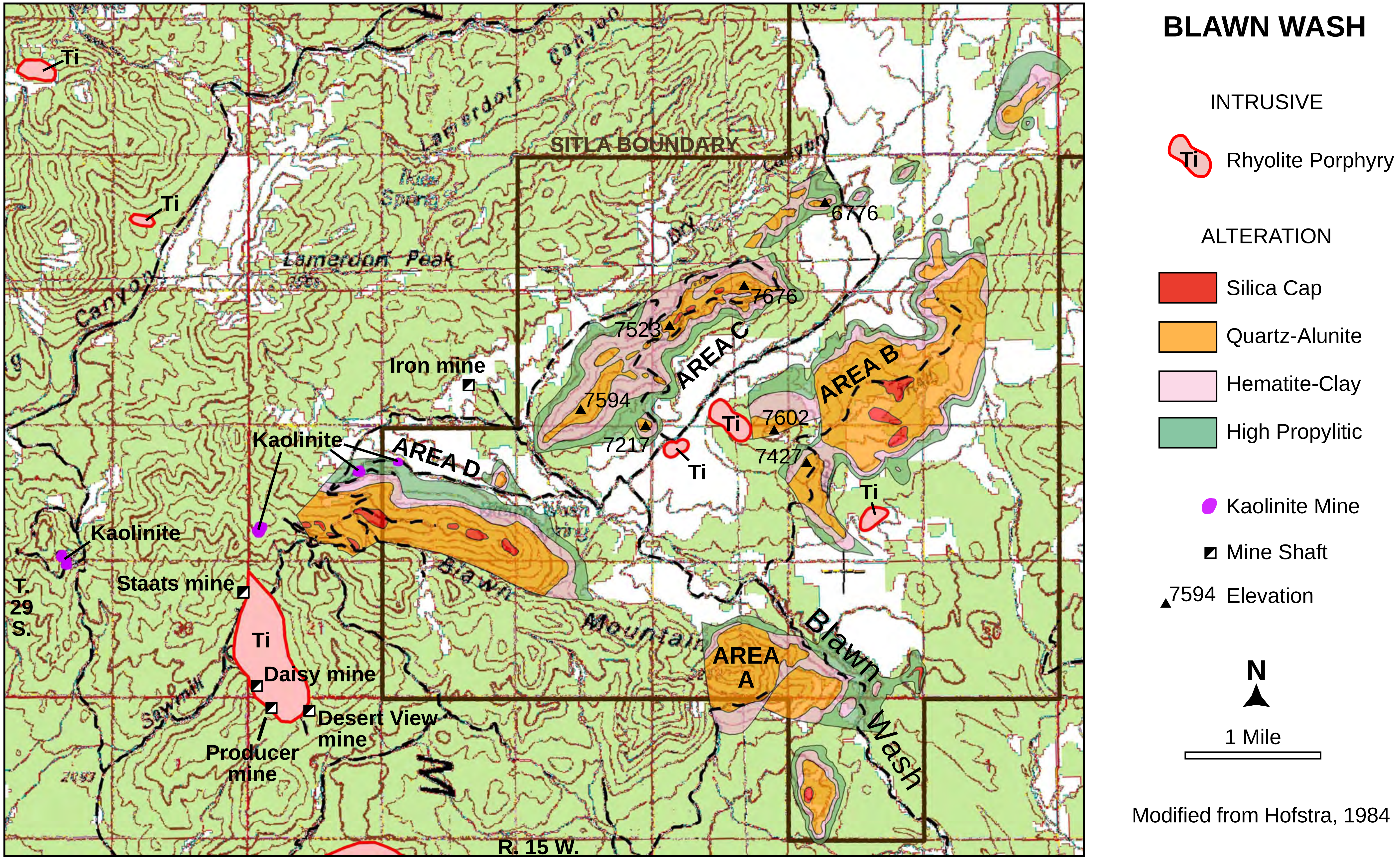
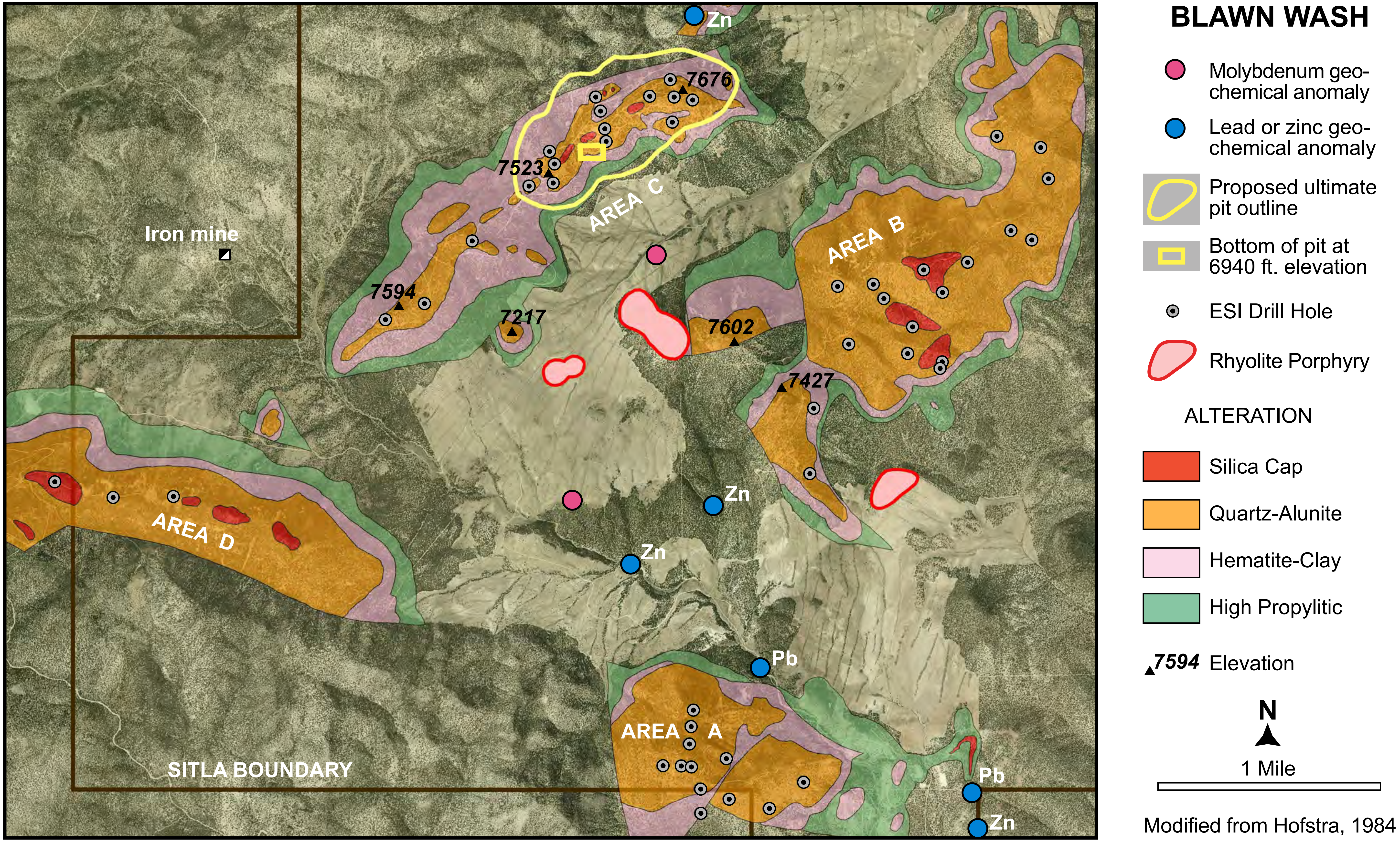
Appendix A

