

U.S. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY





63°34′59″E

30°31′1″N

30°30'0"1

Figure 1.—Parallel northeast-striking carbonatite dikes intruding alvikitic agglomerate (unit Q_{1-2c}) along southwestern part of the volcanic sequence. (Traverse no. 1A)

Figure 2.—Alvikitic agglomerate unit Q_{1-2c} cropping out along the southwestern part of the volcanic sequence. (Traverse no. 1A)

Figure 3.—Magnetite-bearing aphanitic alvikitic agglomerate (unit Q_{1-3c}) that overlies unit Q_{1-2c} along the southwestern part of the volcanic sequence. (Traverse no. 1A)

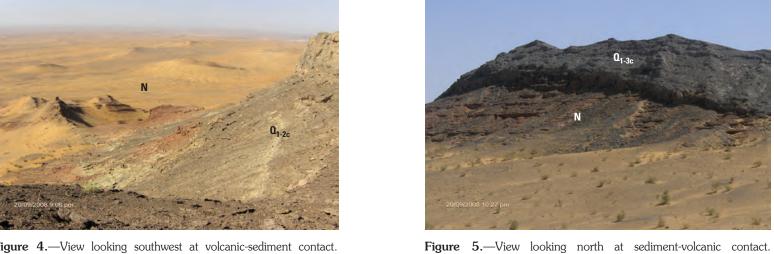
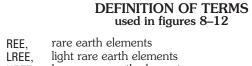


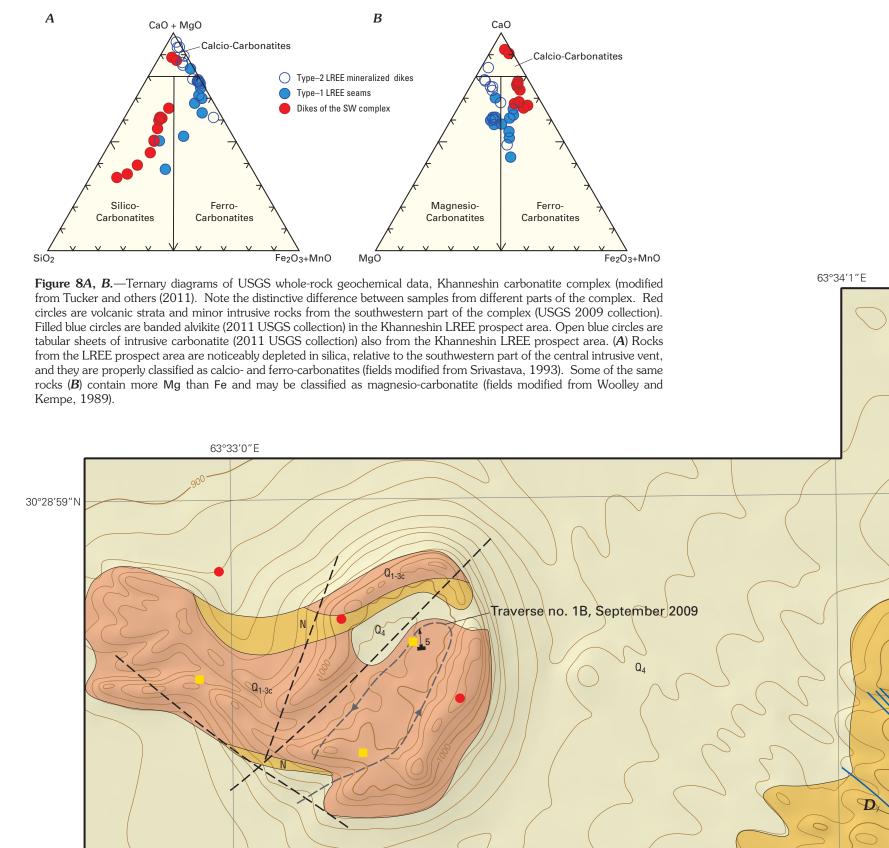
Figure 4.—View looking southwest at volcanic-sediment contact. (Traverse no. 1A)





HREE, heavy rare earth elements ppm, parts per million

Red-filled circles in figures 8–10 are volcanic tuffs and dikes from the southwestern part of the Khanneshin carbonatite complex Blue-filled and unfilled circles in figures 8–10 are LREE-enriched rocks from the Khanneshin LREE prospect area (see Explana-tion of Map Symbols)



30°28′1″N



Figure 6.—View of volcanic vent margin on southern part of the Khanneshin carbonatite complex, looking southeast. (Traverse no. 1A)

