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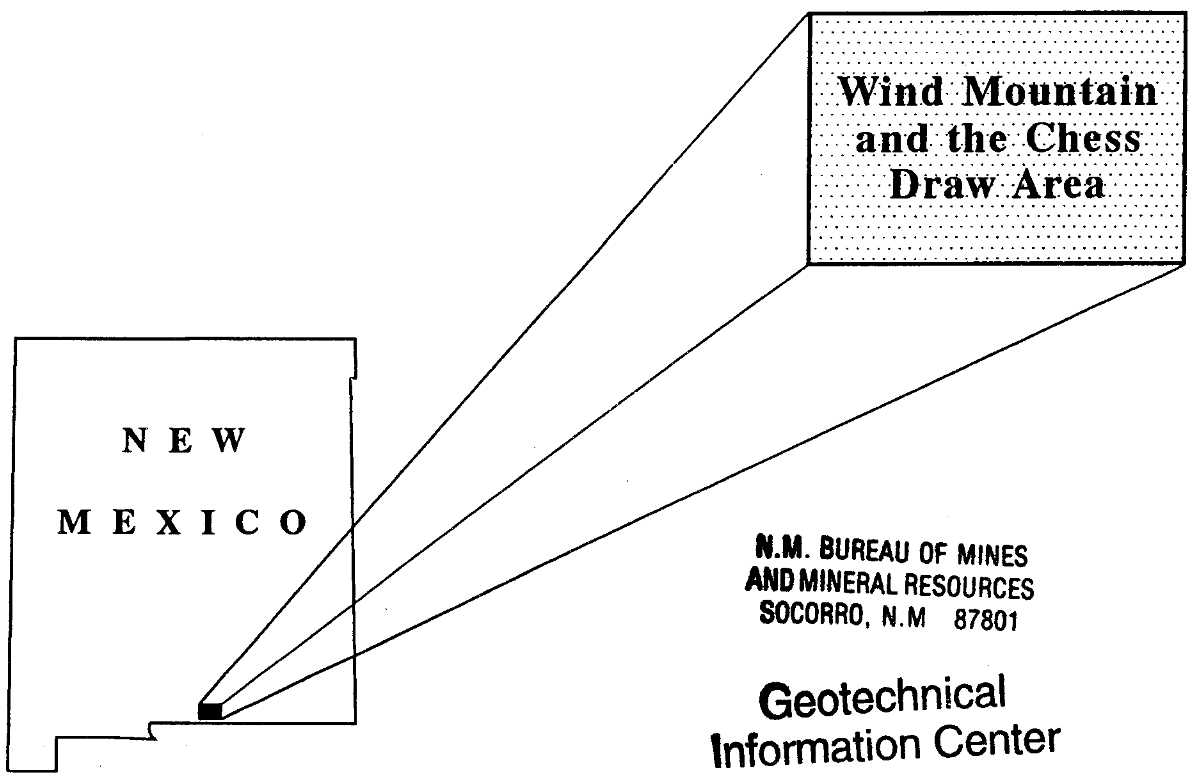
Mineral Land Assessment
Open File Report 1994

Mineral Investigation of Wind Mountain and the Chess Draw Area, Cornudas Mountains, Otero County, New Mexico



U.S. Department of the Interior
Bureau of Mines

MINERAL INVESTIGATION OF WIND MOUNTAIN AND THE CHESS DRAW AREA, CORNUDAS MOUNTAINS, OTERO COUNTY, NEW MEXICO

by

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Intermountain Field Operations Center
Denver, Colorado

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

This open-file report summaries the results of a Bureau of Mines' site specific study. The report has not been edited or reviewed for conformity with the Bureau of Mines' editorial standards. This study was conducted by personnel from the Intermountain Field Operations Center, P. O. Box 25086, Denver Federal Center, Denver, Colo. 80225.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cps	Count per second
ft	foot
ha	hectare
km	kilometer
in.	inch
m	meter
mi	mile
mi^2	square mile
mm	millimeter
t	metric ton
cm	centimeter
ppb	part per billion
ppm	part per million
%	percent
st	short tons
oz	troy ounce
oz/st	troy ounce per short ton
lb	pound
$	dollar (U.S.)

ABSTRACT

In 1992, the U.S. Bureau of Mines conducted a field investigation to evaluate the rare-earth and associated element resources in the Wind Mountain and Chess Draw area in the northern Cornudas Mountains, Otero County, New Mexico. Bureau personnel mapped and sampled prospects and mineralized zones to appraise the mineral resources. Thirty-five samples were taken from rare-earth-element and niobium occurrences and a nepheline syenite pluton.

No rare-earth-element or niobium resources were identified in the Wind Mountain and Chess Draw area. The Bureau identified only minor concentrations of rare-earth-elements and niobium in dikes and breccias. Processing tests on the Wind Mountain nepheline syenite determined that it was suitable raw material for high-iron product uses such as amberglass, fiberglass, and dark body ceramics. A suitable raw material could not be economically produced from the Wind Mountain nepheline syenite that would meet the low-iron specifications for many uses required in the glass and ceramics industries. The nepheline syenite may also be used for roofing granules and as sandblasting material.

INTRODUCTION

The U.S. Bureau of Mines, in cooperation with the New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey, is conducting investigations to evaluate the rare-earth element (REE) and associated metal resources of Tertiary alkaline intrusive complexes in New Mexico. The deposits associated with Tertiary alkaline intrusive complexes have been classified as Great Plain Margin deposits by North and McLemore (1988). Great Plains Margin deposits as defined by North and McLemore, contain precious, base, and associated metals, including REE, deposited in veins, breccias, skarns, and placers. The associated intrusions occur as stocks, laccoliths, dikes, and sills of middle to late Tertiary age along and near the margin between the Great Plains and the Rocky Mountain or Basin and Range physiographic provinces. One interpretation is that these intrusive complexes have formed from magmas generated by partial melting of the upper mantle or lower crust along a subduction zone as outlined by Clark and others (1982). Tertiary alkaline intrusive complexes occur in the Cornudas Mountains, the Lincoln County Porphyry Belt, the Ortiz Mountains, and the Laughlin Peak area in New Mexico, and the Spanish Peaks/Huerfano Park and Cripple Creek areas in Colorado.

Many of these alkaline intrusive complexes have been mined primarily for gold (e.g., Cripple Creek, Colo.; Ortiz and White Oaks, N. Mex. districts) but they also contain concentrations of REE and associated elements (McLemore and others, 1988a, b). Complete analytical data have not been published on the REE and associated element contents of many of these deposits. Tertiary alkaline intrusive complexes in New Mexico may contain significant resources of REE, scandium, strontium, niobium, zirconium, hafnium, beryllium, and titanium, which are considered strategic and critical minerals by the Critical and Strategic Minerals Stockpiling Act (50 U.S.C. 98 et seq.) (1988-89) and Anti-Apartheid Act, Section 504 (1986). This report presents the results of a field investigation conducted in April 1992 in one of these alkaline intrusive complexes in the Cornudas Mountains, Otero County, New Mexico.

Geographic Setting

The Wind Mountain and Chess Draw area is located in the northern part of the Cornudas Mountains, a group of several peaks along the New Mexico-Texas border, approximately 60 mi (97 km) east of El Paso, Tex., and 16 mi (26 km) west of Dell City, Tex. (fig. 1). The Cornudas Mountains are part of the Basin and Range physiographic province near

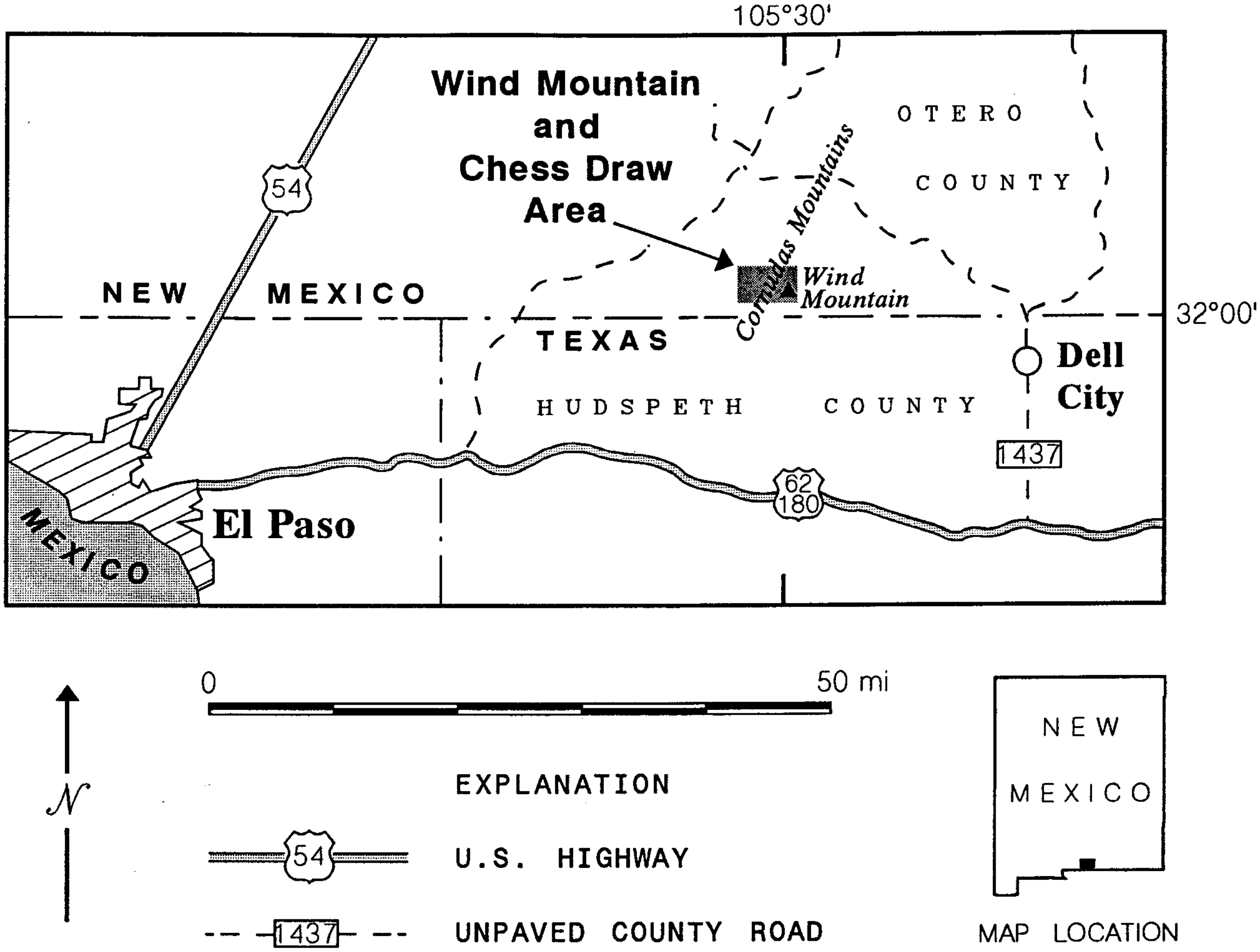

Figure 1.--Index map of the Wind Mountain and Chess Draw area, Cornudas Mountains, Otero County, New Mexico.

the margin with the Great Plains physiographic province. The area investigated includes Wind Mountain, the southwestern part of Chess Draw, Deer Mountain, and part of Flat Top Mountain, and comprises approximately 11,500 acres (4,600 ha) administered by the U.S. Bureau of Land Management, Las Cruces District Office, New Mexico. Elevations range from approximately 4,900 ft (1,490 m) on the surrounding plains to 7,280 ft (2,200 m) on top of Wind Mountain. Access to the area is by unpaved county roads.

Method of Investigation

Literature pertaining to the Cornudas Mountains was reviewed to obtain information concerning geology, mineral occurrences, and mining activity. Two geologists spent 17 days mapping and sampling prospects and mineralized zones. Thirty five rock-chip or grab samples were taken.

Analytical determinations were made by Bondar Clegg, Inc., Denver, Colo. All samples were analyzed three times and averaged for nine REE (lanthanum, cerium, neodymium, samarium, europium, terbium, thulium, ytterbium, and lutetium), scandium, thorium, and uranium by instrumental neutron activation analysis. All samples were analyzed for barium, niobium, and zirconium by X-ray fluorescence; for beryllium by atomic absorption analysis; and for fluorine by specific ion method. Selected samples were also analyzed for gold by fire assay with an atomic absorption finish; antimony, arsenic, bismuth, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, titanium, tungsten, and zinc by inductively coupled plasma emission spectroscopy with a nitric-hydrochloric acid hot extraction; tantalum, strontium, yttrium, and zirconium by X-ray fluorescence; and mercury by cold vapor atomic absorption with a nitric-hydrochloric-tin sulfate acid extraction. Whole rock analysis was done by borate fusion plasma-emission spectroscopy.