Photographs of the Blawn Wash Area



BLAWN WASH

Modified from Hofstra, 1984



Modified from Hofstra, 1984

Photograph 1. *Area A looking south, Blawn Wash in the foreground.*

Photograph 2. *Three hills composing Area B, looking east, hill 7602 in foreground and hill 7427 to right.*

Photograph 3. *Knob of massive Quartz-Alunite on top of the hill of 7602 in Area B.*

Photograph 4. *Northeastern ridge of Area B looking northeast from hill 7602.*

Photograph 5. *Rib of massive Quartz-Alunite alteration on the crest of hill 7427 in the south end of Area B, looking southeast.*

GEOLOGY AND RESOURCES OF ALUMINUM

Photograph 6. *Hill 7427 on left and 7602 on right, looking southwest in Area B.*

Photograph 7. *Massive hematite vein (note red streak near tip of scriber) in Quartz-Alunite alteration on hill 7602 of Area B.*

TABLE 1.-1ndex to numbered alunite locaUties in the cornterminous

Photograph 8. *Looking northeast from near the center of Area C, massive outcrops of Quartz-Alunite on hill 7523 in middle distance and 7676 on skyline. This is the area of the proposed open pit mine.*

Photograph 9. *Panorama of Area C, in the middle distance, looking northwest from near the top of hill 7602. The white knob in the lower left is one of the rhyolite porphyry outcrops. The white cut on top of the Area C ridge, to the right of center, is the alunite bulk sample pit. The proposed alunite open pit is centered near the bulk sample pit and encompasses both the high knob to the right (hill 7676) and the low white hill to the left (7523) of the bulk sample site.*

Photograph 10. *Looking southwest from near the center of Area C, hill 7594 in the middle distance and Area D in the background.*

Photograph 11. *The north end of Area C looking east-northeast from Blawn Mountain. Massive Quartz-Alunite on hill 7676 in center middle-ground, bulk sample test pit in stark white. This encompasses the area of the proposed open pit alunite mine.*

Photograph 12. *The center of Area C looking northwest with hill 7217, a possible altered quartz eye porphyry intrusive, in middle distance.*

Photograph 13. *Vuggy silica from the Silica Zone on the southwest nose of hill 7676, Area C.*

Photograph 14. *The small open cut in Area C where ESI's bulk alunite ore test sample was collected, looking northeast.*

Photograph 15. *Alunite vein in massive Quartz-Alunite rock from the bulk sample test pit on Area C.*

Photograph 16. *White, coarsely crystalline, sub-vertical, northeast-striking alunite veins in Quartz-Alunite alteration on hill 6776, northeast of the main zone of Area C.*

Photograph 17. *Close-up of alunite vein on hill 6776, northeast of the main zone of Area C, pocket knife for scale.*