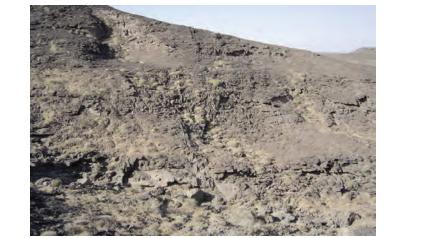
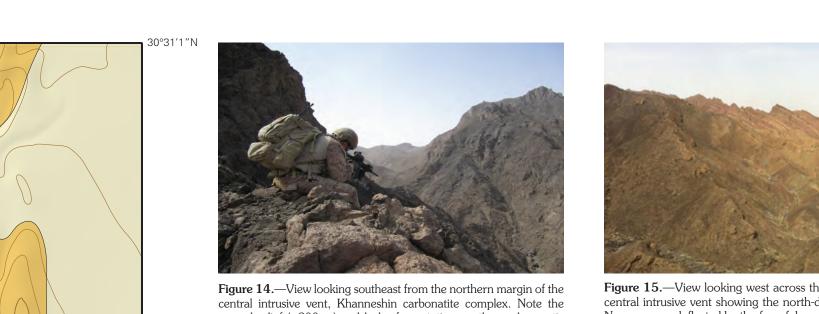


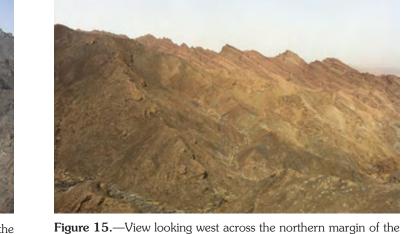
Figure 7.—View of layered agglomerate (unit Q_{1-2c}), looking southwest. (Traverse no. 1A)



63°36'0"E



rugged relief (\sim 200 m) and lack of vegetation on the agglomeratic and brecciated alvikite of the central intrusive vent. (Traverse no. 3)



central intrusive vent showing the north-dipping (~25° N) strata of Neogene age deflected by the forceful emplacement of the intrusive vent. (**Traverse no. 3**)



Figure 16.—Type-1 rare earth element (REE) mineralization in fine-grained ankerite-barite alvikite, Khanneshin carbonatite complex. Two Type-1 banded veins are apparent; one approximately 8 cm thick, the other approximately 4 cm thick. Both have an outer selvage of yellow prismatic burbankite and bastnaesite and an inner zone of barite, celestine, calcite, and fine-grained oxide minerals. (Traverse no. 3)

Figure 17.—Close-up view of another Type-1 mineralized vein with an interior mosaic of fine-grained barite, calcite, celestine and oxides, and a selvage of euhedral crystals of burbankite and bastnaesite. Northeastern margin of the central intrusive vent, Khanneshin carbonatite complex. (Traverse no. 3)

OPEN-FILE REPORT 2011–1244

USGS Afghanistan Project Product No. 198

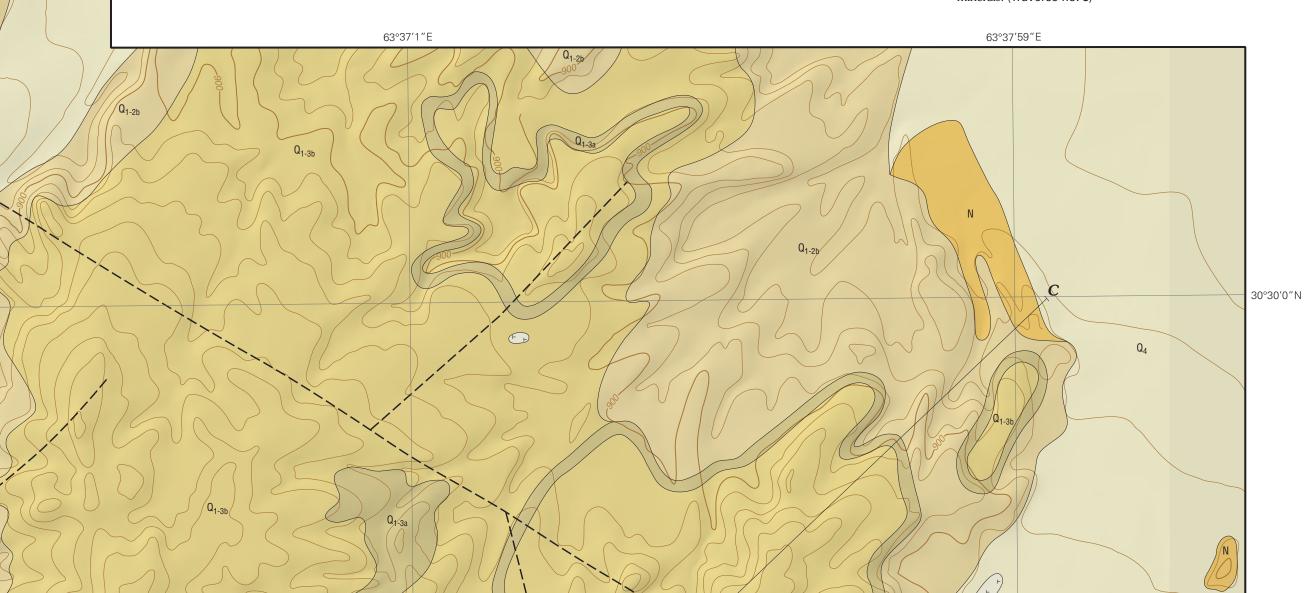




Figure 18.—Tabular sheet, approximately 1.5 m thick (outlined by dashed line), of typical Type-2 mineralization showing very coarse grained rare earth element (REE)enriched carbonatite cutting thinly banded alvikite in the northeastern margin of the central intrusive vent, Khanneshin carbonatite complex. Note the pegmatitic patches, enriched in yellow REE minerals (bounded by dashed circles). (Traverse no. 3)