In addition to the analytical determinations, 20 polished thin sections of samples from mineralized zones and host rocks were examined using a petrographic microscope.

Scanning electron microscope-energy dispersive x-ray spectral analysis (SEM-EDX) was done by James Syoberg, U.S. Bureau of Mines, Reno Research Center, Reno, Nev., using a JOEL T-300 equipped with a Princeton Gama Tech System 4 x-ray analyzer, with an Omega SLS x-ray detector. The SEM-EDX analysis should be considered semiquantitative and was conducted to verify petrographic mineral determinations and to help identify extremely fine-grained minerals.

Processing tests on the Wind Mountain analcite nepheline syenite were done by William Hirt, U.S. Bureau of Mines, Salt Lake City Research Center, Salt Lake City, Utah.

Scintillometer readings were taken with a Geometrics, model GR-101A gamma ray scintillometer.

The brand names referenced above do not imply endorsement by the Bureau of Mines.

Previous Investigations

Clabaugh (1941) mapped the western part of the area, including Deer Mountain, Flat Top Mountain, and the Chess Draw area, while Zapp (1941) mapped the eastern part of the area that includes Wind Mountain. In 1944, the U.S. Geological Survey sampled the malignite dike and associated rocks to determine the trace element content (Fleischer and Cameron, 1946). Collins (1958) conducted a reconnaissance investigation for uranium. Holser (1959) mapped and sampled the malignite dikes around Wind Mountain as part of a study on the occurrence of nonpegmatite beryllium in the United States. Barker and others (1977) and Barker and Hodges (1977) discuss the mineralogy, petrology, and Rb-Sr isotope geochemistry of intrusions in the Diablo Plateau. Boggs (1985 and 1987) and Boggs and Ghose (1985) discuss the zirconium silicate minerals, georgechaoite in the Wind Mountain nepheline syenite and eudialyte in an adjacent malignite dike. McLemore and others (1988) has a general discussion of the Cornudas Mountains. McLemore and Guilinger (1992 and 1993) discuss the geology and mineral resources of the Cornudas Mountains and the potential use of the Wind Mountain nepheline syenite.

GEOLOGIC SETTING

The area investigated is on the northeastern edge of the Diablo Plateau, a large upfaulted block surrounded on the east, south, and west by grabens and on the north by the Sacramento Mountains. Cenozoic hypabyssal alkalic rocks intrude flat-lying Permian sedimentary rocks (fig. 2). These alkalic intrusive rocks are the northern part of the Trans-Pecos magmatic province.

Plugs, laccoliths, dikes, and sills of syenite, trachyte, analcite nepheline syenite, and phonolite have intruded and domed Permian sedimentary rocks. The description of the various rock units below was compiled from Barker and others (1977), Clabaugh (1941), and Zapp (1941).

Permian Sedimentary Rocks

The Permian sedimentary rocks exposed have been divided into three units. An upper unit equivalent to the Leonard or Bone Spring Limestone consists of light gray dolomitic limestone with thin shale beds that may contain abundant chert. It is estimated to be 600 plus ft (180 m) in thickness. The middle unit consists of fine red sandstone and shale with numerous seams of gypsum. It is best exposed due east of the center of Flat Top Mountain.

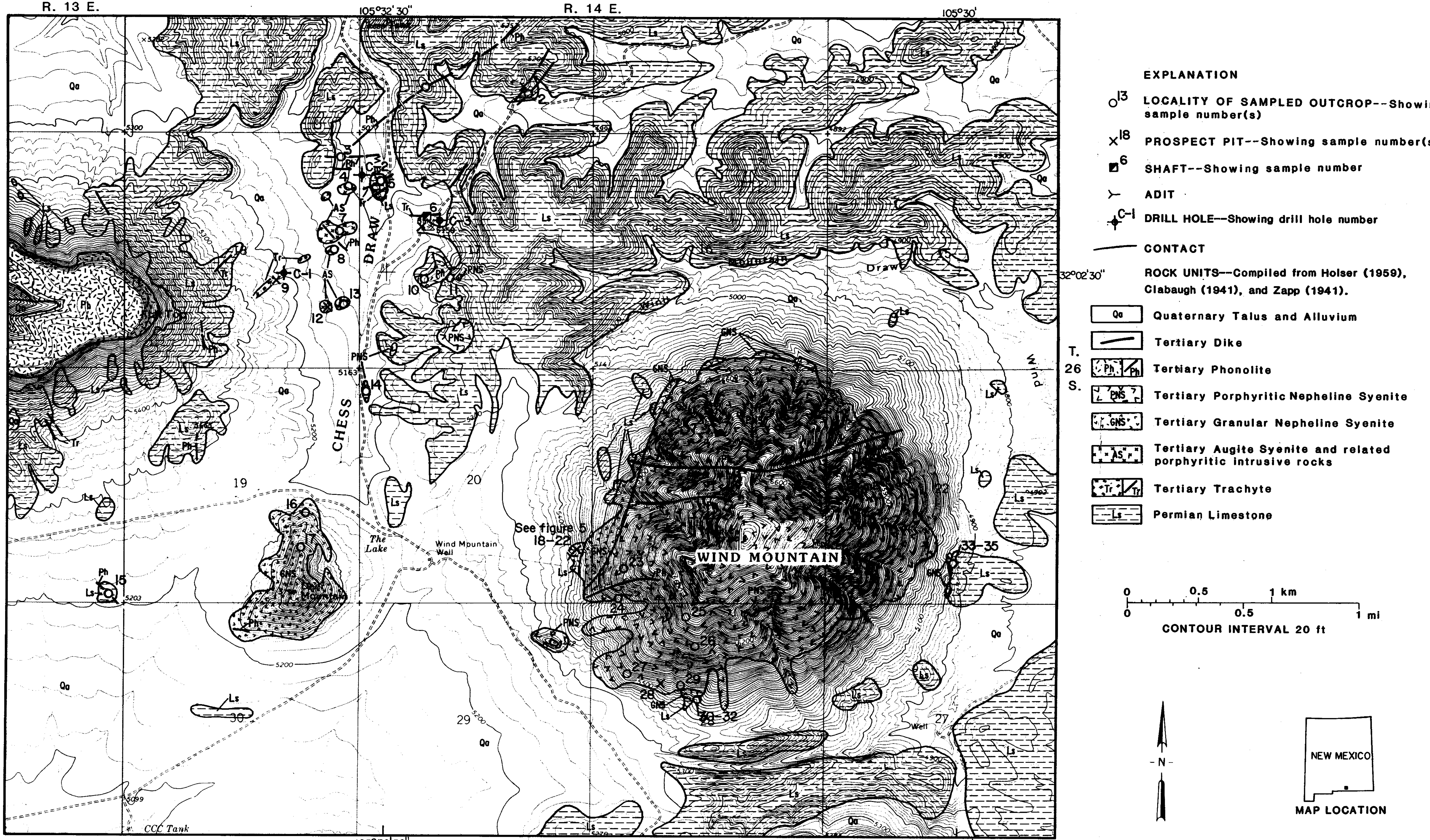

Figure 2.--Sample locality map of the Wind Mountain and the Chess Draw area, Cornudas Mountains, Otero County, New Mexico.

The oldest unit, equivalent to the Hueco Limestone, consists of dark gray to black cherty limestone with shale partings. It is estimated to be approximately 700 ft (210 m) thick and is exposed at the base of Wind and Deer Mountain.

Tertiary Intrusive Rocks

Trachyte

The trachyte is a gray porphyritic rock with an aphanitic matrix. The groundmass of alkali feldspar (probably sanidine) has a trachytic texture with scattered phenocrysts of anorthoclase, sanidine, plagioclase, and some biotite. It occurs as dikes (sample sites 5,6,9, and 11) ranging from 2 ft (0.6 m) to 50 ft (15 m) wide and are traceable over a distance of as much as 500 ft (152 m). The weathered trachyte is solution banded and is yellow to tan to brown in color. Only in a few scattered areas and in drill core is the trachyte unweathered. Accessory sphene and apatite are present. Clabaugh (1941, p. 55) suggests the trachyte is younger than the nepheline syenites but altered trachytic fragments were found in the chill zone of the augite syenite at sample site 4, indicating that it is older.

Nepheline Bearing-Augite Syenite

A small plug of nepheline bearing-augite syenite (sample site 7) forms a low hill in the broad alluvial valley east of Flat Top Mountain (fig. 2). The center of the plug is a gray medium-grained equigranular rock consisting of anhedral anorthoclase, anhedral zoned plagioclase mantled by anorthoclase, augite, biotite, and interstitial nepheline and analcite. Abundant titanomagnetite, apatite, and some sphene are commonly associated with the augite and biotite. The medium-grained augite syenite quickly grades into a dark gray porphyritic rock with an aphanitic groundmass that forms a chill zone around the plug (sample site 8).

The porphyritic chill zone of the augite syenite contains abundant rock clasts and crystal fragments. The phenocrysts in the chilled margin are plagioclase, augite, and kaersutite, that are as much as 1.5 cm long.

Other small irregular igneous outcrops of similar composition with abundant rock clasts and crystal fragments (sample sites 4, 12, and 13) are exposed in the alluvium to the north and south. Clasts of limestone, sandstone, and trachytic and syenitic rocks were identified. These small outcrops appear to be related rocks and are thought to be projections from the main augite syenite body. Sample sites 12 and 13 are extremely fine-grained altered and weathered outcrops that contain abundant rock and crystal fragments and are more of an intrusive breccia.

Nepheline Syenite

The nepheline syenite is primarily exposed on Wind Mountain and Deer Mountain. The nepheline syenite occurs as a granular and a porphyritic type.

The granular nepheline syenite is exposed at Deer Mountain where it appears to be a plug (sample sites 16 and 17). It is a medium-grained (2 to 3 mm) equigranular rock consisting of mottled or streaky cryptoperthite or microperthite, nepheline, analcite, clinopyroxene and amphibole.

The feldspar crystals commonly have a streaked or mottled appearance due to exsolution, where the separation of the potassium and sodium fractions is incomplete. Rapid cooling probably prevented the formation of a clear perthite. In crystals where the separation is complete, the more abundant albite portions of the feldspar crystals exhibit fine polysynthetic twinning. Some perthite crystals contain rims of albite, and albite commonly occurs as overgrowths lining vugs. Small euhedral albite crystals commonly penetrate into patches of clear analcite. The albitization is probably due to deuteric processes. Interstitial nepheline is partly replaced by analcite.

The mafic minerals make up 10% to 15% of the rock and consist of zoned clinopyroxene (aegirine-augite to aegirine), fayalite, biotite, brown to green pleochroic arfvedsonite, and a red-brown pleochroic hornblende. The mafic minerals commonly occur in clumps with inclusions of subhedral to euhedral apatite and titanomagnetite.

The porphyritic type is exposed at Wind Mountain (sample sites 23-29) where it appears to be a laccolith, 1.25 mi (2.0 km) in diameter. It contains euhedral tabular phenocrysts of anorthoclase to a streaky perthite, as long as 2 cm. The groundmass is fine-grained (averaging 0.5 mm in length) consisting of streaky perthite and nepheline crystals. Analcite occurs interstitially to the feldspars and minor amounts of sodalite have been identified.

Mafic minerals make up 10% to 20% of the rock and are interstitial to the groundmass feldspars and nepheline. Fayalite, zoned clinopyroxene (an aegirine-augite core with a rim of aegirine), biotite, and arfvedsonite commonly occur as in aggregates or clusters with inclusions of subhedral to euhedral titanomagnetite and apatite. Fayalite is commonly rimmed by clinopyroxene and biotite. Aenigmatite, eudialyte, catapleiite, georgechaoite, and bastnaesite have also been reported.

The porphyritic nepheline syenite has a granular zone within a few hundred feet of the contact with the limestone (sample sites 21, 30, 31, 33, and 34). The grain size of the granular nepheline syenite averages 0.4 mm on the east side of the intrusion to 0.8 mm on the west side of the intrusion. The granular nepheline syenite consists of tabular streaky or mottled perthite that is dominantly albite, euhedral rhombic to hexagonal nepheline crystals

(20%), and subordinate aegirine crystals (25%). Minor amounts of sodic amphibole and eudialyte were also present.

A medium-gray porphyritic nepheline syenite is present at sample site 14. It contains scattered phenocrysts of alkali feldspar with cores of plagioclase largely altered to analcite and calcite, red-brown kaersutite and biotite, as long as 1.5 cm. The fine-grained groundmass consists of tabular alkali feldspar that is rimmed by albite, zoned clinopyroxene (aegirine-augite with rims of aegirine), and clear analcite is abundant between the feldspar crystals. Apatite crystals and titanomagnetite commonly occur as inclusions in the mafic minerals.