Photograph 18. *Blawn Mountain (Area D) looking southwest. Silica Cap forms the rugged exposures on the crest of the ridge.*

Photograph 19. *Sandy Wash 4/Blawn Mountain kaolinite mine, just west of Blawn Mountain, looking west. This pit appears to be developed on a hydrothermal breccia pipe.*

Photograph 20. *Outcrop of tightly flow-banded rhyolite porphyry.*

Photograph 21. *Bold exposure of strongly flow-banded rhyolite porphyry.*

Appendix B

Trace element geochemistry to accompany plate 4 (Hofstra, 1984)

Blawn Wash Lithogeochemistry

Sample Number	Ag PPM	As PPM	Au PPB	Cu PPM	F %	Mo PPM	Pb PPM	Sb PPM	Sn PPM	W PPM	Zn PPM
8A1	0.2		5	7		10	2				5
15XT6	0.2		5	43		2	2				1
15XT7	0.2		5	4		8	2	8			1
15TBT6	1.4	100	10	5		7	650	2			91
15TBT9	0.2		5	4			2				1
15TBT16	0.2		5	3		10	2				1
15TBT19	0.9	84	20	6		15	4				6
15NGSK	2.8	66	20	12		6	1	13			320
17Ti13	0.2		5	12		1	6				12
17XT5A	0.2		5	4		3	2				1
17XT5C	0.2		5	4		13	11				1
17XT14	0.2		5	2		2	2				1
17XT23	0.2		5	3		1	2				1
17XT26	0.2		5	4		11	36				1
19A1N	0.2		5	6		6	8				22
19A2N	0.2		5	5		2	2				4
19A5	0.2		5	11		3	4				25
19A6B	0.2		5	22		5	5				12
19A6C	0.2		5	6		5	2				1
19A7	0.6		5	11		9	7				32
19A8	0.2		5	6		2	4				11
19A10	0.2		5	10		6	4				11
21A1N	0.2		5	7		2	2				3
21A2N	0.2		5	18		7	4				17
21A3	0.2		5	32		7	8				1
21PP1	0.2		5	6		3	4				353
21PP3	0.2		5	6		3	4				173
21XT7	0.2		5	33		4	5				10
21XT20	0.2		5	8		8	6				18
21NCM19	2.0	383	20	6	0	7	1		6	1	420
21NGM20	1.9	118	20	34	0	5	1		2	2	1,630
21NGM21	2.0	70	20	8	0	5	4		2	2	400
27XT3	1.7	2	10	20		2	168	2			85
27XT16	0.2		5	4		5	20				1
27XT21	0.2		5	2		1	2				2
27XT26W	0.2		5	2		2	2				1
29A1	0.2		5	4		3	6				4
29A4	0.2		5	3		8	2				1
29A7	0.6		5	3		5	86				17
29A9N	0.2		5	5		14	2				5
29A9S	0.2		5	10		7	6				27
29A12	1.3		5	82		8	82				362
29A13A	1.4		5	53		5	22				179
29A13B	0.9		5	7		4	15				7
29A16	0.2		10	11		1	8				25
29A18	0.2		10	108		13	6				235
29A19	2.2	205	10	9		6	59	19			40
29A21	0.2		5	10		3	2				24
29Tnwp3	1.3		5	23		4	18				51
31A1	0.2	390	5	65		5	15	10			106
31A2	0.2		5	8		1	2				2

Sample Number	Ag PPM	As PPM	Au PPB	Cu PPM	F %	Mo PPM	Pb PPM	Sb PPM	Sn PPM	W PPM	Zn PPM
31A3	0.2		5	9		7	8				29
31A5	0.2		5	7		1	7				191
31A7	0.2		5	65		8	7				64
31A9	0.2		5	19	0	66	15			3	39
31A10	0.2		5	10		4	6				17
31A11	0.2		5	150		1	2				6
31Al2	0.2		5	27		6	3				46
31Al2	0.4		5	11		5	21				25
31A13	0.2		5	8		1	2				8
31A14	1.4		5	9		6	43				14
31A14A	0.2		5	9		3	4				5
31XT30	0.2		5	2		1	2				1
31 SK	1.5		5	36		6	19				440
31QV	1.0		5	33		5	30				13
31NGM18	0.9	209	20	35	0	2	14		2	1	64
38A4	0.2		5	16		1	9				23
38A6	0.5		5	4		1	17				12
38A7	0.3		5	2		3	9				8
38A8	0.2	205	20	9		11	8	2			30
38A13	0.2		5	8		5	7				26
38A16	0.2		5	4		3	4				5
38A17	0.5	123	30	8	0	393	2	19	5	4	13
38QV1	0.2		5	11		5	11				33
38NGM15	0.3	10	20	7	0	2	3		1	1	12
38NGM16	0.4	43	20	6	0	8	3		3	1	18
38NGM17	0.4	52	20	7	0	1	5		4	1	19
40A2	0.2		5	5		7	3				2
40A6	0.2		5	7		2	5				10
40A7B	1.4		5	4		6	34				31
40A85	0.2		5	6		5	2				2
40A10	0.2		5	15		20	11				45
40A11	0.2		5	35		3	6				32
40A14	0.2		5	2		1	2				1
40S1B	0.6		5	3		2	22				18
40NGM1	0.7	3	20	6	0	1	17		3	1	20
40NGM2	0.7	5	20	8	0	1	22		1	1	27
40NGM3	0.6	4	20	5	0	2	15		3	2	34
40NG14	0.8	8	20	5	0	1	10		2	2	22
40NGM5	0.7	17	20	5	0	1	18		4	1	12
40NGM6	0.5	8	20	4	0	1	15		4	1	12
40NGM7	0.8	42	20	5	0	3	15		5	2	28
40NGM9	0.6	4	20	4	0	2	24		2	2	30
40NGM10	0.7	6	20	5	0	1	29		3	2	17
40NGM11	0.8	2	20	10	0	1	22		2	2	38
40NGM123	0.9	2	20	5	0	1	19		2	1	50
40NGM13	0.8	3	20	4	0	1	15		3	1	39
40NG1114	0.8	4	20	5	0	1	19		2	2	32

