FAMOUS MINERAL LOCALITIES OF CRIMEA: KARADAG

Alexander I. Tishchenko
Andrusov Geological Museum, Vernadsky Crimean Federal University, Sevastopol
TischenkoAlex@rambler.ru
Anatoly V. Kasatkin
Fersman Mineralogical Museum RAS (Moscow), kasatkin@inbox.ru
Evgeniy A. Shibaev
T.I. Vyazemskiy Karadag Scientific Station – Nature Reserve of the RAS – Branch of the A.O. Kovalevskiy Institute of Biology of the Southern Seas of RAS, Feodosia
evshibaev@mail.ru

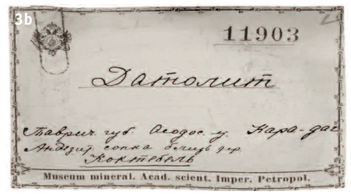
1. Karadag Mountain Range location.

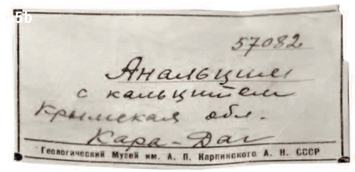
Specimens:
Karadag Mountain Range, Crimean Peninsula.

The Crimean Peninsula, a small region (about 27.000 km^2), comprises sedimentary rocks which greatly dominate (~90 %) over magmatic rocks (~10 %). At present, four hundred and thirty-two mineral species are reliably recorded in the Crimea (Tishchenko, Kasatkin, 2020). The Kerch iron basin at the Kerch peninsula and the Pervomaiskiy quarry in the Bakhchysarai district, which are two of the most famous mineral localities in the Crimea, were already described in the Mineralogical Almanac (Chukanov, 2005; Tishchenko, 2012). We are now inviting the reader to introduce to the , better known as Karadag, one more the great Crimean mineral locality. If you ask the Crimea nature enthusiasts about the best landscape locations of the peninsula, Karadag will be undoubtedly at the top of the list. What makes Karadag so attractive? After fine and noisy South Coast resort and somewhat desert East Crimea, Karadag gets in the way of traveler as harsh and pristine mountainous area

Refer to doctor and writer Sergei Yakovlevich Elpatievskiy (1913), "*Karadag is magnificent; it is like a fairy tale. It is dark, fantastic, and inaccessible from the sea. By Otuzy,*

2. Karagach Ridge, western part of Karadag. Weathering figures *(from left to right)*: Svita, Korol, Koroleva, and Tron.
Photo: Evgeniy A. Shibaev.





3. **Datolite** (a) with an old label (b). 7 x 4 cm. Andesitovaya Hill. Fersman Mineralogical Museum, RAS # 11903.
Photo: Michael B. Leybov.

4. **Agate**. 5 x 3.5 cm.
Sevastopol Museum of minerals # 3234.
Photo: Irina E. Rudenko.

5. **Analcime** and **calcite** (a) with old label (b). 7 x 5 cm. Fersman Mineralogical Museum, RAS # 57082. Photo: Michael B. Leybov.

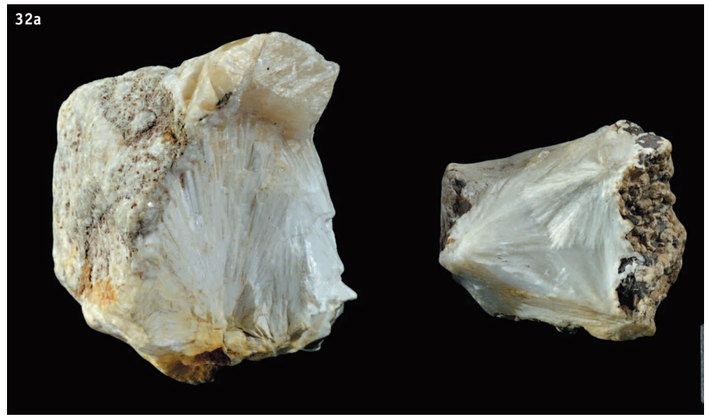
6. **Chalcedone** amygdala with pseudomorphs after zeolite spherulites in a cavity of amygdaloidal basalt. 6 x 3 cm. Karadag Bay. Sevastopol Museum of minerals # 2821.
Photo: Irina E. Rudenko.

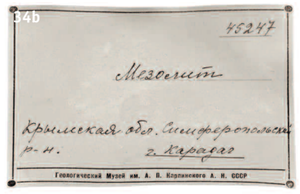
31. **Agate**. 7.5 x 3.5 cm. Karadag Bay. Sevastopol Museum of minerals # 2821. Photo: Irina E. Rudenko.

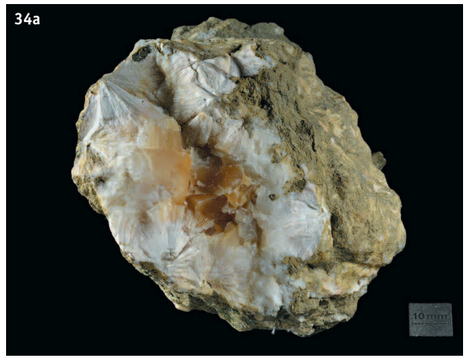
32. **Natrolite** (a) with old label (b). 2.5 x 2.5 cm and 4 x 3 cm. Fersman Mineralogical Museum, RAS # 11172. Photo: Michael B. Leybov.