The Permian limestone has been metamorphosed over a distance of a few meters to a fine-grained marble. The metamorphic mineral assemblage is calcite-grossularite-idocrase-apophyllite-wollastonite, with local prehnite and a trace of chondrodite. The siltstone has been metamorphosed to a hornfels that is cut by veinlets containing quartz crystals, aegirine needles, pectolite, wollastonite, a fibrous sodium-aluminum silicate, sphalerite, a calcium-titanium silicate, and a sodium-zirconium silicate.

The granular nepheline syenite is slightly radioactive at the contact with limestone (sample sites 30, 31, 33, and 34) having scintillometer readings as much as 200 cps. Scintillometer readings over the porphyritic nepheline syenite averaged 70 cps.

Phonolite

The phonolite is a green-gray to dark green aphanitic rock, that occurs as a small plug, a sill, and numerous dikes that cut all of the rock types discussed above. The phonolite has a very fine-grained (0.02 mm) to medium-grained (2 mm) groundmass. The very fine-grained dense dark green phonolite (e.g. the phonolite plug sample site 10, and the dike at sample site 15) consists of abundant acicular aegirine in a mass of alkali feldspar and nepheline, that gives the rock a felted appearance in thin section, and gives the phonolite its green color. In the green-gray coarser-grained phonolite the groundmass consists of laths of alkali feldspar and grains of nepheline between which are numerous acicular aegirine crystals, and a trachytic texture is well-developed. Some of the occurrences of the phonolite are nonporphyritic while others contain abundant alkali feldspar and nepheline phenocrysts. The dike at sample site 15 contains white tabular alkali feldspar phenocrysts and red hexagonal analcite pseudomorphs after nepheline as much as 7 cm in size. The phonolite plug (sample site 10) contains abundant nepheline syenite and limestone rock fragments. Calcite commonly fills vugs. At sample site 3, an altered phonolite dike has been bleached to a light tan color.

The phonolite is slightly radioactive. Scintillometer readings ranged from 125 to 200 cps.

MINING HISTORY

Local ranchers report that the Cornudas Mountains have been investigated by a number of companies and individuals in the past. In 1954, radioactive dikes were prospected by shallow pits for uranium and thorium (Collins, 1958, p. 2).

In 1984, Leonard Minerals Company, Albuquerque, N. Mex., in conjunction with U.S. Borax, conducted an exploration program for REE, niobium, titanium, and zirconium in Chess Draw (Ian C. Scarr, 1986, Summary of drilling in the Cornudas Mountains New Mexico, Chess Draw prospect report, U.S. Borax, obtained from Ben Donegan, Leonard Minerals Company, Albuquerque, N. Mex.). Geologic mapping and sampling were followed by a drilling program. In 1985, three holes were drilled, C-1 to a depth of 900 ft, and C-2 and C-3 each to a depth of 800 ft. Samples of the split core contained only low concentrations of niobium (371 ppm or less), lanthanum (184.5 or less), cerium (243.5 or less), titanium (4,000 ppm or less), zirconium (1,725 ppm or less) and fluorine (16,000 ppm or less). The report stated that although REE's, niobium, titanium, zirconium, and fluorine apparently have been introduced by hydrothermal activity related to the intrusion of the alkaline rocks, drill hole data showed no indications of economic concentrations of these elements and no additional drilling is warranted in the area.

In 1992 and 1993, Addwest Minerals, Inc., was conducting tests to determine the suitability of the Wind Mountain nepheline syenite for use as a raw material in the glass and ceramics industries (James Guilinger, Project Manager, Addwest Minerals, Arvada, Colo., oral commun., April, 1993). One test pit (sample site 28) was dug and eight shallow holes (maximum depth of 100 ft (305 m)) were drilled to obtain samples for evaluation. Addwest Minerals submitted a request for a permit to mine nepheline syenite on Wind Mountain. Wind Mountain is approximately 1.25 mi (2.0 km) in diameter and consists of nepheline syenite and syenite. The proposed mine area, approximately 35 acres (14 ha) containing at least 10 million st (9 million t), is located on the southwestern flank of Wind Mountain in the NW 1/4 Sec. 28, T. 26 S., R. 14 E. Addwest Minerals initially plans to mine approximately 150,000 st (136,000 t) of nepheline syenite per year depending on market conditions (Judith Waggoner, Bureau of Land Mangement, Caballo District, Las Cruces, N. Mex., oral commun., April, 1993).

MINERAL DEPOSITS

Hydrothermal rare-earth-element and niobium occurrences

A few altered radioactive dikes and an intrusive breccia have been prospected by a 15 (4.6 m)-ft-deep shaft and four pits (sample sites 2, 6, 9, 11, and 12). The dikes and breccia are extremely weathered and solution banded.

Primary quartz, pyrite, fluorite, zircon, and niobian rutile were identified in polished thin sections. A secondary REE-calcium-carbonate associated with late calcite, zirconium silicates, and hematite-limonite were found in some vugs. The solution banding common in all of the altered dikes is due to the precipitation of varying concentrations of iron oxides as coatings and spherulites precipitated from iron-bearing solutions moving through these rocks. Most of the iron was probably derived from the weathering of pyrite in the altered rocks. Hematite-limonite pseudomorphs after cubic pyrite were present in some samples.

Although polished thin sections were made from samples 2, 6, 11, and 12, niobium and rare-earth element-bearing minerals were only identified from sample 2. At sample site 2, a porphyritic dike referred to as an injection vein by Zapp (1941, p. 31) has been replaced primarily by quartz. Anhedral quartz averaging 0.02 mm in diameter, has replaced part of the groundmass where alkali feldspar laths average 0.05 mm in length. Scattered feldspar phenocrysts have been replaced by quartz and altered to kaolinite. Euhedral corroded quartz crystals, averaging 0.1 mm in length, line vugs. Subhedral to euhedral zircon crystals, ranging from 0.05 to 0.1 mm, occur in the vugs. Zoned fluorite crystals fill parts of the vugs. A niobium-iron-titanium-oxide mineral (appendix C), niobian rutile (ilmenorutile), 0.35 mm in diameter, was found in a vug (fig. 3). The niobian rutile has a narrow niobium-rich rim with a chemical composition that approximates pyrochlore. Late calcite fills the center of most vugs. An REE-calcium-carbonate occurs as spherulites, 0.01 to 0.05 mm in diameter, in the calcite (fig. 4). The semiquantitative SEM-EDX analysis also detected minor thorium (appendix D). The spherulitic habit of the REE-calcium-carbonate suggests that it probably formed at low temperatures, as a weathering product along with fibrous zirconium silicates and abundant hematite and limonite. Some of the spherulites also contain a core with foreign material that consisted of varying amounts of iron, silica, and alumina by SEM-EDX analysis.

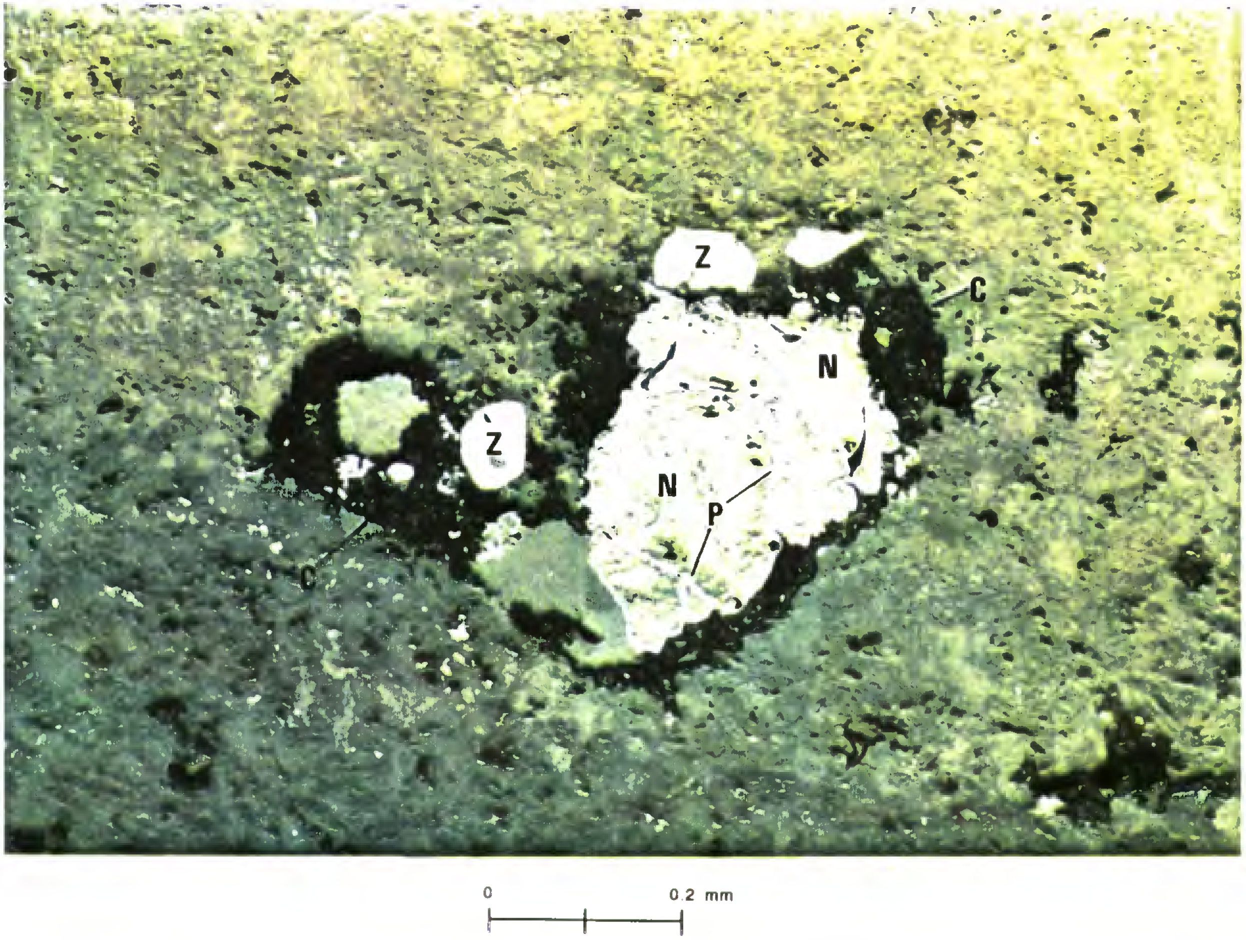

Figure 3. Photomicrograph of altered porphyritic dike at sample site 2 in the Wind Mountain and Chess Draw area, Cornudas Mountains, Otero County, N. Mex., Magnification X 125, reflected light, showing light gray euhedral zircon (Z), gray niobian rutile (N), and calcite (C) filling a vug. The lighter gray rim around the niobian rutile is niobium-rich mineral with a composition that approximates pyrochlore (P).

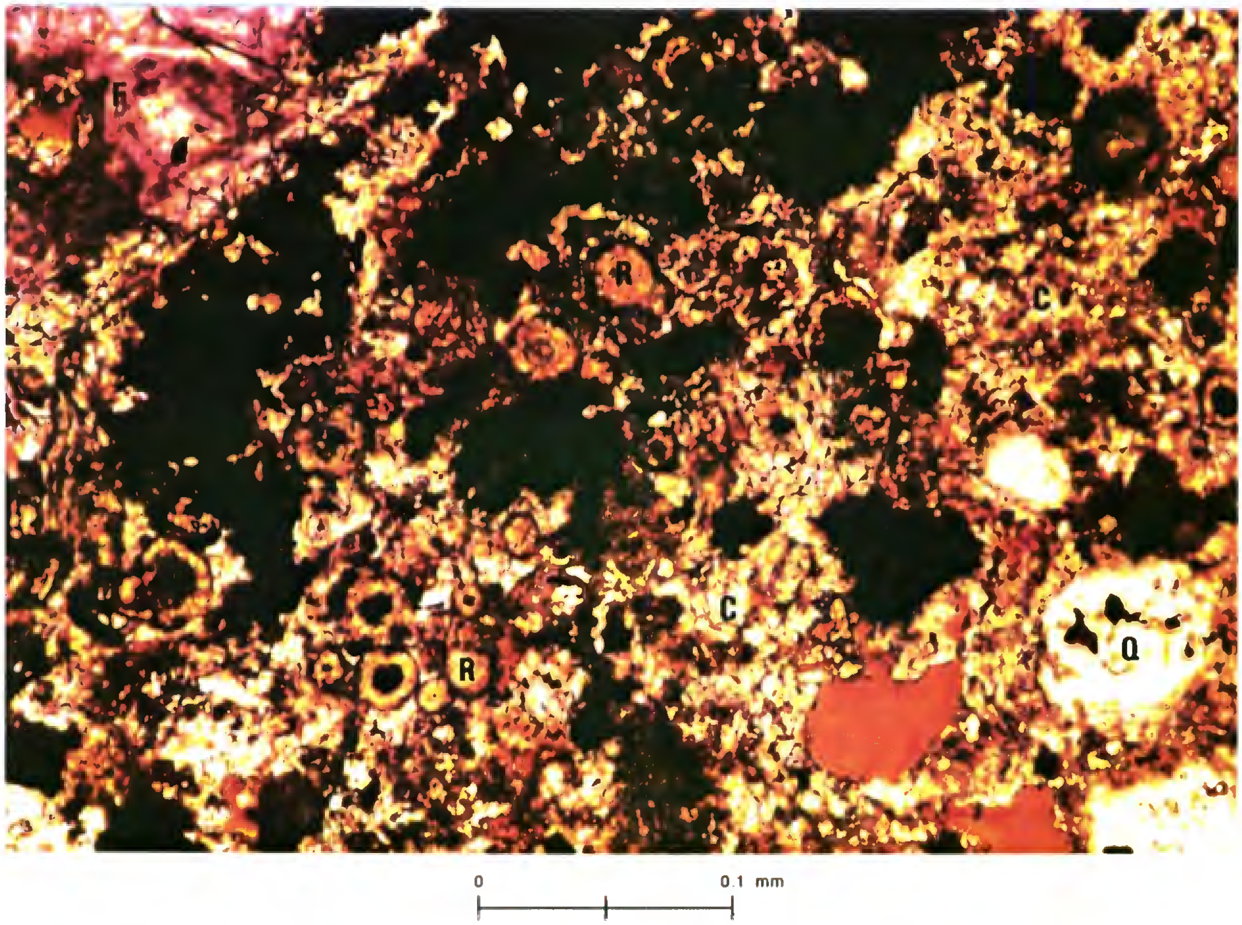

Figure 4. Photomicrograph of altered porphyritic dike at sample site 2 in the Wind Mountain and Chess Draw area, Cornudas Mountains, Otero County, N. Mex., Magnification X 250, plane polarized light, showing spherulitic rare-earth element-calcium-carbonate (R), calcite (C), purple fluorite (F), quartz (Q), and opaque hematite-limonite filling central part of a vug.