From Hofstra, 1984.

Appendix C

Index to Alunite Localities in Figure 8 (Hall, 1978)

GEOLOGY AND RESOURCES OF ALUMINUM

TABLE 1.—*Index to numbered alunite localities in the conterminous United States (see fig. 1 for map)*

[Hydrothermal alunite occurrences and very local sedimentary alunite occurrences having negligible resource potential are located on the map but are not numbered; they are discussed briefly in the text. V, veins; R, replacement deposits; S, sedimentary deposits. Question mark (?) after a number indicates a very high degree of uncertainty. Dash leaders (-----) indicate insufficient data. All reserve and resource figures are subject to revision as further data become available]

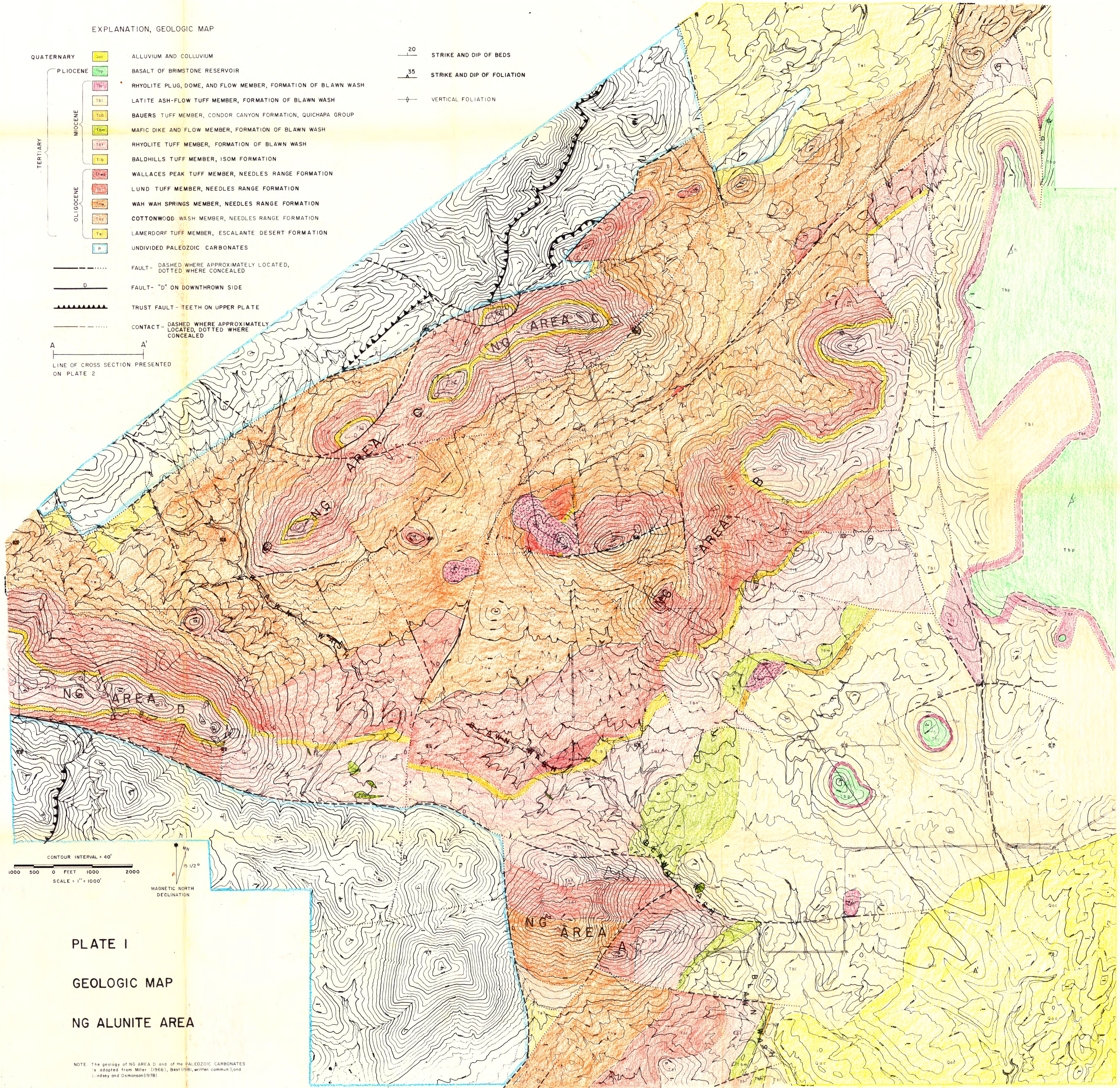
Loc.	District or deposit	State, County	Deposit type	Remarks	References	Reserves (10^6 t)	Estimated alunite content (percent)	Potential resources (10^6 t)	Estimated alunite content (percent)
1	Marysvale	Utah, Piute, Sevier.	V and R	Veins on Alunite Ridge exploited during both World Wars. Low-grade replacement deposits are larger resource than the veins.	Butler and Gale, 1912; Callaghan, 1938, 1973; Loughlin, 1916; Thoenen, 1941; Hild, 1946.	V-1.38 R-7.36	88 43	0.74 33.26	79 23
2	Southern Wah Wah Mtns.	Utah, Beaver, Iron.	R	Alumet consortium developing "NG" lease area. District also includes SX and PV deposits south of Beaver County-Iron County line and west end of White Mtn. area. Most promising domestic alunite resource recognized so far.	Walker and Stevens, 1974; Parkinson, 1974.	232	33	402	28
3	Sheep Rock	Utah, Beaver	R	Alunitized Tertiary rhyolite forms prominent white hill 8 km northeast of Beaver.	Loughlin, 1916; Thoenen, 1941.	2	30	-----	-----
4	Big Pinto Spring.	Utah, Beaver	R	Siliceous sporadically alunitized volcanic rock.		-----	-----	-----	-----
5	Modena	Utah, Iron	R	Alunitized tuff breccia		-----	-----	-----	-----
6	Beauty Knoll	Utah, Washington.	V	Alunite vein in halloysite-bearing altered andesite.	Crawford and Buranek, 1948.	.45?	80?	-----	-----
7	Clover Mtns.	Nev., Lincoln	R	Parts of 18-km² area in T. 7 S., R. 70 E., underlain by altered Tertiary volcanic rocks; extent of alunitization unknown.		-----	-----	-----	-----
