DASHKESAN: NOTES ON GEOLOGY AND MINERALOGY

Compiled by **Michael B. Leybov**
Mineralogical Almanac, minbooks@rambler.ru

All the specimens are from the Dashkesan deposit, Azerbaijan.

Photo by Michael B. Leybov.

In this issue the "*Famous Mineral Localities*" Section is devoted to the Dashkesan deposit, Azerbaijan, located 40 km southwest of the town Gyandzha (it was named Elizavetpol' from 1804 to 1918 and Kirovobad from 1935 to 1989) on the southeastern slope of the Maly Caucasus in the Koshkarchai Valley. In the last century this deposit attracted professional geologists specialized in mineralogy, geochemistry, petrography, and geophysics; scientists from academic institutes; and professors of geological specialties from the best training institutes of the Former Soviet Union. A thousand students visited it during training course. Each collector of minerals from the USSR certainly dreamed of visiting it.

Why is the Dashkesan deposit popular? To scientists, this deposit is a remarkable natural laboratory, where the distinguishing features of mineral and ore formation in a skarn and related hydrothermal rocks can be studied well. To students and professors in geology the walls of the Dashkesan open pits are a visual aid and set a standard for iron and cobalt calc skarn deposits. To everybody not indifferent to stone, Dashkesan is a source of splendid collection specimens, which copiously come from numerous cavities in the skarn bodies.

Remarkable crystal crusts of **andradite** and **magnetite**, individual crystals and intergrowthes of **calcite**, very large and beautiful crystals, twins, and clusters of **chalcopyrite**, spectacular sheaf-shaped **quartz**, including dark violet ***amethyst***, and complexly faced crystals of Cl-bearing **fluorapatite** glorified Dashkesan as a mineralogical locality in the first place. Crystal crusts of pistachio-green **epidote**, pseudomorphs of fibrous gray-green **actinolite** after crystals of **pyroxene**, roses of

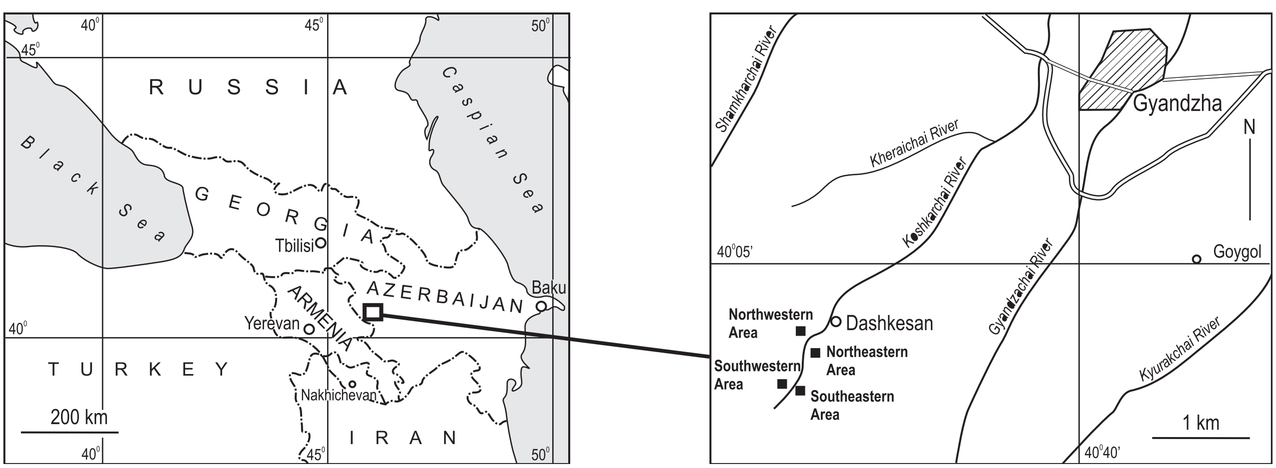

Figure 1. Geographic location of Dashkesan.

Figure 2. A view of the Northeastern open pit. Photo by M.M. Moiseev, 2008.