The drill core from hole C-2 at 25 ft (7.6 m) contained abundant pyrite in a gray trachyte porphyry dike. A polished thin section of the trachyte contains abundant disseminated pyrite and is cut by a few pyrite-quartz veinlets. The plagioclase (andesine) phenocrysts are altered to patches of kaolinite and calcite.

Samples contained only low concentrations of niobium and REE's and no resources were identified. Samples 2, 11, and 12 contained minor concentrations of REE's, ranging from 2,562 to 3,790 ppm rare-earth-oxides (REO). Minor niobium concentrations were present in samples 2, 6, and 12, ranging from 1,924 to 3,336 ppm Nb_2O_5. The highest thorium and uranium concentrations were 391 ppm and 136 ppm, respectively. Fluorine and zirconium concentrations were as high as 2,031 ppm and 4,002 ppm, respectively. Elevated concentrations of gold (as much as 18 ppb), copper (as much as 87 ppm), lead (as much as 494 ppm), zinc (as much as 464 ppm), molybdenum (as much as 125 ppm), and arsenic (as much as 63 ppm) were present.

Scintillometer readings ranged from 125 to 900 cps in the pits and shaft. Background counts in the trachyte dike and syenite bodies and the intrusive breccia averaged about 45 cps while the phonolite averaged about 130 cps.

Eudialyte Bearing-Malignite Dike

A eudialyte-bearing malignite dike (sample sites 18, 19, 20, and 22, fig. 5) that has intruded metamorphosed gray limestone and siltstone, can be traced into the main body of the nepheline syenite laccolith on the west side of Wind Mountain. The dike has been prospected by a 22 (6.7 m)-ft-long adit and three pits. The malignite (term for nepheline syenite containing more than 50% mafic minerals) dike is approximately 300 ft (90 m) long,

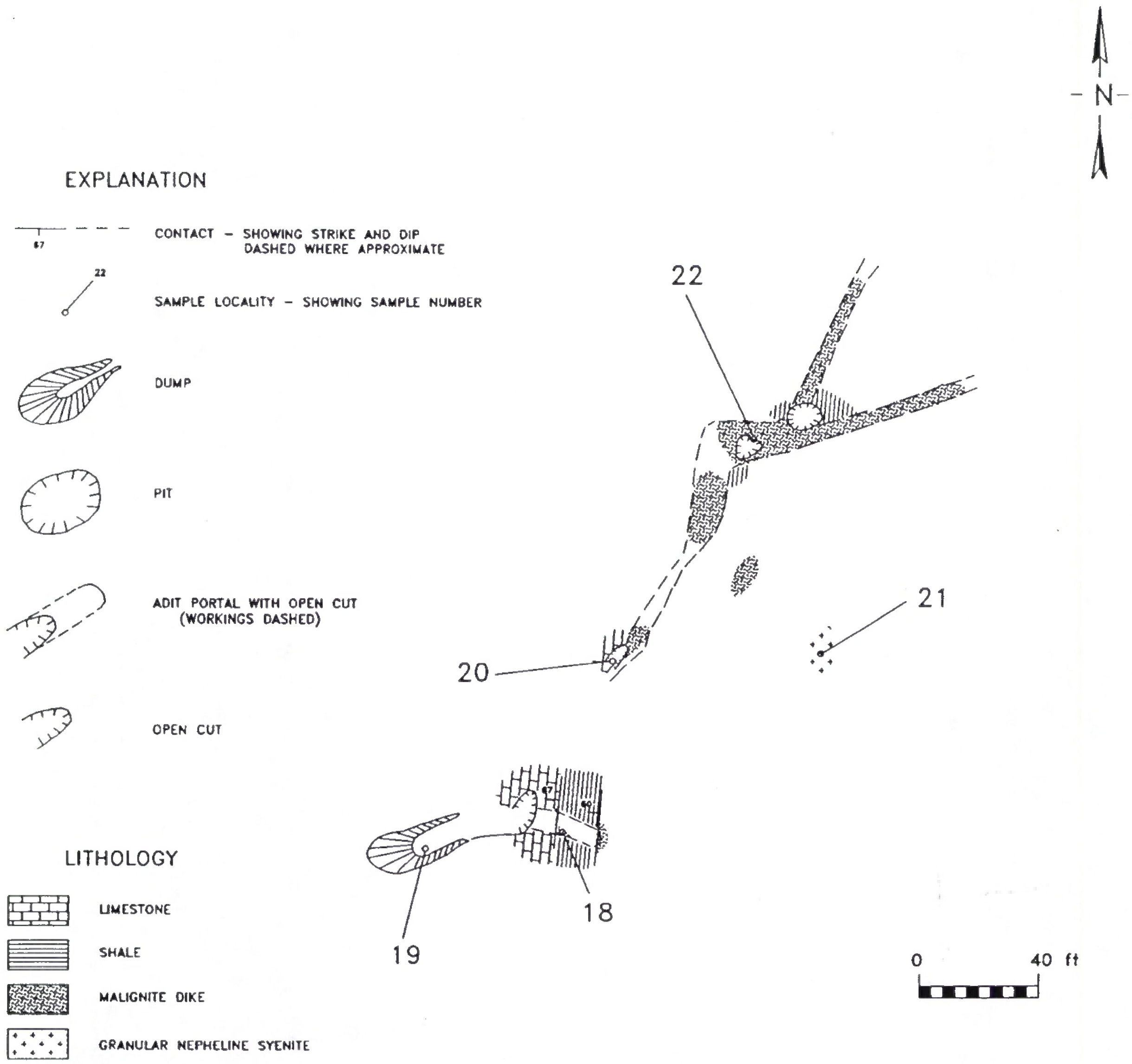

Figure 5. Map of eudialyte bearing malignite dyke in the Wind Mountain and Chess Draw area, Cornudas Mountains, Otero County, N. Mex.

averaging 8 ft (2.4 m) in width, and ranging up to 18 ft (5.5 m) wide. The dark-green fine to medium-grained malignite dike consists primarily of prismatic aegirine crystals and nepheline with albite, perthite, potassium feldspar, riebeckite, eudialyte, analcite, and sodalite. Accessory apatite, pyrite, sphalerite, and galena were noted. Feldspar-rich pegmatitic lenses as much as 6 in. (15.24 cm) wide and several feet in length occur within the dike. Pink to red to reddish brown eudialyte crystals occur in the malignite dike, especially on the edges of the pegmatitic areas. The subhedral to euhedral eudialyte crystals range from 0.2 to 5 mm in diameter and occur as single crystals (fig. 6) or as small aggregates. The eudialyte is the principal REE-bearing mineral. A typical analysis of the eudialyte contained 47.07% SiO_2, 13.39% ZrO_2, 0.18% TiO_2, 0.01% Al_2O_3, 1.22% La_2O_3, 2.05% Ce_2O_3, 0.30% Pr_2O_3, 0.37% Nd_2O_3, 0.05% Sm_2O_3, 0.74% Eu_2O_3, 0.46% Gd_2O_3, 3.69% CaO, 2.71% FeO, 5.12% MnO, 0.21% MgO, 13.22% Na_2O, 0.40% K_2O, 0.59% F, and 2.71% Cl (Boggs, 1987).

Samples contained only low concentrations of REE's and no resources were identified. Four samples (18-20 and 22) of the pegmatitic areas of the dike contained minor concentrations of REE's, ranging from 917 to 2,008 ppm REO. The samples are enriched in light rare-earth-elements. Zirconium concentrations ranged from 3,854 to 9,919 ppm. Thorium is dominant over uranium in all samples. Thorium and uranium concentrations were as high as 212 ppm and 92 ppm, respectively. The malignite dike is also enriched in precious and base metals, molybdenum, fluorine, manganese, and niobium in comparison to the other rocks in the area.

The dike is interpreted to have formed as a late stage pegmatitic differentiate from the nepheline syenite laccolith that is enriched in zirconium, rare-earth elements, as well as the other elements mentioned above. The dike was intruded into the surrounding country rock

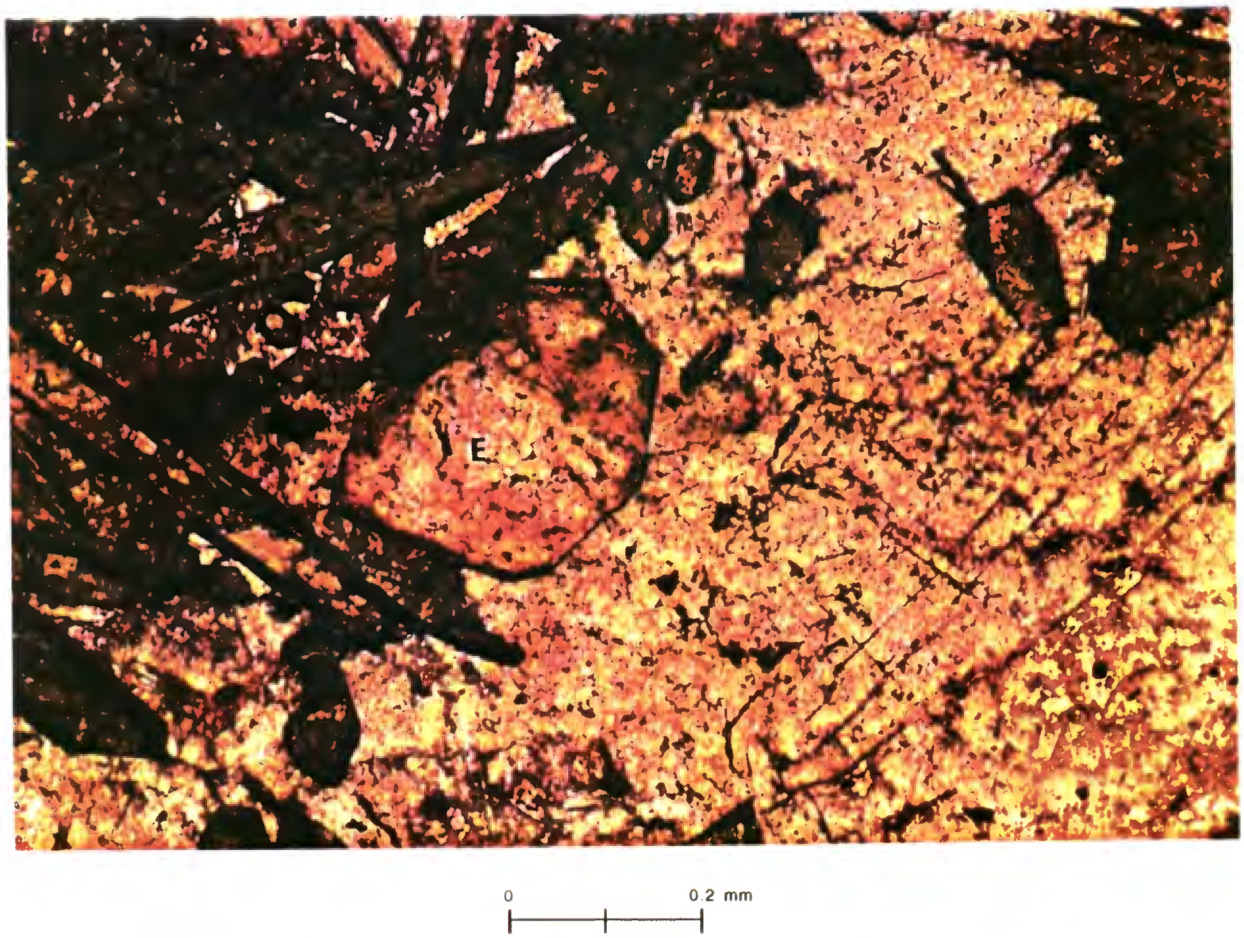

Figure 6. Photomicrograph of malignite dike at sample site 18 in the Wind Mountain and Chess Draw area, Cornudas Mountains, Otero County, N. Mex., Magnification X 125, plane polarized light, showing euhedral eudialyte (E) crystal with prismatic green aegirine (A) crystals, and clear nepheline and analcite.

possibly along a fracture formed during doming of the overlying sedimentary rocks (Boggs, 1987).