8	Boyd	Nev., Lincoln	V	Lens of alunite mined briefly in 1920's.	Hewett and others, 1936; Thoenen, 1941; L. S. Gardner, unpub. data, 1943.	.04 .29	29 21	----- -----	----- -----
9	Railroad Pass.	Nev., Clark	R	Irregular localized alunitization in Tertiary volcanic rocks.	Hewett and others, 1936; Thoenen, 1941; Phalen, 1917; L. S. Gardner, unpub. data, 1944.	1.8	27	4	6
10	Goldfield	Nev., Esmeralda	R	Main mined area at Goldfield not a likely resource; areas south and west of town are more favorable.	Ransome, 1907, 1909.	-----	-----	Main mined area—150? CTR leases—100? MTZ lease—60?	10? 22? 20?
11	Monte Cristo Range.	Nev., Esmeralda	R	Alunitized Tertiary volcanic rocks, extent unknown.		-----	-----	-----	-----
12	Boundary Peak.	Nev., Esmeralda	R	Alunitized Teritiary volcanic rocks associated with mercury deposits.	Bailey and Phoenix, 1944.	-----	-----	-----	-----
13	Bovard	Nev., Mineral	V	Thin alunite veins in altered rhyolite at old Gold Pen mine.	Schrader, 1913; Thoenen, 1941.	.007	50	-----	-----
14	Gabbs Valley Range.	Nev., Mineral	R	Locally alunitized Tertiary tuff and granite; resource may be large, but alunite content is low.		-----	-----	-----	-----
15	Corey Peak	Nev., Mineral	R	White alunitized rhyolite exposed in shallow bulldozed trench: deposit high grade but small.	Archbold, 1966	-----	-----	.9	40
16	The Elbow	Nev., Mineral, Lyon.	R	Irregularly alunitized Tertiary volcanic rocks in area straddling Mineral County-Lyon County line near "The Elbow," bend in East Walker River; leases applied for by private consortium.		-----	-----	40?	20?
17	Sulphur	Nev., Humboldt	V	Alunite veins in altered Tertiary volcanic rocks, mined briefly in 1917.	Clark, 1918; Vanderburg, 1938; Thoenen, 1941; L. S. Gardner, unpub. data, 1944.	.026 .186	75 70	----- -----	----- -----
18	Beatty	Nev., Nye	R	Area of strongly bleached, locally alunitized Tertiary volcanic rocks, 11 km east of Beatty. Cristobalite also abundant locally.		-----	-----	-----	-----
19	Red Mountain-Patagonia.	Ariz., Santa Cruz.	R	"Red Mountain" volcanic complex pervasively alunitized; kaolinite, sericite, pyrophyllite also present; porphyry-type copper mineralization beneath alunitized upper part of the mountain.	Schrader, 1913, 1915; Simons, 1974; Corn, 1975.	-----	-----	200	25?