Figure 3. The town Dashkesan and Northeastern open pit. Photo by M.M. Moiseev, 2008.

hematite and ***mushketovite*** (magnetite) pseudomorphs after them, clusters of large well-shaped crystals of **laumontite**, clear polyhedra of pinkish Co-bearing **pyrite**, and pieces richly impregnated with **cobaltite** are well known from this deposit. The huge individuals (up to 20 cm), including multi-faced semitransparent green crystals of **sphalerite**, bright crimson ***Co-bearing calcite*** as spacious spectacular crusts, small but splendid crystal crusts of pink **erythrite**, shining crystals of **azurite** on crystals of chalcopyrite coated by dark green **covellite**, and radial-fibrous buds of **malachite** are less known to collectors. **Dashkesanite** (**chloropotassichastingsite**), a wonderful Cl-rich amphibole, was discovered here; in contrast to most amphiboles of exotic composition it is the major (>95 vol. %) constituent of the dashkesanite skarn body, which continued for 200 m with a thickness up to 1.5 m (the area is not less than 20 thousand m^2).

Note that friendly management and the geologists of the ore mining and processing enterprise operating the deposit plus cordial locals to the numerous visitors promoted the popularity of Dashekesan.

A dozen scientists dealt with the rich and diverse mineralogy of the Dashkesan deposit. This study, while making no claim to completely characterize the most complex Dashkesan deposit, tries to give general information that is sufficient to raise (or support) interest in this spectacular mineral locality.

Most data given here are compiled from the monograph by Mir-Ali Kashkai (1907–1977), Azerbaijan's leading geologist, entitled *"Petrology and Metallogeny of the Dashkesan and Other Iron Deposits of Azerbaijan"* (Kashkai, 1965).

was trenched, the ore bodies were sampled and the outcrops of ore were described in detail.

In 1929–1932, the deposit was drilled; a total of 42 drill holes 4811 m long. As a result of this work, in 1933 and 1934 the ore reserves were approved. During those years the mineralogical and geochemical features of the Dashkesan deposit were studied and explored.

G.A. Krutov (1936, 1937), the greatest specialist in cobalt ores, jointly with G.A. Kremchukov and N.B. Borisovich (1936) studied the mineralogy of Co-bearing locations at Dashkesan, including skarn rocks of the iron deposits. In particular, Krutov (1936) discovered the new mineral dashkesanite and characterized it in detail. This mineral was later undeservedly discredited as an independent mineral species, but it "*obtained its right*" again recently as chloro-potassichastingsite, corresponding to the modern nomenclature of amphiboles after a restudy with modern techniques and "*official*" approval by the Commission on New Minerals and Mineral Names of the International Mineralogical Association (Pekov *et al.*, 1998, 2005).

M.A. Karasik (1940, 1941, 1946), who studied the cobalt deposit, published some papers about Dashkesan mineralogy and ore genesis. Later, A.I. Makhmudov (1982) also investigated the cobalt mineralization.

A.S. Marfunin (1955) studied in detail the igneous and skarn rocks of Dashkesan. Also, Barsanov (1952, 1953); M.-A. Kashkai (1955, 1957, 1958, 1965); Kashkai and Guseinov (1955); Kashkai and Liberzon (1959); and Kashkai, Kornev, Akhmedov, and Babaev (1958, 1962) published articles about some geological problems and mineral resources of Dashkesan. In particular, Kashkai and Liberzon in 1952 studied the ores and explored the southern locations of iron and cobalt deposits. These studies and a calculation of the iron reserves at Dashkesan provided a reliable basis upon which to construct the Transcaucasus metallurgical plant in Rustavi, Georgia. At the deposit proper, which was mined by open pits, the town of Dashkesan arose.

2. Brief Geology and Petrography

The district of the Dashkesan deposit belongs to the Somkhito-Karabakh structural zone of the Maly Caucasus and comprises Middle and Upper Devonian volcanosedimentary rocks forming the Dashkesan gentle syncline striking parallel to the Caucasus strike.