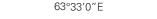
63°39'0"E

Q1.2h

30°28′59″N

Traverse no. 3, February 2011

Q₄



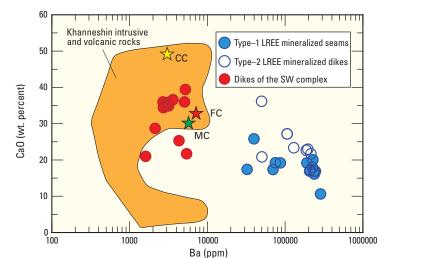
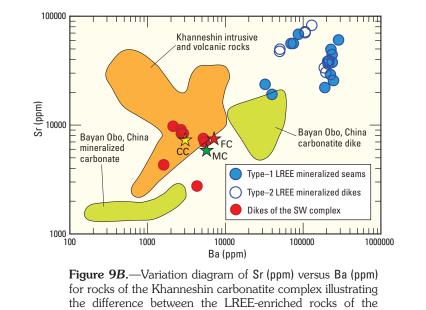


Figure 9A.—Variation diagram of CaO (weight percent) versus Ba (ppm) for rocks of the Khanneshin carbonatite complex illustrating the difference between the LREE-enriched rocks of the marginal zone, central intrusive vent, and normal alvikite and sövite of the Khanneshin carbonatite. Average calcio-carbonatite (yellow star), ferro-carbonatite (red star), and magnesio-carbonatite (green star) from Woolley and Kempe (1989). Note the very high concentrations of Ba. relative to CaO, in the REE-enriched rocks of the Khanneshin carbonatite. One percent (parts per hundred) equals 10,000 ppm (parts per million). Diagram modified from Tucker and others (2011).