TABLE 1.—*Index to numbered alunite localities in the conterminous United States*—Continued

Loc.	District or deposit	State, County	Deposit type	Remarks	References	Reserves (10^6 t)	Estimated alunite content (percent)	Potential resources (10^6 t)	Estimated alunite content (percent)
20	Sugarloaf Peak.	Ariz., Yuma	V	Veins, localized stockworks in sheared sericitized dacite of uncertain age, 8 km west of town of Quartzsite.	Heineman, 1935; Thoenen, 1941.	0.232	55	-----	-----
21	Hassayampa River.	Ariz., Maricopa	R	Alunitized and kaolinized Tertiary rhyolite in 130-hectare area, 16 km south of Wickenburg, along margins of Hassayampa River Valley.	Sheridan and Royse, 1970.	-----	-----	-----	-----
22	Red Mountain-Lake City.	Colo., Hinsdale	R	Alunitized silicified quartz latite of Miocene age on summit area of Red Mountain, 5 km south of Lake City.	Larsen, 1913; Steven and others, 1974.	-----	-----	250	30
23	Marble Mountain.	Colo., Rio Grande.	R	Alunitized Tertiary andesitic volcanic rocks on ridge 5 km north of old Jasper mining camp.	L. S. Gardner, unpub. data, 1943.	5.2	37	9	30
24	Rosita Hills	Colo., Custer	R	Mount Robinson and Democrat Hill volcanic vents, rhyolite tuff locally alunitized. Minor diaspore at Mount Robinson.	Cross, 1891, 1896; Thoenen, 1941; L. S. Gardner, unpub. data, 1943.	-----	-----	2.7	15
25	Calico Peak	Colo., Dolores	R	Strong silicification, local alunitization in hydrothermally altered Tertiary latite volcanic plug. Muscovite, kaolinite, minor pyrophyllite also present.	Cross and Spencer, 1900; Thoenen, 1941; Serna-Isaza, 1971; L. S. Gardner, unpub. data, 1943.	-----	-----	2 9	17 15
26	Alum Creek	Colo., Conejos	R	Local alunitization in Tertiary volcanic vent complexes above Alum Creek, immediately south of Rio Grande County boundary.	Calkin, 1967	-----	-----	-----	-----
27	Alum Mountain.	N. Mex., Grant	R	Pervasively alunitized and kaolinized Tertiary latitic tuff-breccia on Alum Mountain and both sides of Alum Canyon. Local supergenic alum encrustations.	Hayes, 1907	-----	-----	90	20
28	Saddleback Mountain.	N. Mex., Grant	R	Strongly silicified, locally alunitized Tertiary volcanic rocks at extreme northwest end of Steeple Rock mining district.		-----	-----	60	30
29	Juan Peak	N. Mex., Sierra	R	Strongly silicified alunitized Tertiary rhyolitic tuffs and breccias 10 km northwest of Monticello.		-----	-----	-----	-----
30	Rattlesnake Canyon.	N. Mex., Luna	R	Silicified alunitized Tertiary volcanic rocks in low hilly terrain near mouth of Rattlesnake Canyon, 14 km northwest of Florida rail siding.		-----	-----	-----	-----
31	Enumclaw	Wash., King, Pierce.	R	Locally alunitized Tertiary andesitic volcanic rocks; clay minerals accompany the alunite in much of the rock.	Thoenen, 1941; Huntting, 1966; Livingston, 1971.	1.1	48?	-----	-----
32	Quaking Asp (Aspen) Mountain.	Wyo., Sweet-Water.	R	Alunitized tuffaceous siltstone exposed in bottom of trench excavated in Tertiary terrestrial sediments 20 km southeast of Rock Springs.	Love and Blackmon, 1962.				
33	Wilson County.	Tex., Wilson	R?	Alunite in "decomposed trachyte" in 8-hectare area 48 km southeast of San Antonio.	Braun, 1921	-----	-----	-----	-----
34	North-central Texas.	Tex., Fannin, Grayson, Denton, Tarrant, Johnson.	S	White natroalunite nodules along unconformity between Cretaceous Woodbine Formation and overlying Eagle Ford Group, exposed intermittently in roadcuts and outcrops over a 5-County area, ranging 215 km from northeast to southwest. However, nodular layer is discontinuous and only 15-30 cm thick.	Stephenson, 1946; Ross and others, 1968.	-----	-----	-----	-----
35	Medley	Tex., Jeff Davis	R	Alunite dispersed in hydrothermally altered Tertiary rhyolite-trachyte flows 27 km west of Ft. Davis. Cristobalite, kaolinite, iron oxide also present.	Shurtz, 1951	-----	-----	-----	-----
36	Cuyuna North Range.	Minn., Crow Wing.	S	Alunitized black argillite in Rabbit Lake Formation of Precambrian X age in localities 16 km apart in Cuyuna North Range iron-ore district.	Schmidt, 1963	-----	-----	-----	-----
	Total					252.521	-----	1,413.6	-----

Appendix D

Plates 1, 3, and 4 from Hofstra (1984)