The Middle Jurassic sediments are (from the bottom upwards) quartz porphyries and their tuffs; tuffaceous siltstone and quartz tuffstone; aglomeratic tuff intercalated with psamitic tuff; porphyries; stratified yellow tuffite; magnetite tuffstone and sandstone; block tuffite and tuff conglomerate; and fine-fragmented tuff and tuffite.

Figure 6. **Geological scheme of the Dashkesan iron deposit,** after Kashkai (1965):

Quarternary:

Q — (1) Alluvium, diluvium, eluvium.

Upper Cretaceous:

Cp-ms — (2) Campanian-Maastrichtian, limestone;

St — (3) Santonian, volcanic and occasional porphyritic rocks;

S-L — (4) Coniacian, stratified sandstone and marl with intercalations of conglomerate.

Lower Cretaceous – Upper Jurassic:

a b Cr-km — (5) Kimmeridgian, porhyritic dolerite: (a) extrusive and effusive dolerite; (b) stratiform pluton.

Upper Jurassic:

km — (6) Kimmeridgian, Upper Formation of tuffs and tuffites;

a b km — (7) Lower Formation: (a) alunite-, pyrophyllite-, and kaolinite-altered sequence; (b) tuffite underlying and overlying alunite-altered sequence;

(8) hornfels after the Oxfordian-Kimmeridgian and partly Middle Jurassic rocks;

(9) iron skarn bodies;

Cr-km — (10) Oxfordian-Kimmeridgian, marmorized limestone (Lusitanian sequence);

Ox-km — (11) Oxfordian-Kimmeridgian, limestone (Lusitanian sequence);

Ox — (12) Oxfordian, tuffaceous rocks (calcareous tuffite, conglomerate, gravelstone, and tuffstone);

Cl — (13) Callovian, porphyritic rocks and dacite;

Cl — (14) Callovian, mudstone and sandstone with intercalations of marl.

Middle Jurassic:

bt 2 — (15) Bathonian, Ti-bearing magnetite sandstone and tuffstone;

(16) Bathonian, tuff (tuff breccia), aglomeratic (block) tuffite and tuffaceous conglomerate with ball flows;

bt 1 — (17) Lower Bathonian, stratified yellow tuffite;

bt — (18) Lower Bathonian, porphyritic rocks and porphyritic dolerite;

a b bt — (19) Lower Bathonian: (a) aglomeratic tuff intercalated with fine-fragmented tuff and tuffstone, (b) their silicified varieties.

bj_2 — (20) Upper Bajocian, fine-stratified tuffaceous siltstone and quartz tuffstone;

a b bj_2 — (21) Upper Bajocian: (a) quartz porphyry and its tuff, (b) their silicified varieties.

Intrusive rocks (Lower Cretaceous, Neocomian):

Ph_1 — (22) gabbroic rocks (gabbro, norite, gabbro-diorite, diorite) of the first intrusive phase;

Ph_2 — (23) granitic rocks (adamellite-granodiorite, tonalite-quartz diorite) of the second intrusive phase;

Ph_3 — (24) granitic aplite and alaskite of the third intrusive phase;