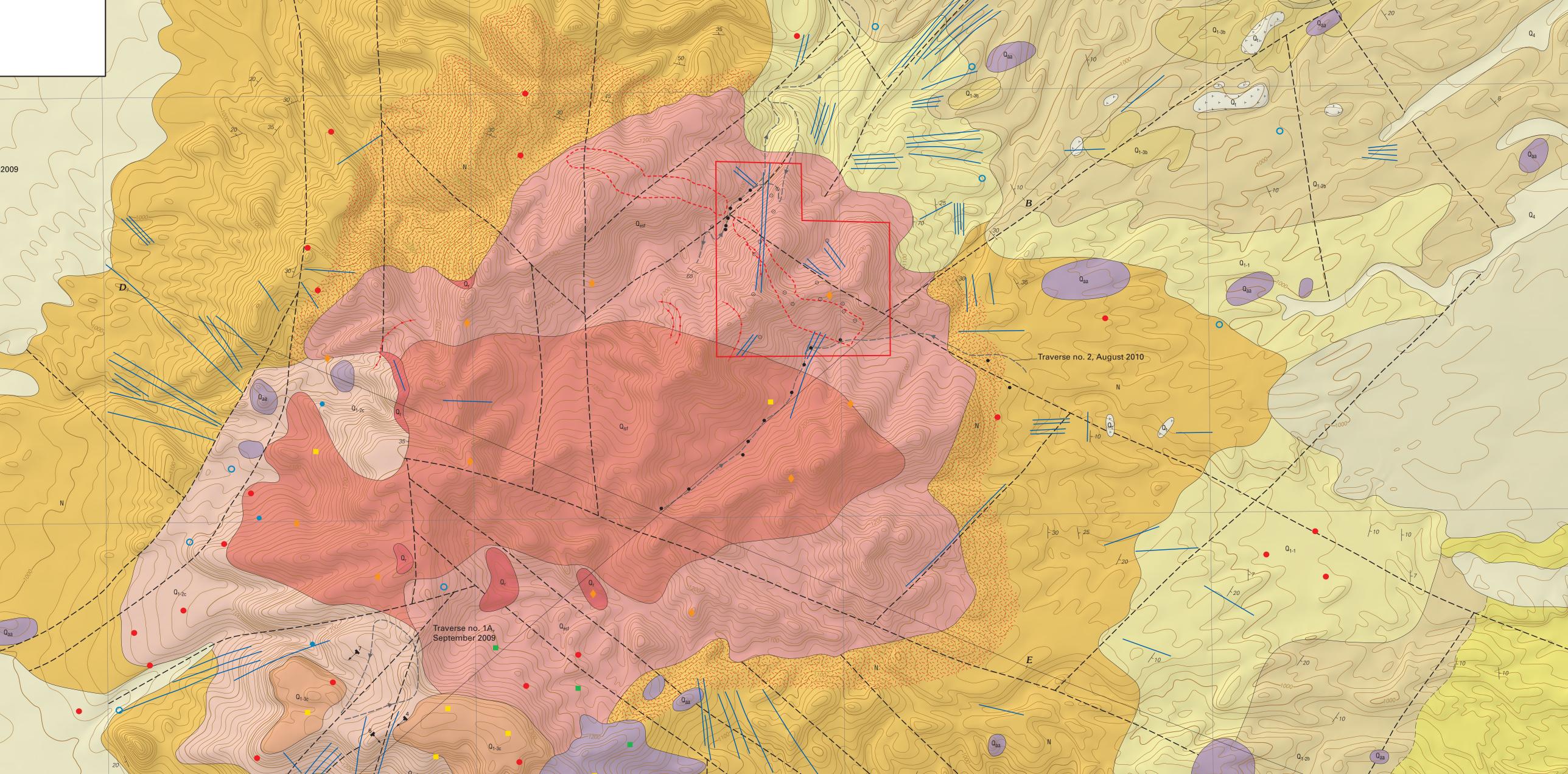




Figure 19.—Close-up view of Type-2 mineralization in a coarsegrained carbonatite dike. Note the coarse-grained igneous texture with idiomorphic crystals of fluorite (purplish blue), barite (gray), and calcite (white) and prismatic aggregates of the yellow rare-earth minerals khanneshite (burbankite group) and bastnaesite-(Ce). Width of the sample is \sim 40 cm. (Traverse no. 2)



Figure 20.—Close-up view of bastnaesite and khanneshite (yellow) in pegmatoidal patch of Type-2 mineralized tabular sheet shown in figure 18. Other visible minerals include fluorite, barite, and calcite. (Traverse no. 3)



marginal zone, central intrusive vent, and normal alvikite and sövite of the Khanneshin carbonatite. Note the very high concentrations of Ba, relative to Sr, in the REEenriched rocks of the Khanneshin carbonatite. Also shown are concentrations in carbonatite dikes at Bayan Obo (China) (data from Yang and others, 2009). One percent (parts per hundred) equals 10,000 ppm (parts per million). Diagram modified from Tucker and others (2011).

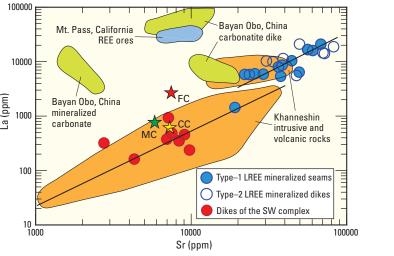


Figure 10A.—Variation diagram of La (ppm) versus Sr (ppm) illustrating the magnitude and significance of REE enrichment in the marginal zone, central intrusive vent, Khanneshin carbonatite complex (symbols as in fig. 8). Also shown are the fields for ordinary Khanneshin intrusive and volcanic rocks sampled in 2009 and 2010, and average calciocarbonatite (yellow star), ferro-carbonatite (red star), and magnesio-carbonatite (green star) from Woolley and Kempe (1989). The positive correlation of the LREE and Sr in the REE-enriched rocks indicates the propensity of the LREE to substitute for Sr in khanneshite (burbankite group) and carbocernaite, the primary carbonate minerals of the Khanneshin complex. Also shown are mineralized carbonate and carbonatite dikes from Bayan Obo (data from Yang and others, 2009) and average ores from Mountain Pass (data from Castor, 2008). Diagram modified from Tucker and others (2011).

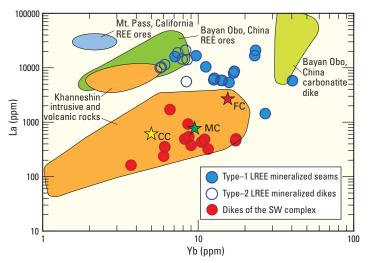
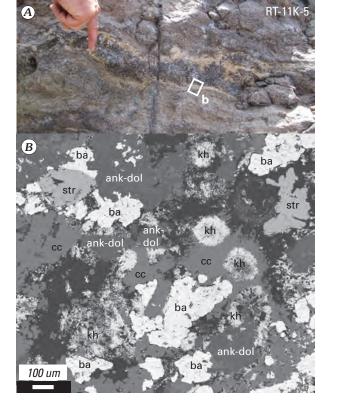
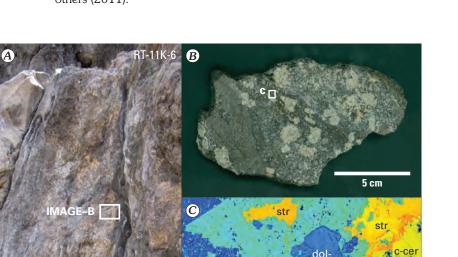
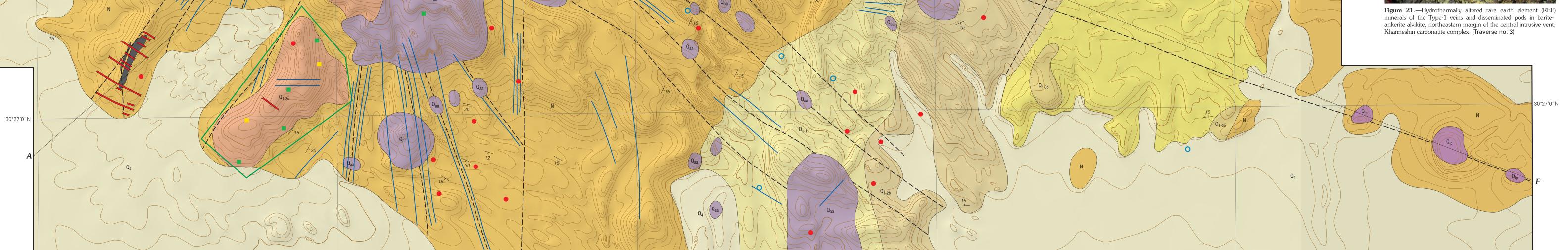