The dike is weakly radioactive. Scintillometer readings ranged from 155 to 600 cps.

Nepheline Syenite

Nepheline syenite is a silica deficient phaneritic igneous rock that contains greater than 5% nepheline, sodium and potassium feldspar, and has varying but small amounts of mafic silicates and other accessory minerals. Nepheline syenite contains no free quartz. Nepheline syenite is mined for used as a raw material for the glass and ceramic industries. Wind Mountain, approximately 1.25 mi (2 km) in diameter, rises about 2,000 ft (610 m) above the surrounding plain and is composed of nepheline syenite and syenite (McLemore and Guilinger, 1993, p. 148). The Bureau examined the southwestern flank of Wind Mountain within and around a proposed mine site.

Description

The Wind Mountain nepheline syenite is a gray porphyritic rock (fig. 7). In seven samples (sample sites 23-29), it consists of tabular alkali feldspar phenocrysts 1 to 2 cm in length in a fine-grained groundmass of streaky and mottled tabular perthite crystals, averaging 0.5 mm in length. Albite occurs as clear rims and as irregular streaks in potassium feldspar derived from exsolution of the alkali feldspar. Nepheline crystals range from 2 to 3 mm in diameter and make up approximately 5% to 15% of the samples. Occasionally graphic intergrowths of nepheline and clinopyroxene were present. Analcite commonly occurs interstitially to the feldspars and makes up as much as 10%. A few sodalite crystals were found in sample 28.

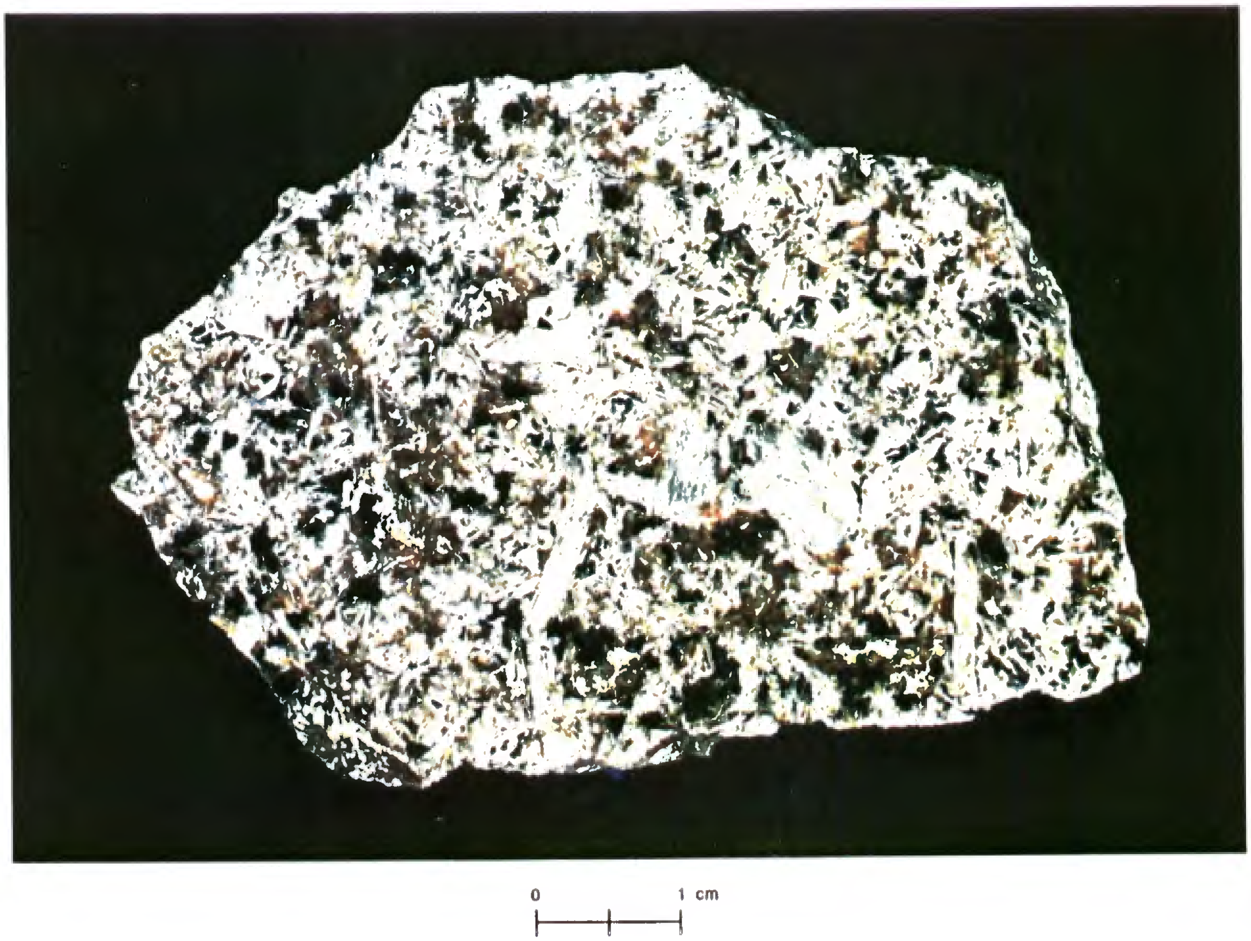

Figure 7. Photograph of Wind Mountain nepheline syenite specimen from sample site 28, showing white tabular feldspar crystals, brownish nepheline and analcite, and black mafic minerals.

Mafic minerals make up 10% to 20% of the rock and range from 0.1 to 3 mm in size. They tend to occur in clusters and are interstitial to the feldspars. Clinopyroxene is the most abundant and occurs most commonly as zoned crystals with pale-green aegirine-augite cores to dark-green aegirine rims. SEM-EDX analysis detected an increase in sodium and a decrease in calcium from the core to the rim of the crystals. At sample sites 26 and 27, fayalite crystals are rimmed with clinopyroxene, biotite, and sodic amphibole (the green and brown pleochroic colors suggests that it is an alkali amphibole of the eckermannite-arfvedsonite group). The fayalite is altered to iddingsite along cracks in the crystals. Prismatic apatite crystals, as long as 0.5 mm and subhedral to euhedral titanomagnetite crystals, ranging from 0.01 to 0.5 mm in diameter, commonly are present as inclusions in the mafic minerals. Accessory sphalerite, monazite, and zirconium silicates were also identified.

The weathered slides contain turbid feldspars that appear to be partially altered to clays. Nepheline crystals in some slides are turbid around the edges and partially altered to analcite. A few slides contained some secondary calcite and fibrous zeolites.

Only two nepheline syenites are currently mined, Stjernoy, Norway, and Blue Mountain, Ontario, Canada. Many mineral companies have had exploration programs to identify additional nepheline syenite bodies that are of similar quality and uniformity, and of sufficient size. Nepheline syenites are found in other places in the world but they are not sufficiently homogeneous, or do not have the necessary textural features, mineralogy, and chemistry to produce a satisfactory iron deficient product for most uses in the glass and ceramic industries.

The Precambrian Blue Mountain nepheline syenite is a uniform, foliated medium-grained rock. It is composed of albite (48% to 54%), nepheline (20% to 25%), and microcline (18% to 23%) and accessory minerals that seldom amount to more than 6%. The accessory minerals are biotite (0% to 4%), hastingsite (0% to 3%), muscovite, (0% to 3%), aegirine, garnet, corundum, zircon, calcite, apatite, cancrinite, and sphene. (See Payne, 1968, p. 261. and Hewitt, 1960.)

The Cambrian-Ordovician Stjernoy nepheline syenite is a fine- to coarse-grained rock that is divided into two types, a biotite- and a hornblende-pyroxene-bearing type. Both are composed of perthite feldspar (56%), nepheline (34%), and minor or accessory plagioclase, calcite, clinopyroxene, hornblende, biotite, sphene, magnetite, apatite, rutile, zircon, and corundum. The biotite type contains 2.5% to 6.0% biotite and the hornblende-pyroxene type contains 0.3% to 3.8% common hornblende, 1.3% to 3.8% aegirine with small amounts of biotite. (See Geis, 1979, p. 1287-1288.)

The Wind Mountain nepheline syenite contains almost three times the percentage of mafic minerals (15% compared with 5%) found in the Blue Mountain and Stjernoy nepheline syenites. It also contains less than half the nepheline (5% to 15% compared with 20% to 34%) found in Blue Mountain and Stjernoy deposits, although it contains approximately 10% analcite. Addwest Minerals reports that the nepheline content varies from 5% to 15% in the weathered zone. Petrographic studies of Addwest drill core from below the weathered zone show nepheline contents of about 20%.

Analytical Data

The Wind Mountain nepheline syenite contains an average of 18.22% Al_2O_3, 4.36% Fe_2O_3, 0.99% FeO, 7.63% Na_2O, and 5.17% K_2O. The whole rock analysis of seven samples (23-29, appendix B) from the southwestern flank of Wind Mountain are consistent, and the nepheline syenite is chemically homogeneous. The Wind Mountain nepheline syenite is higher in iron and lower in alumina than the nepheline syenites being mined at Blue Mountain, Ontario, Canada, and Stjernoy, Norway. The chemical content of nepheline syenites from Wind Mountain, New Mexico, Blue Mountain, Ontario, and Stjernoy, Norway is shown for comparison in the following table.

OXIDE	Wind Mountain (average of 7 analysis; samples 23-29 Appendix B)	Blue Mountain (average of 5 analysis, Hewitt, 1960, no. 10, p. 141)	Stjernoy (analysis no. 11, Heier, 1961, p. 142)
SiO_2	60.03	58.93	52.73
TiO_2	0.16	0.06	0.51
Al_2O_3	18.22	23.10	23.71
Fe_2O_3	4.36	2.09	1.89
FeO	0.99	na	1.04
MgO	0.27	0.10	0.24
MnO	0.27	na	0.06
CaO	1.24	0.83	2.54
Na_2O	7.63	10.33	7.78
K_2O	5.17	4.12	8.08
P_2O_5	0.09	0.02	0.05
LOI	1.92	na	na
H_2O	na	0.53	0.31
CO_2	na	na	0.77
Total	100.35	101.01	99.71

The slightly radioactive granular zone (sample sites 30, 31, 33, and 34) around the porphyritic nepheline syenite, in contact with the limestone, is enriched in rare-earth-elements, niobium, thorium, and uranium. The granular nepheline syenite zone contains at least twice the concentrations of rare-earth-elements (1,029 to 1,261 ppm REO), niobium (518 to 611 ppm), thorium (78.9 to 190 ppm), and uranium (19 to 49 ppm). The porphyritic analcite nepheline syenite (sample sites 23-29) contains only 465 to 769 ppm REO, 168 to 285 Nb, 26 to 44 ppm thorium, and 7 to 13 ppm uranium.

Processing Tests

Processing tests were conducted by the U.S. Bureau of Mines to determine potential methods to reduce the Fe_2O_3 content to less than 0.1%. Wet high-intensity magnetic separation (WHIMS), cross-belt magnetic separation, attritioning, flotation, and combinations of these techniques were tested. None of the tests lowered the Fe_2O_3 to less than the targeted 0.1%. The best results were achieved with a Dings cross-belt magnetic separator on the 20 x 100 mesh fraction from which 84% of the weight from the initial feed was recovered that contained 0.63% Fe_2O_3.

The lowest iron content in the Bureau's testing is relatively close to that achieved by Addwest Minerals in their testing and a slightly different sample or a modification of the process could easily account for the difference. Addwest Minerals reported that by using rare-earth permanent magnets they can produce a product with an iron content of 0.4% to 0.5% Fe_2O_3 (James Guilinger, Projects Manager, Addwest Minerals, 5460 Ward Rd. Suite 370, Arvada, Colo. 80002, oral commun., April, 1993).