EXPLANATION, GEOLOGIC MAP

QUATERNARY		Qac	ALLUVIUM AND COLLUVIUM
TERTIARY	PLIOCENE	Tbp	BASALT OF BRIMSTONE RESERVOIR
	MIOCENE	Tbr	RHYOLITE PLUG, DOME, AND FLOW MEMBER, FORMATION OF BLAWN WASH
		Tbl	LATITE ASH-FLOW TUFF MEMBER, FORMATION OF BLAWN WASH
		Tcb	BAUERS TUFF MEMBER, CONDOR CANYON FORMATION, QUICHAPA GROUP
		Tbm	MAFIC DIKE AND FLOW MEMBER, FORMATION OF BLAWN WASH
		Tbt	RHYOLITE TUFF MEMBER, FORMATION OF BLAWN WASH
		Tib	BALDHILLS TUFF MEMBER, ISOM FORMATION
	OLIGOCENE	Tnwp	WALLACES PEAK TUFF MEMBER, NEEDLES RANGE FORMATION
		Tnl	LUND TUFF MEMBER, NEEDLES RANGE FORMATION
		Tnw	WAH WAH SPRINGS MEMBER, NEEDLES RANGE FORMATION
		Tnc	COTTONWOOD WASH MEMBER, NEEDLES RANGE FORMATION
		Tel	LAMERDORF TUFF MEMBER, ESCALANTE DESERT FORMATION
		P	UNDIVIDED PALEOZOIC CARBONATES

FAULT- DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED

D
FAULT- "D" ON DOWNTHROWN SIDE

TRUST FAULT - TEETH ON UPPER PLATE

CONTACT- DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED

A A'
LINE OF CROSS SECTION PRESENTED ON PLATE 2

20
STRIKE AND DIP OF BEDS

35
STRIKE AND DIP OF FOLIATION

VERTICAL FOLIATION

CONTOUR INTERVAL = 40'

1000 500 0 FEET 1000 2000

SCALE = 1" = 1000'

MAGNETIC NORTH DECLINATION

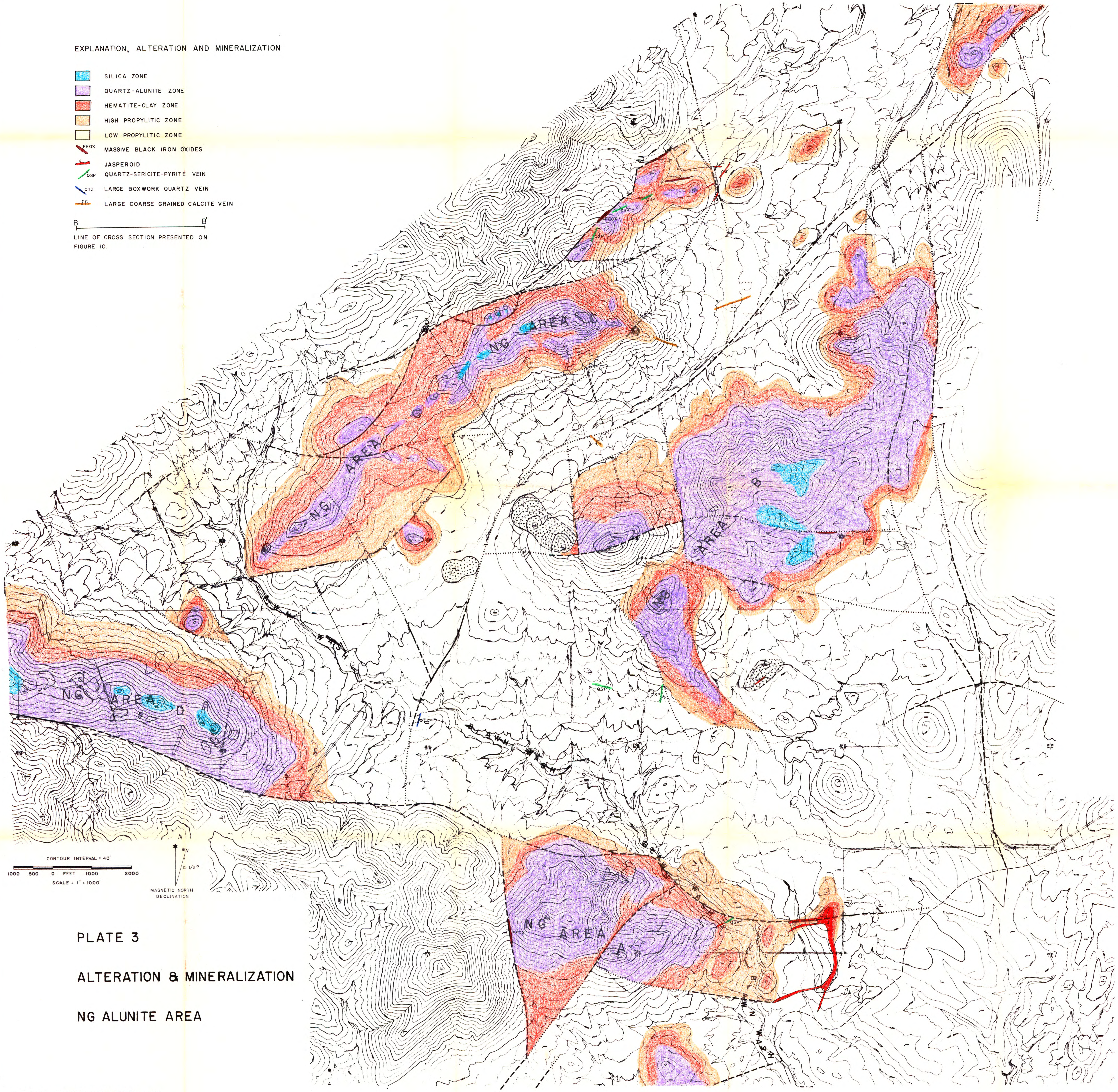
PLATE I

GEOLOGIC MAP

NG ALUNITE AREA

NOTE The geology of NG AREA D and of the PALEOZOIC CARBONATES is adapted from Miller (1966), Best (1981, written commun.), and Lindsey and Osmonson (1978).