Figure 10B.—Variation diagram of La (ppm) versus Yb (ppm) illustrating the magnitude and significance of REE enrichment in the marginal zone, central intrusive vent, Khanneshin carbonatite complex (symbols as in fig. 8). La (ppm) is representative of the LREE and Yb (ppm) is representative of the HREE. Common alvikites of the Khanneshin complex have LREE and HREE concentrations similar to average ferro-, magnesio-, and calcio-carbonatites worldwide. The highly enriched alvikites of the marginal central vent are enriched in the REE by an order of magnitude, and they are comparable in grade to the world-class deposits of Bayan Obo (data for average Bayan Obo ores from Yuan and others, 1992) and Mountain Pass (data from Castor, 2008). Diagram modified from Tucker and others (2011).







63°34'59"E 63°36'0"E 63°37′1″E 63°37'59"E Topography and shaded relief derived from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) 30-meter Global Digital Elevation Model (GDEM) data, SCALE 1:10 000 Hydrography derived from ASTER GDEM data 1 KILOMETER Projection and grid: Universal Transverse Mercator (UTM), zone 42 north CONTOUR INTERVAL 10 METERS World Geodetic System (WGS) 1984 Datum

Bayan Obo, China Khanneshin Typeconcordant seam of LREE mineralization (hanneshin Type-LREE mineralized discordant dikes Mt. Pass, Californ **REE** ores La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu

63°34′1″E

2009

Figure 11.—Rare earth concentrations normalized to chondritic values (Nakamura, 1974). The Khanneshin whole-rock concentrations are from the LREE-enriched zone (filled and open blue circles). All samples are highly enriched in the LREE relative to the HREE, with typical concentrations of La, Ce, Pr, and Nd above or near 1 weight percent concentrations. These are comparable in grade to the world-class REE ores from Bayan Obo, China (green crosses) and Mountain Pass, Calif. (blue-filled stars). Note that the Type-1 concordant seams from Khanneshin are more enriched in the HREE than are the Type-2 igneous dikes from Khanneshin. Both types of mineralized rocks from Khanneshin are slightly more enriched in HREE than ores from Mountain Pass. Diagram modified from Tucker and others (2011).

INTRODUCTION

VOLCANIC AND SEDIMENTARY STRATIFIED ROCKS OF THE

Q_{1-2c}

Q_{esf}

Q_{isf}

This map is a modified version of the Geological map of the Khanneshin carbonatite complex, scale 1:10,000 (Cheremytsin, 1976). The original map and cross sections are contained in Soviet report no. R1142 (Cheremytsin and Yeremenko, 1976), which was prepared in cooperation with the Ministry of Mines and Industries of the Republic of Afghanistan in Kabul in 1976 under contract number 55-184/17500. This modified map illustrates the geological structure of the Khanneshin carbonatite complex and includes cross sections of the same area. The unit colors on the map and cross sections differ from the colors shown

on the original version. The units are colored according to the color and pattern scheme of the Commission for the Geological Map of the World (CGMW) (http://www.ccgm.org). This map reproduces the topology (contacts, faults, and so forth) of the

original Soviet map and cross sections, and includes modifications based on our examination of these documents and on observations made during brief field visits in September 2009, August 2010, and February 2011. Elevations on the cross sections are derived from the original Soviet topography and may not match the Global Digital Elevation Model (GDEM) topography used on the current map. We have attempted to translate the original Russian terminology and rock classification into modern English geologic usage as literally as possible without changing any genetic or process-oriented implications in the original descriptions. We also use the age designations from the original map.

Some field photograph sites are shown on the map by symbols keyed by number to the figures. The photographs were taken by U.S. Geological Survey scientists (Robert Tucker, Stephen Peters, Mike Chornack, Said Mirzad, and Daniel Hayba) and personnel with the Task Force for Business and Stability Operations (TFBSO) during the field visits mentioned above. We acknowledge Forrest Horton, under contract to TFBSO, for field and logistical assistance given during Traverse 2.