The occurrence of the mafic minerals commonly in aggregates with numerous inclusions of titanomagnetite appears to be the major factor in the success of magnetic separation techniques in the removal of iron in the crushed nepheline syenite. Two size fractions (28 by 35 mesh and 35 by 48 mesh) of the processed material were examined for iron-bearing minerals by SEM (Denise Chirban, Geologist, U.S. Bureau of Mines, Salt Lake City

Research Center, Salt Lake City, Utah, written commun., August, 1992). The remaining iron in the processed material is from iron incorporated within the nepheline and analcite, iron in mafics (dominantly pyroxene) that were included in or attached to the felsic minerals. The remaining mafic minerals range from 5 to 400 microns in diameter and average between 50 to 100 microns in diameter. Occasionally iron oxide or manganese oxide were found as coatings or vug fillings. Rarely was magnetite found in the samples.

Uses

Nepheline syenite is used as a source of alumina (Al_2O_3), soda ash (Na_2O), and potash (K_2O). More than 70% of the nepheline syenite produced is used in glass manufacture: container glass, fiberglass, opal glass, sheet glass, and tableware glass. Approximately 10% to 15% is used in the manufacture of ceramics glazes, enamels, sanitaryware, dinnerware, floor and wall tile, electrical porcelain, art pottery, chemical porcelain, dental porcelain, porcelain balls, and mill liners. Nepheline syenite is also used as extender fillers and inert fillers in the manufacture of paints and plastics. Minor amounts are also used as extenders, fillers, and pigments. (See Minnes and others, 1983.)

In glass manufacture, the alumina enhances the workability of molten glass, and increases resistance to physical and thermal shock. The alkalis, soda and potash, act as a flux or vitrifying agent, forming glass at relatively low temperatures.

In ceramic manufacture, nepheline syenite is also used for its excellent fluxing properties. It serves as a vitrifying agent, contributing to the glassy phase which binds other constituents together and gives strength to the product.

The nepheline syenites currently used by the glass industry are characteristically a -30 mesh product having an alumina (Al_2O_3)content in excess of 23%, alkali content in excess of

14%, and iron content less than 0.1%. The ceramic industry uses a -200 mesh product and is high fluxing with a low level of iron and other impurities.

European markets usually require a 0.1% or less Fe_2O_3 content for the final product while North American markets require 0.08% Fe_2O_3 or less. Other metallic elements must also be at similar low levels and refractory minerals must be absent. (See Minnes and others, 1983, p. 932-933.)

The Wind Mountain nepheline syenite did not meet the specifications for the low iron (less than 0.1% Fe_2O_3) end uses; it meets the requirements for the higher iron end uses. The Wind Mountain nepheline syenite can be used as a raw material for amber glass, fiberglass, flatglass, and dark body ceramics. It could also be used for roofing granules and sandblasting material.

Nepheline syenite is used as a raw material in the manufacture of amber glass for beer bottles. Coors Glass Manufacturing Company uses nepheline syenite in combination with silica sand, recycled glass cullet, soda ash (sodium carbonate), lime (calcium carbonate), graphite (carbon), salt cake (sodium sulfate), and melite (iron aluminum silicate). The company uses approximately 33 st (30 t) per day (12,000 st (10,900 t) a year) of the nepheline syenite. One of the most important factors in the production of nepheline syenite is the consistency of the material, primarily in the alumina and iron content. The company currently purchases nepheline syenite with an alumina content of 23% Al_2O_3 and an iron content of 0.5% Fe_2O_3 maximum. It is used as a source of alumina which increases the durability of the glass (Dave Westbrook, Process Support Specialist and Randy Cook, Industry Manager, Coors Glass Manufacturing Company, 10619 W. 50 th Ave., Wheatridge, Colo., oral commun., April, 1993). The appropriate amount of iron is added in the form of melite to produce amber glass with 18% to 20% transmissivity at 550 nanometers, that blocks out 75% of the ultraviolet light. Ultraviolet light causes the beer to go bad.

Nepheline syenite is also used as a raw material in the manufacture of fiberglass. Owens-Corning Fiberglass Company incorporates nepheline syenite in its fiberglass to add alumina to increase its durability and strength (Steven Cowap, Engineer, Owens-Corning Fiberglass Corporation, Grandville, Ohio, oral commun., April, 1993). The high alkali content of the nepheline syenite also substitutes for some of the expensive soda ash required. Nepheline syenites with iron content less than 1% are acceptable.

Manville Corporation also uses nepheline syenite as a source of alumina at some of its plants producing fiberglass. Manville Corporation currently uses a nepheline syenite with a maximum Fe_2O_3 content of 0.11% and an alumina content of approximately 23.0% (Phillip Tucker, Research Engineer, Manville Corporation, Mountain Technical Center, Littleton, Colo., oral commun., June, 1993). The Wind Mountain nepheline syenite, although it is lower in alumina and higher in iron content, could be used at some of its plants. More of the nepheline syenite would be required due to the lower alumina content, and the higher iron content would change the characteristics of the fiberglass by raising the emissivity and consequently increasing the heat retention.

The Wind Mountain nepheline syenite has potential use for ceramic colored bodies in the wall and floor tile industries (Steven McEntire, Dal-Tile Corporation, 7834 Hawn Freeway, Dallas, Tex., oral commun., June, 1993) and in sanitaryware (e.g. toilets) (John Williams, Trinity Ceramics, Dallas, Tex., oral commun., June, 1993). The iron contents are too high for the higher value ceramic noncolored body products or glazes.

Addwest Minerals is also developing markets to use the "waste" or remaining nepheline syenite from the glass and ceramic products, for roofing granules and as sandblasting material (James Guilinger, project geologist, Addwest Minerals, Inc., oral commun., June, 1993). The use of the low value material would also leave little waste rock to handle.

The advantage of nepheline syenite for use in sandblasting material is that it contains no free silica. Increasing restrictions on silica dust to prevent any environmental and health risk, such as silicosis, require that alternative raw materials be considered other than the typical silica sands.

The Wind Mountain nepheline syenite has the required properties of the base rock used in ceramic-coated colored roofing granules. The base rock must block ultraviolet that causes degradation of the asphalt in the shingles, and have uniformity, low porosity, toughness and resistance to weathering, and adaptablity to the coloring process (Karen Codiano, Owens Corning Fiberglass, Summit Products Laboratory, Summit, Ill., oral commun., June, 1993).

Pulaskite, an alkaline rock very similar to nepheline syenite, is mined from Arkansas and used for construction aggregates and roofing granules. Pulaskite contains less than 5% nepheline and less than 10% mafic minerals. Attempts to produce ceramic or glass grade products from the pulaskite have not been successful because the impurities are too finely divided to be economically removed. The Fourche Mountain nepheline syenite in Pulaski County, Arkansas, can be processed down to approximately 1% Fe_2O_3, 21% Al_2O_3, 61% SiO_2, and 0.2 TiO_2. The 3M Company has four plants strategically located across the United States that use different base rock material, varying from a diabase to pulaskite, to produce roofing granules (Rick Ruzga, 3M Company, Industrial Minerals Division, Building 209-1W-14, St. Paul, Minn., 55144, oral commun., June, 1993).

ECONOMIC CONSIDERATIONS

The REO and niobium occurrences in the Chess Draw area are too low grade and too small to support a commercial mining operation. The REO concentrations, as much as 0.38%, are much lower in comparison to the bastnaesite-bearing ore mined by open-pit method at Mountain Pass, Calif., where resources total 31 million st (28 million t) averaging 8.6% REO with a cutoff grade of 5% (Unocal Corporation, 1988, p. 53). The niobium oxide concentrations, as much as 0.33% Nb_2O_5, is lower than deposits that have been mined in the past in North America (e.g., 25.4 million st (23 million t) averaging 0.44% Nb_2O_5 at Oka, Quebec, Canada, and 12.2 million st (11 million t) averaging 0.66% Nb_2O_5 at St. Honore, Quebec, Canada (Mariano, 1989, p. 151)). The Araxa and Catalao niobium deposits in Brazil comprise over 400 million st (360 million t) of 1.0% to 3.0% Nb_2O_5 (Mariano, 1989, p. 150).

The Wind Mountain nepheline syenite is suitable for use as a raw material in glass and ceramic products where low iron specifications are not required. A new nepheline syenite producer may have difficulty getting into existing markets. Glass and ceramic manufacturing companies that buy nepheline products require a consistent quality and supply of the raw material, and prefer an established producer. Alumina and iron contents cannot vary from shipment to shipment. The cost of the raw material must be significantly lower for a company to change its supplier whose product they have probably used for many years. Addwest Minerals would have an advantage over most U.S. markets in cheaper transportation costs. The closest nepheline syenite supplier is in Ontario, Canada, and a producer in the Texas-Mexico area could take advantage of a growing number of ceramic and glass plants that would use a nepheline syenite raw material (Conrad Rieger, Ceramic Engineer, R. T. Vanderbilt Company, 30 Winfield St., Norwalk, Conn. 06856, oral commun., June, 1993).

Glass grade nepheline syenite (-30 mesh, containing a minimum of 23% Al_2O_3 and 14% combined alkalis) as of 1992 sells for $28 per st for the low iron (maximum 0.1% Fe_2O_3) product and $22 per st for the high iron (maximum 0.35% Fe_2O_3) product. Ceramic grade nepheline syenite sells for $66 per st (bagged, -200 mesh, maximum 0.07% Fe_2O_3). The filler grade material is approximately $80 to $85 per st. (See Harben, 1992, p. 56.) Addwest Minerals reports that the prices for the Wind Mountain nepheline syenite products would range from $8 per st to $75 per st (James Guilinger, Projects Manager, Addwest Minerals, Inc., 5460 Ward Rd. Suite 370, Arvada, Colo. 80002, oral commun., June, 1994)..

CONCLUSIONS

No REE or niobium resources were identified in the Wind Mountain and Chess Draw area. The Bureau identified only minor concentrations of REE's and niobium in dikes and breccias. Processing tests on the Wind Mountain nepheline syenite determined that it was suitable raw material for high-iron product uses such as amberglass, fiberglass, flatglass, and dark body ceramics. A suitable raw material could not be economically produced from the Wind Mountain nepheline syenite that would meet the low-iron specifications for many uses required in the glass and ceramics industries. The nepheline syenite may also have a significant use for roofing granules and as sandblasting material.

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Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and and Chess Draw area in the Cornudas Mountains, Otero County, N. Mex.

[INA, instrumental neutron activation analysis performed three times; ICP, inductively coupled plasma-emission spectroscopy; AA, atomic absorption spectroscopy; FA-AA, fire assay with an atomic absorption spectroscopy finish; XRF, x-ray fluorescence; SI, specific ion method; CVAA, cold vapor atomic absorption spectroscopy; <, less than; na, not analyzed; ppm, parts per million; ppb, parts per billion]

Sample Number	La PPM (INA)	Ce PPM (INA)	Nd PPM (INA)	Sm PPM (INA)	Eu PPM (INA)	Light Group REO	Tb PPM (INA)	Tm PPM (INA)	Yb PPM (INA)	Lu PPM (INA)	Y PPM (XRF)	Heavy Group REO	Total REO	LREO/ HREO	% LREO	Th PPM (INA)	U PPM (INA)	Th/U Ratio
1	201	340	100	16.7	1.0	773	2	<2	9	1.2	97	137	910	6	84.9	51.6	15	3.4
2	620	959	260	41.6	2.4	2203	6	3	29	3.0	246	359	2562	6	86.0	335.0	136	2.5
3	206	280	58	6.5	0.6	647	<1	<2	7	1.0	54	78	725	8	89.3	40.0	10	4.0
4	75	140	55	10.0	1.9	330	1	<2	4	0.6	40	57	387	6	85.2	15.0	4	3.8
5	87	150	50	7.8	1.8	347	<1	<2	3	0.4	31	43	390	8	88.9	21.0	7	3.0
6	77	130	52	12.4	1.4	321	7	<10	34	3.5	371	522	843	1	38.1	351.0	82	4.3
7	79	140	60	10.0	2.7	341	1	<2	3	0.4	28	41	381	8	89.4	15.0	4	3.8
8	83	140	56	8.9	2.3	338	1	<2	3	0.4	32	46	384	7	88.1	18.0	5	3.6
9	195	250	58	6.5	0.8	598	<1	<2	5	0.7	51	71	670	8	89.4	60.7	16	3.8
10	218	380	130	20.0	1.4	879	3	2	11	1.5	127	181	1061	5	82.9	68.2	21	3.2
11	729	1220	360	55.1	3.2	2771	6	3	22	2.6	25	70	2842	40	97.5	186.0	12	15.5

Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and and Chess Draw area in the Cornudas Mountains, Otero County, N. Mex.--Continued