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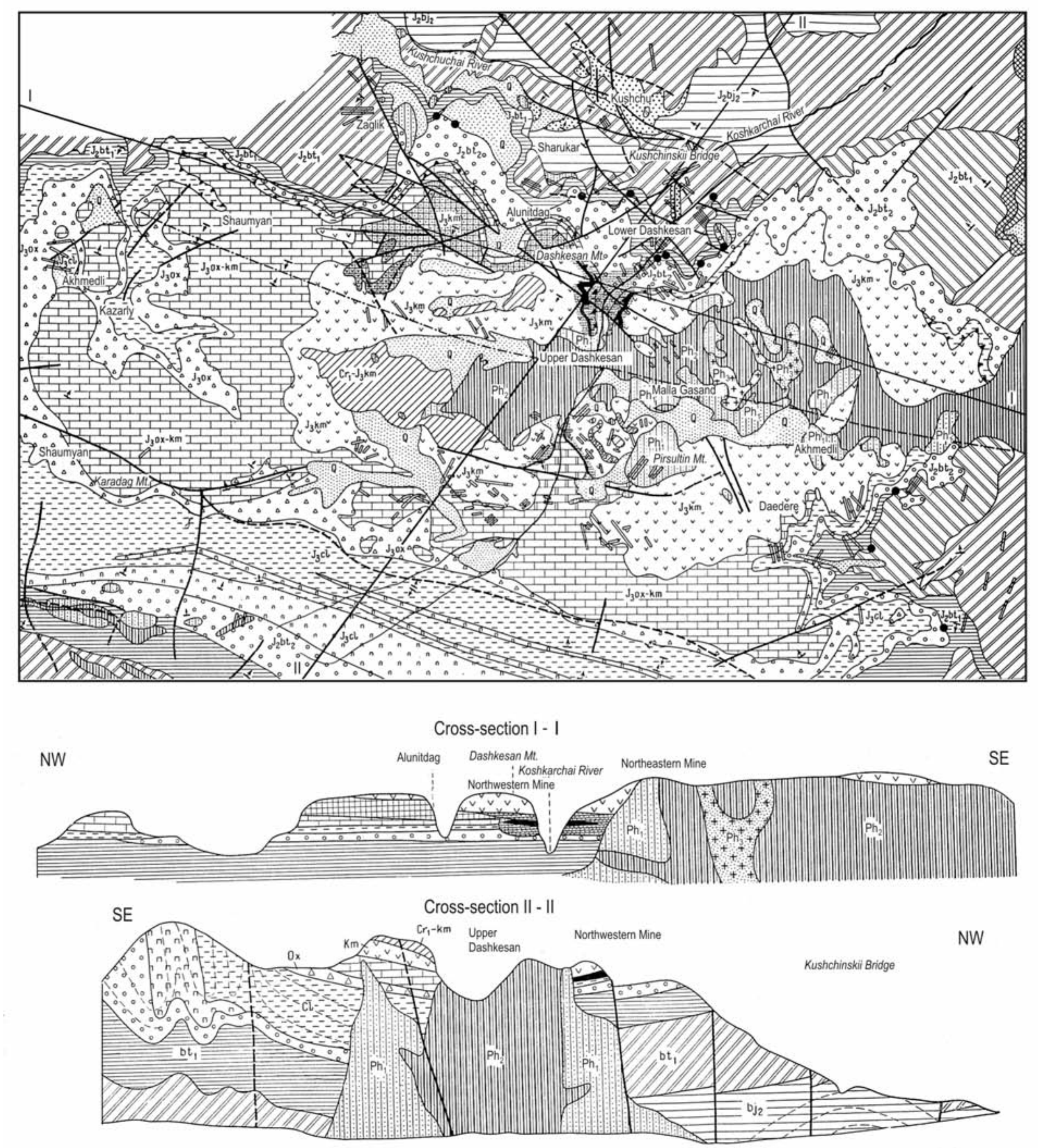

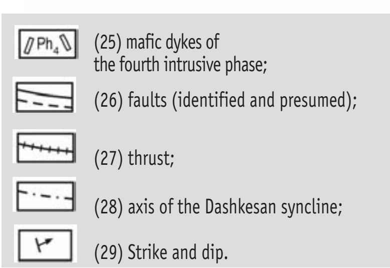

The Upper Jurassic sediments are intercalated mudstone, sandstone, and marl overlain by aglomeratic tuff, calcareous tuffite and tuffbreccia, limestone (up to 250 m in thickness), tuff, and tuffite.

All of these sequences are intruded by the large Early Cretaceous Dashkesan multiphase gabbro-granite pluton that is discordantly overlain by the Upper Cretaceous sandstone and marl.

Four phases are identified in the Dashkesan intrusion: (1) gabbro, gabbro-syenite, quartz diorite, and syenodiorite; (2) adamellite, granodiorite, and syenodiorite; (3)

Figure 7.
Model of the Northeastern Area of the Dashkesan iron deposit,
after Kashkai (1965):

(1) Kimmeridgian, tuffstone;
(2) overlying hornfels;
(3) magnetite body;
(4) underlying hornfels after tuffaceous conglomerate;
(5) horlfelsed tuffstone;
(6) fine tuff breccia;
(7) ironized sandstone;
(8) tuffaceous conglomerate;
(9) dyke of plagioclase porphyry;
(10) pre-ore dykes of porphyrytic dolerite;
(11) granitic rocks (second phase);
(12) gabbroic rocks (first phase);
(13) garnet skarn;
(14) garnet skarn with hematite.