ROCKS OF GEOTHERMAL ORIGIN

Travertine (Pleistocene)—White to yellowish-white, fine-grained botryoidal

VOLCANIC AND SEDIMENTARY STRATIFIED ROCKS OF THE

EASTERN AND NORTHEASTERN PART OF THE

CARBONATITE COMPLEX

Eolian sand (Holocene)—Surrounds the Khanneshin structure; 3 to 5 m thick

Proluvial fan (Holocene and Pleistocene?)—Unconsolidated, very coarse

grained, poorly sorted and poorly graded conglomerate and breccia; debris

calcite and aragonite limestone

flow (lahar?)

⊢ Qt

 Q_4

Q₂₋₃

Qr

INTRUSIVE Satellitic (hypabyssal) and volcanic rocks

Leucite phonolite (Pleistocene)—Massive, dense, dark-gray to green, porphyritic phonolite with phenocrysts of leucite and sanidine (50 to 70 percent of the rock). Groundmass contains fine- to medium-grained, gray to green clusters (1–1.5 mm in diameter) of aegerine and sanidine

Q_{aa} Alvikite agglomerate tuff (Pleistocene?)—Calcite carbonatite agglomerate and tuff; contains alvikite fragments, kamaphorites, and xenoliths of alvikite, sövite, and Neogene sedimentary rocks

/ Carbonatite dikes (Pleistocene?)—Massive, generally subvertical dikes, several centimeters to 1-2 m thick; fine- to medium-grained calcite-bariteankerite carbonatite. Many dikes have radial geometry, cutting through Neogene red beds, intrusive rocks, and lower carbonatite tuffs of unit Q_{aa}

EXPLANATION OF MAP SYMBOLS ——— Contact—Dashed where inferred ———— Fault or fracture—Inferred <u>40</u> Strike and dip of bedding

Trench

——— Traverse line—Arrow shows direction

• Mineralized area containing radioactive elements

••••• Seam of rare earth element (REE) enrichment

----- Rare earth element (REE) enrichment zone—(Tucker and others, 2011) • **USGS sample**—Taken on Traverse nos. 2 and 3

• Russian sample

Site of photograph in Traverse nos. 1A and 1B—Tip of arrow at point of observation; number keyed to figure

REFERENCES

Abdullah, S., and Chmyriov, V.M., eds., 1977, Map of mineral resources of Afghanistan: Kabul, Ministry of Mines and Industries of the Democratic Republic of Afghanistan, Department of Geological and Mineral Survey, scale 1:500,000. [Prepared by V/O Technoexport U.S.S.R.]

Abdullah, S., Chmyriov, V.M., Stazhilo-Alekseev, K.F., Dronov, V.I., Gannon, P.J., Lubemov, B.K., Kafarskiy, A.K., and Malyarov, E.P., 1977, Mineral resources of Afghanistan, 2d ed.: Kabul, Ministry of Mines and Industries of the Democratic Republic of Afghanistan, Afghan Geological and Mines Survey, United Nations Development Programme Support Project AFG/74/12, 419 p.

Castor, S.B., 2008, The Mountain Pass rare-earth carbonatite and associated ultrapotassic rocks, California: The Canadian Mineralogist, v. 46, no. 4, p. 779–806.

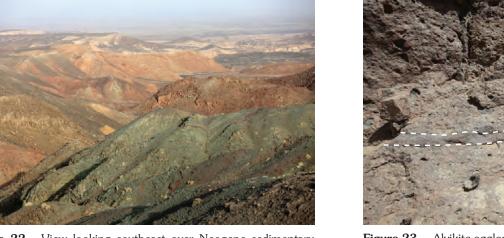


Figure 22.—View looking southeast over Neogene sedimentary strata (red arkose and green argillite in the foreground) and carbonatite tuff and ash in the distance. (Traverse no. 2)

Figure 23.—Alvikite agglomerate intruded by fine-grained carbonatite dike. Dike is marked by dashed line. (Traverse no. 2)

Q_{1-2a}

Figure 24.—Close-up view of welded carbonatite tuff cut by thin (10-cm) dike of coarse-grained bastnaesite-khanneshite-pyrochlore carbonatite. (Traverse no. 2)

63°39'0"E

Modified from original compilation of

Cheremytsin, 1976; see References



Figure 25.—View looking east at the volcanic strata of the central intrusive vent. Dark stratified rocks (S) in the foreground are alvikite tuffs and lavas; overlying them are light-colored massive carbonatite flows (C) and agglomeratic tuffs. (Traverse no. 2)



Figure 26.—Steeply inclined bedded siltstone and argillite of Neogene age, cut by a thin dike of white carbonatite. (Traverse no. 2)

Figure 27.-Massive carbonatite agglomerate enclosing a large block (marked by dashed line) of coarse-grained holocrystalline carbonatite (sövite). (Traverse no. 2)

of siltstone and claystone Carbonatite pipe INTRUSIVE IGNEOUS ROCKS OF THE CENTRAL INTRUSIVE VENT OR STOCK Apatite Barite-ankerite-alvikite (Pleistocene?) (exterior stock facies)—Medium- to fine-grained, dark-gray to black; forms an exterior half-ring around the + Strontianite interior stock facies. Transitions gradationally into the interior stock facies • Rare earth carbonate Calcite sövite carbonatite (Pleistocene?) (interior stock facies)-Medium- to Magnetite

very coarse grained calcite sövite; gray, thinly laminated and spotted; contains xenoliths of phlogopite fenite (glimmerite); accessory minerals are apatite, magnetite, and pyrochlore. Forms the interior facies of the central