T-2617 ALBERT H. HOFSTRA, 1983



EXPLANATION, ALTERATION AND MINERALIZATION

🟦	SILICA ZONE
🟪	QUARTZ-ALUNITE ZONE
🟥	HEMATITE-CLAY ZONE
🟧	HIGH PROPYLITIC ZONE
☐	LOW PROPYLITIC ZONE
FEOX	MASSIVE BLACK IRON OXIDES
J	JASPEROID
QSP	QUARTZ-SERICITE-PYRITE VEIN
QTZ	LARGE BOXWORK QUARTZ VEIN
CC	LARGE COARSE GRAINED CALCITE VEIN
B ——— B'	LINE OF CROSS SECTION PRESENTED ON FIGURE 10.

PLATE 3

ALTERATION & MINERALIZATION

NG ALUNITE AREA

T-2617 ALBERT H. HOFSTRA, 1983

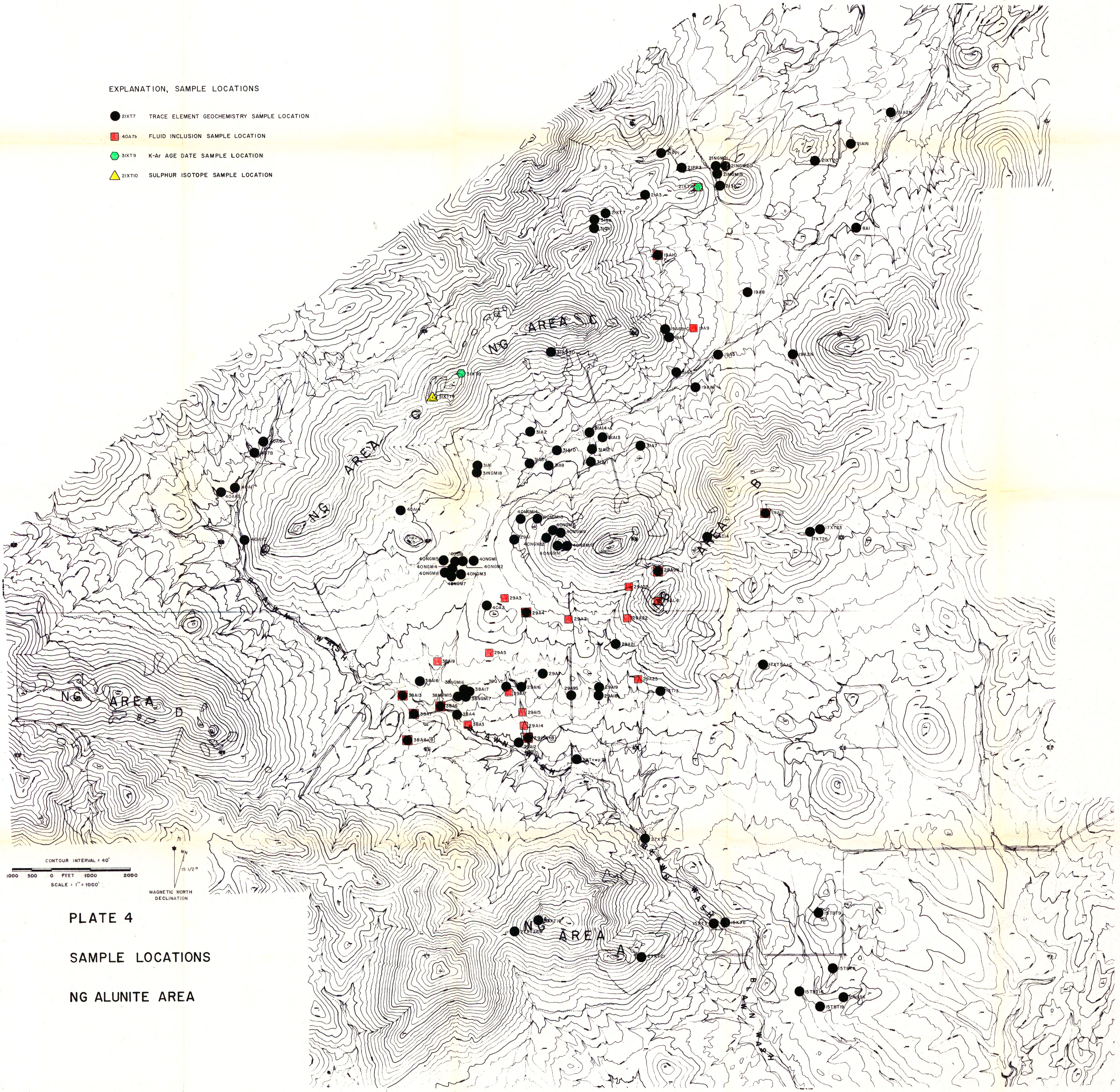


PLATE 4

SAMPLE LOCATIONS

NG ALUNITE AREA

T-2617 ALBERT H. HOFSTRA, 1983