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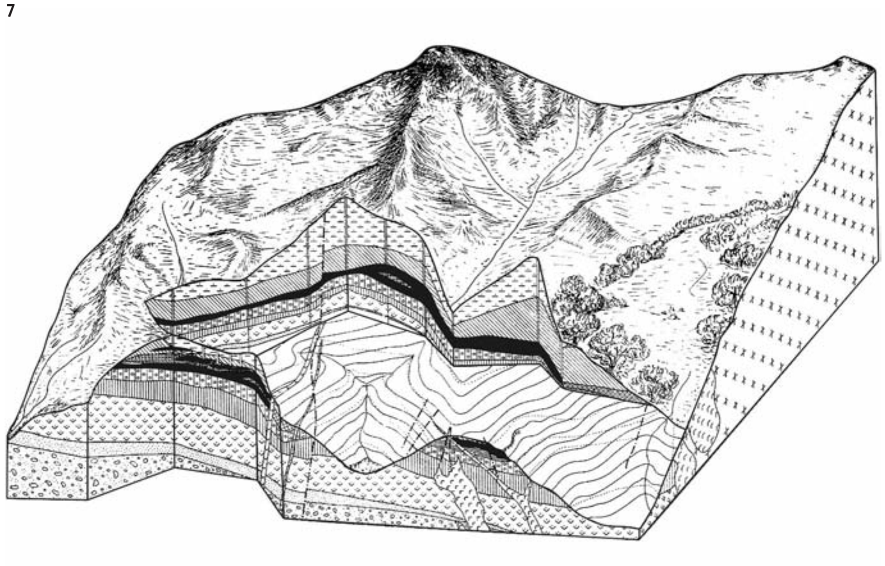

dykes and bodies of alaskite and granitic aplite; and (4) numerous dykes of dolerite, porphyry dolerite, and lamprophyre.

The western part the extended Dashkesan pluton is cut by the Koshkarchai Valley opening the northern and southern contacts of the pluton, where the Northwestern, Northeastern, Southwestern and Southeastern Areas of the Dashkesan deposit are located. The southern areas are situated 5–6 km from the northern areas; the eastern and western areas are separated by the narrow Koshkarchai Valley.

At the Dashkesan deposit, stratiform skarn magnetite orebodies are concentrated in the Upper Jurassic (Callovian-Oxfordian-Kimmeridgian) sediments.

Wall rocks are hornfelsed, skarned, and hydrothermally altered. The Dashkesan skarn predominantly replaced silicate rocks, whereas limestone is skarned to a lesser extent. Ore skarns are divided into garnet-pyroxene with magnetite, garnet with hematite and magnetite, and dashkesanite with magnetite. The rocks were altered during a post-skarn stage to form hydrosilicate minerals, quartz, and calcite. The deposit is featured by the dashkesanite Co-bearing skarn in the Northeastern Area.

The structure of the four areas of the Dashkesan deposit is different. In the Northwestern Area, a skarn orebody is hosted in marmorized limestone only in the western part. Toward the East, the limestone is tapered and the thickness of the skarn orebody increases up to 70 m in hornfelsed tuff. The orebody is 1.7 km in length along strike and 1.9 km in length along the dip which plunges 10–12^{o} SW. In the Northeastern Area, a skarn orebody is concordant between the Callovian-Oxfordian hornfels and hornfelsed tuffite and Kimmeridgian volcanic sequence. It differs from the orebody of the Northwestern Area in being smaller in size and having thin concordant beds of dashkesanite skarn at the top of the orebody. In the Southeastern Area, the main stratiform skarn orebody overlaps limestone plunging to the NNW at 10–12^{o}. It is traced along strike for 2.5 km and along dip for 1.3 km. In the Southwestern Area, the stratiform orebody is traced for 4 km in latitudinal direction. It comprises some ore lenses separated by barren skarn.