WESTERN AND SOUTHWESTERN PART OF THE

CARBONATITE COMPLEX

Alvikite tuffs and lava flows (Pleistocene?) (top layer of volcanogenic

Sedimentary strata (Pleistocene?) (lower layer of volcanogenic unit)-Thick-

bedded, gray to greenish-gray, coarse- to medium-grained sandstone and

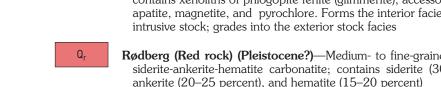
carbonatite tuff; fragments composed of volcanic rocks, Neogene sedimen-

tary rocks, and carbonatite intrusives. Interlayered with thin beds (2–20 cm)

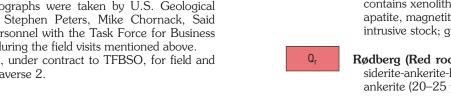
siltstone, alternating with massive, poorly sorted, very angular fragmental

unit)-Massive, fragmental amygdaloidal flows and tuffs; horizontal flows

Rødberg (Red rock) (Pleistocene?)—Medium- to fine-grained black to red siderite-ankerite-hematite carbonatite; contains siderite (30-35 percent), ankerite (20–25 percent), and hematite (15–20 percent)



10 m thick



- DESCRIPTION OF MAP UNITS Q_{Ip}

Figure 12.—Mineralogy and crystallization sequence of the concordantly REE-mineralized rocks, RT-11K-5, February traverse, 2011. (A) Photograph of the concordant symmetric bands of mineralized barite-strontianite alvikite. (B) Gray-toned backscattered electron microscope image of box b, showing margin of light-colored band of ankeritic dolomite, barite, strontianite, calcite, and spherical areas (immiscible droplets?) of khanneshite. Calcite and khanneshite appear as late, interstitial minerals surrounding early formed phenocrysts of barite and strontianite. Abbreviations: **ba**, barite; **str**, strontianite; **cc**, calcite; ank-dol, ankeritic dolomite; kh, khanneshite. Modified from Tucker and others (2011).

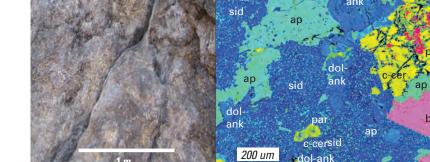


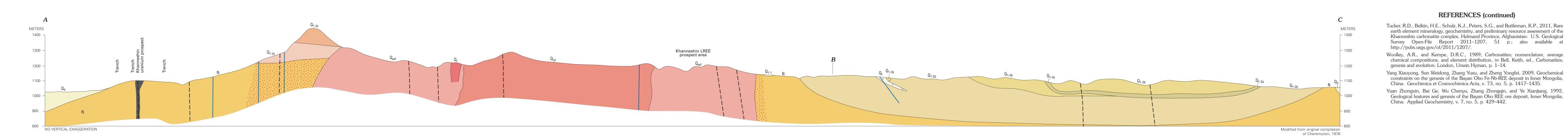
Figure 13.—Mineralogy and crystallization dikes, Khanneshin carbonatite complex. (A The rectangle of image **B** shows the approx pictured in **B**. (**B**) Rock slab of sample **RT-11** cernaite in a matrix of dolomitic ankerite, sig image C shown as inset box c. (C) False-color image showing the textural relations amor ankerite (dol-ank), siderite (sid), barite (ba) parisite-(Ce) (par). Dolomitic ankerite, with s early phenocrysts; apatite, barite, and str parisite-(Ce) forms a late alteration mineral o and others (2011).