Sample Number	La PPM (INA)	Ce PPM (INA)	Nd PPM (INA)	Sm PPM (INA)	Eu PPM (INA)	Light Group REO	Tb PPM (INA)	Tm PPM (INA)	Yb PPM (INA)	Lu PPM (INA)	Y PPM (XRF)	Heavy Group REO	Total REO	LREO/ HREO	% LREO	Th PPM (INA)	U PPM (INA)	Th/U Ratio
12	942	1510	380	52.3	3.2	3379	7	5	22	3.1	290	411	3790	8	89.2	391.0	102	3.8
13	56	100	45	8.6	1.4	247	1	<2	4	0.5	43	61	308	4	80.2	13.0	3	4.3
14	141	240	84	13.2	1.8	562	2	<2	6	0.7	65	92	654	6	85.9	31.0	9	3.4
15	231	380	130	20.1	1.7	894	3	<2	10	1.3	108	153	1047	6	85.3	50.0	15	3.3
16	72	130	49	9.0	2.3	306	1	<2	4	0.5	38	55	361	6	84.9	17.0	5	3.4
17	74	130	57	8.7	1.5	318	1	<2	4	0.6	41	58	376	5	84.5	19.0	6	3.2
18	220	350	110	15.4	1.7	817	2	<2	8	1.1	69	100	917	8	89.1	102.0	32	3.2
19	478	754	210	31.4	2.2	1727	4	4	21	2.6	175	258	1985	7	87.0	76.8	35	2.2
20	308	470	120	19.3	1.5	1075	3	<2	15	1.9	106	157	1232	7	87.2	212.0	92	2.3
21	101	170	55	8.1	0.8	394	<1	<2	5	0.8	35	51	445	8	88.5	19.0	6	3.2
22	447	766	230	34.2	2.4	1731	4	3	22	2.6	190	277	2008	6	86.2	43.0	24	1.8
23	147	240	73	10.6	1.2	552	1	<2	7	1.0	60	86	639	6	86.5	39.0	11	3.5
24	132	210	68	10.0	1.1	493	1	<2	6	0.8	53	76	569	6	86.6	34.0	11	3.1
25	160	250	82	10.9	1.2	590	2	<2	7	1.0	66	95	685	6	86.1	48.0	13	3.7

Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and and Chess Draw area in the Cornudas Mountains, Otero County, N. Mex.--Continued

Sample Number	La PPM (INA)	Ce PPM (INA)	Nd PPM (INA)	Sm PPM (INA)	Eu PPM (INA)	Light Group REO	Tb PPM (INA)	Tm PPM (INA)	Yb PPM (INA)	Lu PPM (INA)	Y PPM (XRF)	Heavy Group REO	Total REO	LREO/ HREO	% LREO	Th PPM (INA)	U PPM (INA)	Th/U Ratio
26	178	290	82	13.4	1.1	661	2	<2	10	1.3	73	108	769	6	86.0	40.0	13	3.1
27	126	210	68	10.0	1.1	486	1	<2	6	0.9	46	67	553	7	87.8	31.0	10	3.1
28	106	180	41	8.2	1.1	394	1	<10	5	0.7	50	71	465	6	84.7	26.0	7	3.7
29	162	250	71	10.8	1.1	580	1	<2	7	1.0	63	90	670	6	86.5	44.0	11	4.0
30	249	400	120	17.1	1.6	922	2	<2	9	1.3	73	107	1029	9	89.6	111.0	27	4.1
31	271	440	120	18.5	1.5	997	2	<2	12	1.6	96	140	1137	7	87.7	127.0	49	2.6
32	100	140	70	12.7	2.4	379	2	<2	5	0.6	65	91	470	4	80.6	49.0	7	7.0
33	266	420	110	17.9	1.1	955	2	<2	15	2.0	111	163	1117	6	85.4	90.0	22	4.1
34	296	470	130	21.0	1.5	1073	3	<2	17	2.2	128	188	1261	6	85.1	78.9	19	4.2
35	3	6	<10	0.6	<0.5	11	<1	<2	<1	<0.2	<1	0	11	11	100.0	0.9	4	0.2

Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and Chess Draw area in the Cornudas Mountains, Otero County, N.Mex.--Continued

Report Number	Au PPB (FA-AA)	Ag PPM (ICP)	Cu PPM (ICP)	Pb PPM (ICP)	Zn PPM (ICP)	Mo PPM (ICP)	Ni PPM (ICP)	Co PPM (ICP)	Bi PPM (ICP)	As PPM (ICP)	Sb PPM (ICP)	Hg PPM (CVAA)	Ti PPM (ICP)
1	<5	<0.2	16	34	184	4	1	<1	<5	21	<5	1.000	na
2	<5	<0.2	5	494	464	31	6	2	<5	<5	<5	0.011	914
3	8	<0.2	4	20	67	5	2	<1	<5	<5	<5	0.016	1832
4	12	<0.2	9	6	43	4	12	6	<5	8	<5	0.022	4279
5	<5	<0.2	<1	12	29	3	1	<1	<5	<5	<5	<0.010	na
6	<5	<0.2	87	279	6	125	2	<1	<5	63	<5	0.196	1224
7	na	na	na	na	na	na	na	na	na	na	na	na	na
8	18	<0.2	6	6	54	5	5	5	<5	<5	<5	<0.010	na
9	<5	<0.2	7	40	130	12	4	2	<5	27	<5	0.053	na
10	na	na	na	na	na	na	na	na	na	na	na	na	na
11	<5	<0.2	4	49	119	26	10	2	<5	11	<5	0.013	2457
12	<5	<0.2	4	254	108	5	17	2	<5	<5	<5	0.056	1066
13	6	<0.2	7	11	57	4	10	6	<5	<5	<5	0.017	3320
14	na	na	na	na	na	na	na	na	na	na	na	na	na
15	<5	<0.2	5	43	225	13	<1	<1	<5	19	<5	<0.010	957
16	na	na	na	na	na	na	na	na	na	na	na	na	na
17	na	na	na	na	na	na	na	na	na	na	na	na	na
18	20	<0.2	22	62	206	48	10	3	<5	8	<5	<0.010	na
19	17	5.2	30	118	278	41	1	<1	<5	5	<5	0.018	na
20	20	1.7	23	185	732	25	<1	1	<5	14	5	<0.010	na
21	<5	<0.2	6	196	26	3	<1	<1	<5	15	<5	<0.010	na
22	<5	5.0	42	86	114	38	<1	1	<5	38	<5	<0.010	na
23	na	na	na	na	na	na	na	na	na	na	na	na	na
24	na	na	na	na	na	na	na	na	na	na	na	na	na
25	na	na	na	na	na	na	na	na	na	na	na	na	na
26	na	na	na	na	na	na	na	na	na	na	na	na	na
27	na	na	na	na	na	na	na	na	na	na	na	na	na
28	<5	<0.2	5	21	105	5	<1	<1	<5	<5	<5	<0.010	na
29	na	na	na	na	na	na	na	na	na	na	na	na	na
30	<5	<0.2	4	49	347	7	2	1	<5	10	<5	<0.010	na
31	na	na	na	na	na	na	na	na	na	na	na	na	na
32	<5	<0.2	5	14	156	108	2	1	<5	11	5	<0.010	na
33	na	na	na	na	na	na	na	na	na	na	na	na	na
34	<5	0.5	8	65	192	4	<1	<1	<5	7	<5	<0.010	na
35	<5	0.3	2	5	<1	<1	3	1	<5	6	<5	<0.010	na

Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and Chess Draw area in the Cornudas Mountains, Otero County, N.Mex.--Continued

Report Number	Fe PCT (ICP)	Mn PPM (ICP)	Ba PPM (XRF)	Cr PPM (ICP)	W PPM (ICP)	Nb PPM (XRF)	Rb PPM (XRF)	Sc PPM (INA)	Sr PPM (XRF)	Zr PPM (XRF)	Be PPM (AA)	Ta PPM (XRF)	F PPM (SI)
1	0.49	1080	90	8	<20	392	na	0.2	na	3156	18.9	na	182
2	3.20	1611	250	11	<20	1345	na	0.2	na	2763	26.1	96	2031
3	1.89	539	110	12	<20	436	na	0.5	na	1862	11.4	na	243
4	2.49	673	850	21	<20	167	na	6.5	na	733	6.0	na	627
5	1.65	34	820	4	<20	161	na	1.3	na	1000	5.7	na	579
6	3.24	38	80	7	<20	2332	na	1.4	na	4002	4.9	158	991
7	na	na	1100	na	na	111	112	4.6	878	642	5.4	na	729
8	2.86	856	1200	15	<20	131	na	2.7	na	891	6.4	na	547
9	2.32	1017	220	7	<20	403	na	0.6	na	1441	8.6	na	343
10	na	na	240	na	na	545	288	0.9	104	3674	23.9	na	905
11	2.49	692	630	3	<20	777	na	1.2	na	2580	7.9	56	1495
12	1.20	16	320	13	<20	2270	na	3.5	na	3458	9.3	118	859
13	3.12	670	360	12	<20	64	na	5.5	na	442	5.2	na	527
14	na	na	480	na	na	287	199	1.0	241	1193	10.9	na	724
15	0.57	1199	200	7	<20	443	na	0.5	na	1834	22.8	na	1727
16	na	na	710	na	na	134	91	2.5	306	1142	8.8	na	740
17	na	na	600	na	na	141	126	1.6	279	1534	10.5	na	482
18	1.03	543	140	26	<20	364	na	4.5	na	3854	34.6	na	3137
19	0.50	2068	130	14	<20	583	na	0.5	na	9522	33.9	na	1944
20	0.27	2882	100	14	<20	798	na	0.2	na	9919	92.0	na	464
21	0.68	347	80	9	<20	155	na	1.6	781	1641	13.1	na	674
22	0.41	1605	120	14	<20	306	na	0.2	na	9914	27.7	na	250
23	na	na	190	na	na	246	181	1.2	90	1878	17.2	na	226
24	na	na	260	na	na	243	179	1.4	86	1870	15.1	na	310
25	na	na	270	na	na	285	176	0.9	121	2267	19.3	na	274
26	na	na	150	na	na	263	185	1.4	41	2528	15.1	na	251
27	na	na	160	na	na	203	181	1.5	64	1572	12.2	na	258
28	1.41	889	80	13	<20	168	193	1.1	33	1226	16.0	na	379
29	na	na	320	na	na	266	209	0.7	127	2073	19.5	na	414
30	0.67	1627	150	12	<20	518	na	5.6	na	2425	19.4	na	1448
31	na	na	120	na	na	569	255	0.5	58	5456	52.0	na	278
32	0.68	642	80	20	<20	164	na	6.4	na	554	21.5	na	2537
33	na	na	90	na	na	611	248	0.4	175	5472	35.5	na	365
34	0.29	1903	100	6	<20	547	na	0.4	na	6451	36.2	na	310
35	0.12	34	50	5	<20	6	na	0.8	na	17	1.1	na	409

Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and Chess Draw area in the Cornudas Mountains, Otero County N. Mex.--continued