The magnetite ores of the deposit are divided into massive ore, impregnated ore, and ore skarn. Massive ore composes bodies 25–30 m thick and separate lenses 10–20 m thick; they contain up to 90% magnetite. There are ores enriched in sulfides (up to

20%). Impregnated ores gradually transitioning to massive ores occur as stratiform bodies and lenses. The magnetite grade in them is 40–70%. Ore skarns are different from impregnated ores in lower content of magnetite (30–40%) and higher content of garnet (60%).

3. Skarns of Dashkesan

The skarn zones of the Dashkesan deposit are distinguished by various exoskarns, wall-rock skarns, and post-skarn metasomatic rocks; endoskarns are minor.

Endoskarns (skarned intrusive rocks) are characterized by a relict texture; however, the parent rock is not always determined. In thin (3–5 cm) dykes of gabbro-dolerite, porphyry dolerite, and plagioclase porphyry, endoskarns are observed in thin zones.

Garnet; pyroxene-garnet; garnet with epidote and calcite; garnet with quartz and magnetite; garnet with actinolite, epidote, and quartz; and dashkesanite *exoskarns* are identified. Ore skarns belong to the following types: garnet with magnetite, pyroxene-garnet with magnetite, dashkesanite with magnetite, and garnet with hematite and magnetite.

Garnet skarn

Garnet skarn developed in both the hanging and foot walls of skarn bodies, occasionally only in the hanging wall, and it occurs as extended lenticular bodies of 2–10 m in thickness. The garnet skarn frequently contains a small amount of magnetite, epidote, calcite, and quartz.

Garnet of the grossular-andradite solid solution series is the major mineral of this skarn. Andradite with the andradite:grossular end-member ratio from 2 : 1 to 6 : 1 is the most abundant.

Three types of garnet segregations were found in the garnet skarn: (1) aggregates with grain size ranging from 0.03 to 0.05 mm; this type of garnet skarn being the most abundant in the hanging and foot walls of iron bodies is observable as "*spots*" in hornfels; (2) coarse-grained garnet as separate crystals 0.5–1 cm in size, occasionally up to 5–7 cm; these crystals filling fractures and cavities are accompanied by magnetite, epidote, calcite, and quartz; and (3) crusts of small (usually 2–3 mm) euhedral crystals coating walls of fractures in skarn, underlain and overlain hornfels and wall rocks.

Pyroxene-garnet skarn

This skarn type was found in combination with the garnet type, but it is less abundant. The pyroxene-garnet segregations usually range from 0.5 to 1 m in thickness, less frequently thicker. The proportion of pyroxene and garnet is extremely variable as indicated even in short intervals. Occasionally the content of pyroxene reaches 70%; usually it is 30–40%, while the content of garnet is up to 70%. Pyroxene is usually attributed to the hedenbergite-diopside solid solution series. Along with these minerals, magnetite (up to 20%), quartz (up to 30%), calcite (up to 10%), and amphibole (up to 8%) are present; a few sulfide minerals are typical.

The pyroxene-garnet skarn with magnetite is less abundant then the garnet skarn. It is observed in the southern areas close to limestone and along the contact between dykes and limestone. The pyroxene is hedenbergite or salite.

Garnet skarn with epidote and calcite

Garnet skarn with epidote and calcite is the most abundant contact rock in all of the areas of the Dashkesan iron deposit. The proportion of minerals, crystal size, and type of aggregates are widely variable. The major minerals are accompanied by a small amount of scapolite, diopside, chlorite, actinolite, magnetite, and hematite.

This skarn occurs in the contact zone of intrusion or dykes, particularly in the hanging and foot walls of orebodies. The druses of epidote or calcite are hosted in skarn in places (for example, in the hanging wall of magnetite bodies in the Northeastern and Southeastern Areas).

The grains of garnet range from minute to 2–3 cm in size, the most frequently 0.1–0.5 mm. Epidote occurs as columnar individuals from 0.1 to 5 mm in length along the long axis. Occasionally garnet is rimmed by epidote and thin epidote-calcite veinlets are observed.