| dol C-Cer | now (lanar;) | | , , , , , , , , , , , , , , , , , , , | |
|---|--|---|---|--|
| id ap dol- | Q _{1-3a} Carbonatite lava flow (Pleistocene?) (upper bed of upper volcanogenic unit)—Porous, bluish-gray, with porphyritic texture; ranges from 10–20 cm to 4–5 m thick. Contains phenocrysts of rhombohedral calcite crystals (1 mm) | Sandstone and siltstone (Neogene)—Altered and hornfelsed red sandstone and siltstone in and near the contact within igneous rocks of the subvolcanic and volcanic-rock facies; brecciated and recrystallized, medium to fine grained | Cheremytsin, V.G., comp., 1976, Geological map of the Khanneshin carbonatite complex, <i>in</i> Cheremytsin, V.G., and Yeremenko, G.K., Report of the Khanneshin group on the results of prospecting and evaluational activity for 1976 [in Russian]: Kabul, Department of Mines and Geology Survey, report no. R1142, one sheet, scale 1:10,000. [Prepared by V/O Technoexport U.S.S.R. for the Ministry of Mines and Industries of the Republic of Afghanistan, Department of Mines and Geology Survey, | |
| ap sid ank ap ba | Q _{1-3b} Carbonatite tuff (Pleistocene?) (lower bed of upper volcanogenic unit)—Highly abundant, medium-grained, porous, gray and brown, and weakly consolidated. Contains very angular fragments of carbonatite, Neogene sedimentary rock, and magnetite, apatite, and biotite phenocrysts Q _{1-2a} Sandstone and carbonatite conglomerate (Pleistocene?) (upper bed of | N Sandstone and siltstone (Neogene)—Unaltered, fine- to medium-grained, orange to brick-red sandstone and siltstone alternating with thin green beds of fine-grained sandstone PROSPECT AREAS | under contract no. 55-184/17500.] Cheremytsin, V.G., and Yeremenko, G.K., 1976, Report of the Khanneshin group on the results of prospecting and evaluational activity for 1976 [in Russian]: Kabul, Department of Mines and Geology Survey, report no. R1142, 84 p. and 7 map pls. [Prepared by V/O Technoexport U.S.S.R. for the Ministry of Mines and Industries of the Republic of Afghanistan, Department of Mines and Geology Survey, under | |
| ation sequence of the apatite-rich intrusive x. (A) Outcrop of intrusive dike RT-11K-6. pproximate location of the hand specimen RT-11K-6 showing the phenocrysts of carbo- | Q1-2b Middle volcanogenic unit)—Coarse-grained, light-gray and brownish-gray sandstone interbedded with siltstone Q1-2b Carbonatite siltstone and sandstone (Pleistocene?) (lower bed of middle volcanogenic unit)—Siltstone, fine-grained, horizontally and thinly | Khanneshin uranium prospect—Denotes the area of Neogene sedimentary rocks in the southwestern part of the complex identified by Cheremytsin and Yeremenko (1976) as prospective for uranium and thorium Khanneshin light rare earth element (LREE) prospect area—Red outline | contract no. 55-184/17500.] Nakamura, Noboru, 1974, Determination of REE, Ba, Fe, Mg, Na and K in carbonaceous and ordinary chondrites: Geochimica et Cosmochimica Acta, v. 38, no. 5, p. 757–775. Peters, S.G., Ludington, S.D., Orris, G.J., Sutphin, D.M., Bliss, J.D., and Rytuba, J.J., | |
| te, siderite, apatite, and barite. Location of -colored backscattered electron microscope among carbocernaite (c-cer), dolomite- e (ba), strontianite (str), apatite (ap), and with siderite rims, and carbocernaite form | Q1-1 Q Q1-1 Carbonatite tuff (Pleistocene?) (lower volcanogenic unit) | denotes the area of intrusive igneous rocks of the subvolcanic facies in the northeastern part of the central intrusive vent, identified by Cheremytsin and Yeremenko (1976) as prospective for LREE | eds., and the U.S. Geological Survey–Afghanistan Ministry of Mines Joint Mineral Resource Assessment Team, 2007, Preliminary non-fuel mineral resource assessment of Afghanistan: U.S. Geological Survey Open-File Report 2007–1214, 810 p., 1 CD-ROM disk and 1 DVD-ROM disk; also available at http://pubs.usgs.gov/of/2007/1214/. | Figure 28.—Contact (dashed line) between coarse-grained alvikite |
| and strontianite form interstitial minerals; eral of carbocernaite. Modified from Tucker | and green, medium-grained carbonatite tuff; contains rocks of geothermal origin, fragments of carbonatite, and Neogene sandstone, siltstone, and argillite | Khanneshin phosphorus prospect area—Green outline denotes the area of alvikite tuffs and lava flows identified by Cheremytsin and Yeremenko (1976) as prospective for phosphorus | Srivastava, R.K., 1993, Chemical classification of silica-rich carbonatites: Indian Journal of Geochemistry, v. 8, p. 15–24. | agglomerate above fine-grained carbonatite lava cut by carbonatite dikes. (Traverse no. 2) |
| | | | | |



Figure 29.—Red and green clastic sedimentary rocks of Neogene Figure 30.—Weathered pits in alvikite agglomerate sampled age intruded by a thin, sill-like dike of white carbonatite. Dike is previously by Soviet geologists in the central intrusive vent. (Traverse no. 2)

REFERENCES (continued)



METERS 1 Modified from original compilation Index map outlining USGS-Afghanistan of Cheremytsin, 1976 mineral project areas. Area of this report

marked by dashed line. (Traverse no. 2)

Geologic Map of the Khanneshin Carbonatite Complex, Helmand Province, Afghanistan, Modified From the 1976 Original Map Compilation of V.G. Cheremytsin

This map is available for sale by U.S. Geological Survey, Information Services, Box 25286, Denver Federal Center, Denver, CO 80225 For product and ordering information: World Wide Web: http://www.usgs.gov; Telephone 1-888-ASK-USGS Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government

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