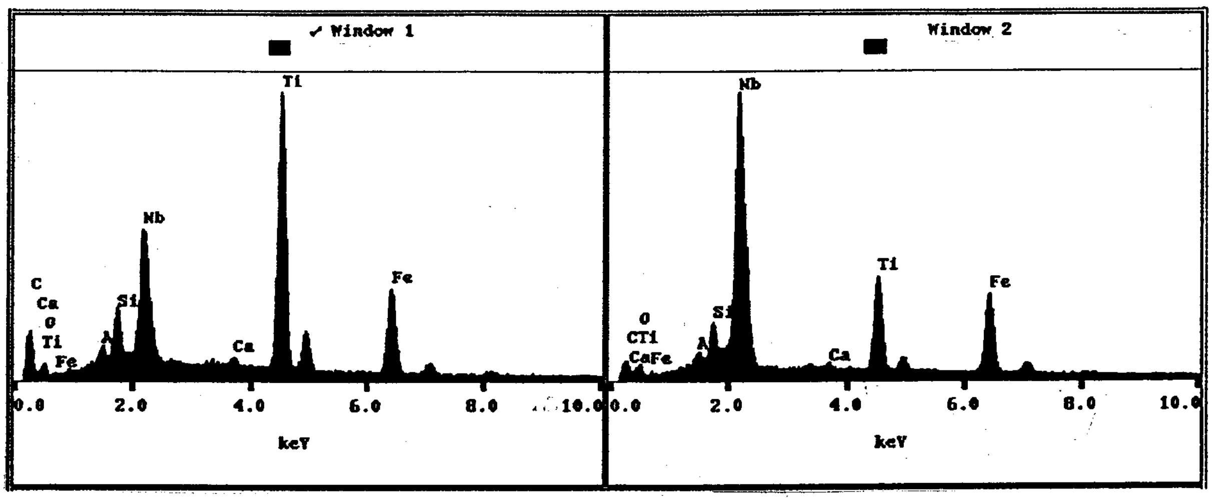
Sample No.	Length type	Description
1	2.0 ft (0.6 m) chip	Dark gray-green phonolite dike intruding limestone, strikes N. 55° E. and dips approximately vertical, 5-10 ft (1.5-3 m) wide; 150 cps.
2	3.0 ft (0.9 m) chip	Altered porphyritic dike intruding limestone, scattered feldspar phenocrysts in an aphanitic groundmass, solution banded, yellow to dark brown bands containing hematite-limonite, strikes N. 33° E. and dips approximately vertical, 5-8 ft (1.5-2.4 m) wide, Groundmass replaced by anhedral quartz averaging 0.02 mm in diameter. Vugs contain spherulitic REE-calcium-carbonate, fluorite, zircon, quartz, niobian rutile, calcite, and hematite-limonite; 300 to 500 cps.
3	2.0 ft (0.6 m) chip	Altered phonolite dike, porphyritic, bleached light tan, scattered feldspar phenocrysts in an aphanitic groundmass, strikes N. 75° E. and dips approximately vertical; 125 cps.
4	2.0 ft (0.6 m) chip	Dark gray aphanitic "augite syenite" chill zone containing numerous rock and crystal fragments; few scattered biotite phenocysts, some trachyte porphyry and sedimentary clasts, vugs filled with calcite, fluorite, pyrite, and quartz; 50-60 cps.
5	4.0 ft (1.2 m) chip	Altered trachyte porphyry dike intruding sandstone, scattered feldspar phenocrysts in an aphanitic groundmass, solution banded, yellow to chocolate brown bands containing hematite-limonite, relatively unaltered parts of dike consist of dark to medium-gray aphanitic groundmass with scattered white feldspar phenocrysts, strikes N. 50° E. and dips approximately vertical, approximately 40 ft (12 m) wide, calcite; 50-60 cps.
6	Grab	Shaft, 15-ft(5 m)-deep; altered trachyte porphyry dike intruding sandstone, scattered feldspar phenocrysts in an aphanitic groundmass, solution banded, yellow to reddish brown to purple bands containing hematite-limonite; 450 cps.
7	1.0 ft (0.3 m) chip	Gray medium-grained nepheline bearing augite syenite plug; 50 cps.
8	1.0 ft (0.3 m) chip	Dark gray aphanitic "augite syenite" porphyry chill zone; scattered feldspar and biotite phenocrysts in a dark-gray aphanitic groundmass; 50 cps.
9	3.0 ft (0.9 m) chip	Pit, 5 ft (1.5 m) by 5 ft (1.5 m); altered trachyte porphyry dike intruding sandstone, scattered feldspar phenocrysts in an aphanitic matrix, solution banded, yellow to tan to brown bands containing hematite-limonite, few relatively unaltered parts of dike consist of dark to medium gray aphanitic matrix with scattered white feldspar phenocrysts, contains scattered clasts of sandstone and syenitic rocks as much as 15 in. (38 cm) in diameter; 75-100 cps.
10	1.0 ft (0.3 m) chip	Dark-green phonolite plug with numerous rock clasts and crystal fragments, aphanitic groundmass with anorthoclase crystal fragments, nepheline syenite rock fragments, some calcite filling vugs; 200 cps.
11	3.0 ft (0.9 m) chip	Altered trachytic dike intruding limestone, aphanitic groundmass with scattered feldspar phenocrysts and rock clasts, solution banded, yellow to reddish brown bands containing hematite-limonite; 800 cps.
12	3.0 ft (0.9 m) chip	Pit, 15 ft (5 m) by 10 ft (3 m), altered intrusive breccia, bleached and stained by hematite-limonite, numerous subangular to subrounded igneous and sedimentary rock clasts as much as 6 in. (15 cm) in diameter and crystal fragments in a aphanitic matrix, many altered to kaolinite and replaced by quartz and calcite; 900 cps.
13	3.0 ft (0.9 m) chip	Altered intrusive breccia, solution banded, tan to brown bands containing hematite-limonite, numerous subangular to subrounded igneous and sedimentary rock clasts as much as 6 in. (15 cm) in diameter and crystal fragments in a aphanitic matrix, sedimentary clasts appear to be limestone and shale, igneous clasts appear to be syenite and trachyte, many altered to kaolinite and replaced by quartz and calcite; 40 cps.
14	1.0 ft (0.3 m) chip	Gray syenite porphyry, scattered amphibole and feldspar phenocrysts; 100 cps.
15	Grab	Dark-green phonolite dike, aphanitic groundmass with tabular feldspar phenocrysts as much as 25 mm in length and red altered nepheline crystals.
16	1.0 ft (0.3 m) chip	Light gray nepheline syenite, granular; 70 cps.
17	1.0 ft (0.3 m) chip	Light gray nepheline syenite, granular; 75 cps.
18	1.5 ft (0.45 m) chip	Two parallel 2 in. (5 cm) wide pegmatitic aegirine-nepheline dikes in hornfels; 175 cps.
19	Grab	Fragments of dark green malignite dike with pegmatitic material from dump, aegirine, nepheline, eudialyte.

Appendix A.--Analytical results and sample descriptions for samples from the Wind Mountain and Chess Draw area in the Cornudas Mountains, Otero County N. Mex.--continued

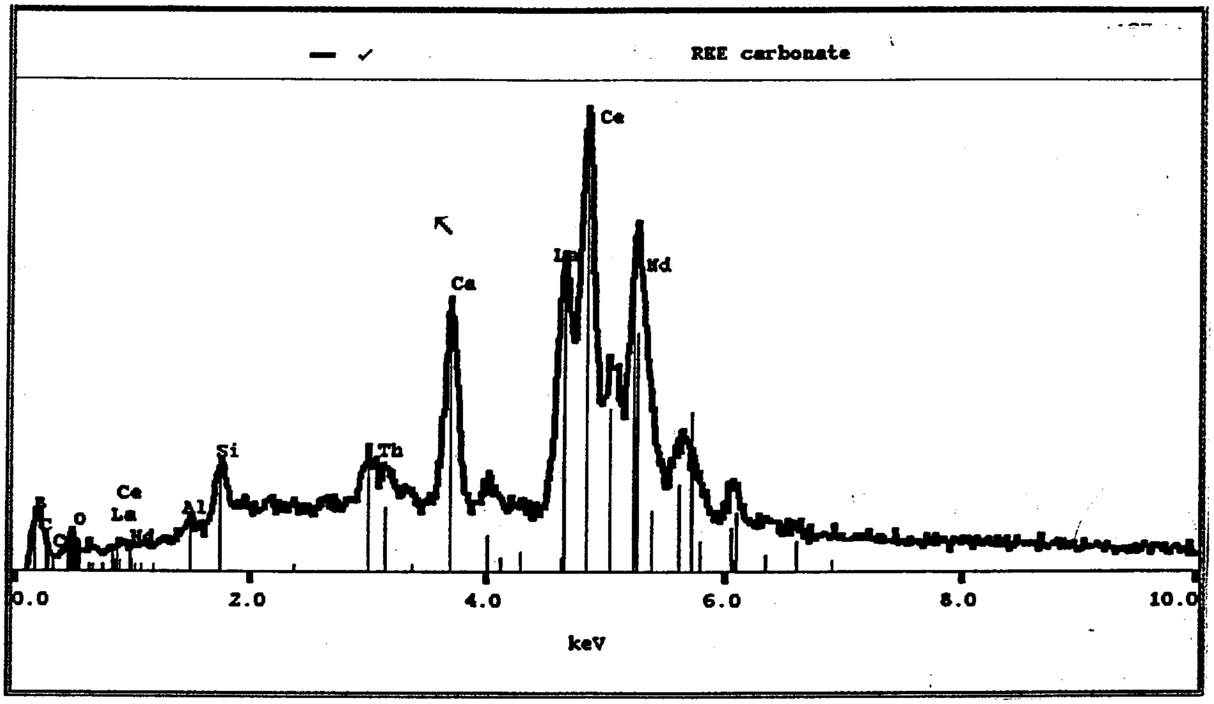
Sample No.	Length type	Description
20	0.5 ft (0.15 m) chip	Pegmatitic lense in dark green malignite dike, aegirine, nepheline, eudialyte; 300 cps.
21	1.0 ft (0.3 m) chip	Light gray nepheline syenite, granular; 70 cps.
22	3.0 ft (0.9 m) chip	Pegmatitic lense in dark green malignite dike, aegirine, nepheline, eudialyte; 300 cps.
23	0.5 ft (0.15 m) chip	Light gray nepheline syenite, porphyritic.
24	1.0 ft (0.3 m) chip	Light gray nepheline syenite, porphyritic; 125 cps.
25	1.0 ft (0.3 m) chip	Light gray nepheline syenite, porphyritic.
26	2.0 ft (0.6 m) chip	Light gray nepheline syenite, porphyritic.
27	1.0 ft (0.3 m) chip	Light gray nepheline syenite, porphyritic.
28	Grab	Pit; Light gray nepheline syenite, porphyritic, from Addwest Minerals, Inc. test pit.
29	2.0 ft (0.6 m) chip	Light analcite nepheline syenite, porphyritic.
30	3.0 ft (0.9 m) chip	Light gray nepheline syenite, granular, sample taken 10 ft (3 m) from contact with marble; 200 cps.
31	1.0 ft (0.3 m) chip	Gray nepheline syenite-marble contact; 225 cps.
32	1.0 ft (0.3 m) chip	Pale green hornfels, sample taken 10 ft (3 m) from contact with nepheline syenite, metamorphosed coarse siltstone to very fine sandstone, primarily quartz grains, cut by quartz veins; 125 cps.
33	5.0 ft (1.5 m) chip	Gray nepheline syenite, fine-grained granular; 175 cps, sample taken 5 ft (1.5 m) to 10 ft (3 m) from the contact with limestone.
34	5.0 ft (1.5 m) chip	Gray nepheline syenite, fine-grained granular, sample taken a contact with limestone; 225 cps.
35	3.0 ft (0.9 m) chip	Light gray to white limestone, sample at contact with nepheline syenite; 100 cps.

Appendix B.--Whole rock analysis of selected samples from the Wind Mountain and Chess Draw area in the Cornudas Mountains, Otero County, N. Mex.
[BES, borate fusion plasma-emission spectroscopy; GRAV; gravimetric method; PCT, percent]

Sample Number	SiO_2 PCT (BES)	TiO_2 PCT (BES)	Al_2O_3 PCT (BES)	Fe_2O_3 PCT (BES)	FeO PCT (BES)	MnO PCT (BES)	MgO PCT (BES)	Na_2O PCT (BES)	K_2O PCT (BES)	CaO PCT (BES	P_2O_5 PCT (BES)	LOI PCT (GRAV)	**Total PCT**
7	56.18	1.66	18.06	3.96	2.35	0.17	2.05	5.85	4.66	4.04	0.66	0.29	97.58
10	59.70	0.30	18.37	3.79	1.13	0.40	0.37	8.95	4.94	1.54	0.07	1.12	99.55
14	60.67	0.43	18.42	3.19	1.10	0.26	0.50	6.92	5.21	1.70	0.12	2.50	99.92
16	58.31	0.55	19.82	3.44	1.16	0.13	0.52	6.85	5.41	1.91	0.15	1.86	98.95
17	58.52	0.43	20.04	3.63	0.84	0.13	0.39	6.74	5.67	1.12	0.08	3.20	99.95
21	57.03	0.13	19.31	3.67	1.96	0.25	0.25	6.76	4.91	3.34	0.06	2.07	97.78
23	59.94	0.16	18.04	4.84	0.64	0.29	0.26	7.36	5.19	1.28	0.09	2.38	99.83
24	59.99	0.21	17.99	4.83	1.09	0.30	0.33	7.56	5.07	1.24	0.11	1.65	99.28
25	60.34	0.16	18.24	4.45	0.71	0.28	0.29	7.72	5.24	1.44	0.09	2.04	100.29
26	60.21	0.15	18.04	4.14	1.54	0.30	0.24	8.43	5.36	1.15	0.05	1.02	99.09
27	59.88	0.16	18.65	4.30	0.90	0.25	0.26	7.68	5.39	1.30	0.05	1.68	99.60
28	59.14	0.15	17.96	3.69	1.51	0.24	0.24	6.97	4.73	1.37	0.13	2.70	97.31
29	60.73	0.16	18.66	4.28	0.55	0.25	0.27	7.69	5.20	0.91	0.09	2.00	100.24
31	58.03	0.16	17.63	6.56	0.77	0.45	0.21	9.37	4.85	0.93	-0.01	1.88	100.07
33	57.00	0.08	18.43	6.30	0.26	0.38	0.31	8.72	4.26	1.22	0.02	3.16	99.88



Appendix C.--Semiquatitative scanning electron microscope-energy dispersive spectrums for niobium mineral from sample site 2. Window 1 is the spectrum detected from a point in the center of the crystal and window 2, on the right-side of the page, is the spectrum from a point on the rim of the crystal.



Appendix D.--Semiquantitative scanning electron microscope-energy dispersive spectrum for spherulitic rare-earth carbonate mineral from sample site 2.