Garnet skarn with quartz and magnetite

Skarn of this type is typical of the Dashkesan deposit, especially in its eastern areas. Magnetite frequently occurs as druses of large crystals. Quartz fills interstices between crystals of garnet and magnetite, and in vugs up to 20 cm across, in which occasionally it is amethyst.

Magnetite-garnet and garnet-magnetite skarns are gradually transformed into the surrounding massive magnetite bodies. Frequently, garnet and magnetite intergrow each other or the former is enclosed in the latter. Epidote, calcite, quartz, chlorite, and actinolite fill interstices and replace garnet. The same minerals occur as veinlets. Andradite is the predominant garnet; grossular is rare.

Garnet skarn with hematite and magnetite is widespread in the western part of the Northwestern Area and southern areas. Actinolite, calcite, and quartz are subordinate in this skarn. Hematite of two generations crystallized before and after magnetite. Mushketovite, a pseudomorph of magnetite after hematite, is often observed.

Wall rocks are found in outer narrow zones adjacent to endo- and exoskarn. They are composed of plagioclase, pyroxene, epidote, and quartz. Their mineralogy depends on the replaced silicate rock. Plagioclase-pyroxene-epidote and plagioclase-epidote-quartz assemblages are the major types. The composition of plagioclase is highly variable: bytownite-anorthite, labradorite, labradorite- bytownite, and albite were identified in these rocks. The pyroxene is hedenbergite. The texture of the primary rocks is retained in places.

Post-skarn hydrothermal assemblages

The initial high-temperature stage of the metasomatic process resulted in typical skarns, which were reported above. At the last stage, the primary skarn minerals were replaced by actinolite, epidote, quartz, calcite, albite, and chlorite. Post-skarn assemblages are epidote, actinolite, actinolite-dashkesanite, hematite-actinolite, actinolite-hematite, chlorite-epidote, epidote-chlorite, calcite-magnetite, and epidote-magnetite.

4. Brief Mineralogy of Ore Assemblages at the Dashkesan Deposit

At the Dashkesan deposit, one hundred minerals were found, forty of which are supergene and formed in the oxidizing zone. In addition to magnetite, hypogene minerals are hematite; Fe, Co, Zn, Cu, Pb, Ni, and Mo sulfides; cobaltite; glauckodot; arsenopyrite; safflorite; native gold and silver (electrum); maghemite; ilmenite; and rutile. Garnet of the grossular-andradite solid solution series, pyroxenes of the diopside-hedenbergite-augite system (mostly, actinolite and dashkesanite), epidote, wollastonite, carbonates (mostly calcite), quartz, plagioclases, chlorites, zeolites (mostly laumontite), biotite, muscovite (sericite), pyrophyllite, talc, and kaolinite are important gangue minerals; scapolite, ilvaite, spinel, allanite-(Ce), dickite, alunite, and apatite were also identified.

What follows is a brief characterization of the most important hypogene minerals of the Dashkesan deposit according to the literature. Supergene mineralization is beyond this article.

Magnetite is one of the most abundant minerals of the skarn lodes in the all areas of the Dashkesan deposit, where it forms large bodies. In the Northern Area and other areas of the deposit, clusters of hydrothermal magnetite were found. Veinlets with this late magnetite cut skarns with magnetite.

The morphology of the magnetite depends on that of the orebodies and the stage of ore formation. For example, dense and fine-grained magnetite predominates in massive ore; in cavities, it is predominantly coarsely-crystalline, forming druses and occasionally occurring as separate crystals up to 3 cm in size, less frequently larger.

Figure 9. **Laumontite** *in situ*.

Figure 10. Pseudomorph of **actinolite** after **hedenbergite** *in situ*.

Figure 11. **Apatite** *in situ*.

Figure 12. **Quartz** *in situ*.

Figure 13. Crystal crusts of **andradite** *in situ*.
Width of image 30 x 20 cm.

Figure 14. **Erythrine** on **hedenbergite**.

Photo by M.M. Moiseev, 2008.