33. Druse of **analcime** crystals (up to 0.5 cm). 7.0 x 6.5 cm. Coastal slope of the Karagach Ridge close to Kuzmichev Kamen Cliff. Sevastopol Museum of minerals # 1013. Photo: Irina E. Rudenko.

34. **Mesolite** (a) with old label (b). 9 x 10 cm. Fersman Mineralogical Museum, RAS # 45247. Photo: Michael B. Leybov.







morphology of magmatic bodies, relationships of igneous rocks each other and sedimentary complexes are described in-depth for the first time; and tectono-magmatic structures are systematically described in detail. The Karadag mineralogy in that book is very briefly described and is compiled from various literary sources.

The long-term metallogenic research of Ukraine, Crimea, and Black Sea supervised by the renowned Soviet and Ukrainian geologist Evgeniy Fedorovich Shnyukov, academician of the National Academy of Sciences of Ukraine, are reflected in some big reports (Shnyukov *et al.*, 1997, 1999, 2010). They give a detail description of gold-bearing disseminated-veinlet mineralization in propylitic-altered basalts and basaltic andesite and its ore and gangue minerals. Native gold, cinnabar, and molybdenite are observed at Karadag for the first time. Gusev (2014) reported new representative chemical data for the Karadag volcanic rocks, which are trachybasalt, basaltic andesite, trachyte, dacite, rhyodacite, trachydacite, and rhyolite.

Since the early 2000s, the geology and mineralogy of Karadag has been actively studied by the authors of this article. The list of the Karadag minerals (Tishchenko, 2009) and report on the Crimea minerals including a detailed description of the minerals found at Karadag (Tishchenko, 2015) were published. As a result of field trips in 2016–2019, identification of many Karadag minerals was revised and the new data on their morphology, chemical composition and paragenetic assemblages were obtained for the first time. We identified the following minerals at Karadag for the first time: aluminite, halite, heulandite-Na, apophyllite-(KOH), julgoldite-(Fe^{3+}), clinoptilolite-Ca, clinoptilolite-Na, rozenite, sideronatrite, szomolnokite, stellerite, stilbite-Na, thenardite, felsőbányaite, ferrisaponite, chamosite, erionite-K, erionite-Na (Tishchenko *et al.*, 2017, 2018; Tishchenko, Kasatkin, 2020; Kasatkin, 2021). Kasatkin (2021) identified meta-aluminite in the collection of I.E. Rudenko, Sevastopol Museum of minerals. Further mineralogical study of Karadag is expected.

Notes on Geology of Karadag

The Karadag geology has been studied for over 100 years. Researchers' views on its stratigraphy and tectonics are still controversial and debatable. For example, volcanic

35. Section of **chalcedony** (carnelian) – **quartz** veinlet. 8 x 2 cm. Levinson-Lessing Cliff area. Sevastopol Museum of minerals # 2722. Photo: Irina E. Rudenko.

Table 1. ***Karadag minerals***

Mineral	Formula	1		2	3
		1.1	1.2		
Elements					
Copper	Cu		+		
Gold	Au		+		
Silver	Ag		+		
Sulfides					
Arsenopyrite	FeAsS		+		
Galena	PbS		+		
Chalcopyrite	$CuFeS_2$		+		
Cinnabar	HgS		+		
Marcasite	FeS_2		++		
Molybdenite	MoS_2		+		
Pyrite	FeS_2		+++		
Sphalerite	ZnS		+		
Halides					
Halite*	NaCl				+
Oxides					
Corundum	Al_2O_3	+			
Hematite	Fe_2O_3		+++		+++
Hercynite	$FeAl_2O_4$	++			
Ilmenite	$FeTiO_3$	+++			
Magnesioferrite	$MgFe_2O_4$	++			
Magnetite	$Fe^{2+}Fe^{3+}_2O_4$	+++			
Opal	$SiO_2 \bullet nH_2O$		+++		
Quartz	SiO_2	+++	+++		
Rutile	TiO_2	+			
Hydroxides					
Goethite	$Fe^{3+}O(OH)$		+++	+++	+++
Lepidocrocite ?	$Fe^{3+}O(OH)$				+
Manganite ?	$Mn^{3+}O(OH)$				+
Carbonates					
Ankerite ?	$CaFe(CO_3)_2$		++	++	
Aragonite	$CaCO_3$		+		
Calcite	$CaCO_3$		+++	+++	+++
Dolomite	$CaMg(CO_3)_2$		++	++	
Malachite	$Cu_2(CO_3)(OH)_2$				+
Siderite	$FeCO_3$		++	+++	
Strontianite	$SrCO_3$		+		
Sulfates					
Aluminite*	$Al_2(SO_4)(OH)_4 \bullet 7H_2O$				+
Baryte	$BaSO_4$		+		
Felsőbányaite*	$Al_4(SO_4)(OH)_{10} \bullet 4H_2O$				+
Gypsum	$CaSO_4 \bullet 2H_2O$			+++	+++
Jarosite	$KFe^{3+}_3(SO_4)_2(OH)_6$		+		+
Meta-aluminite*	$Al_2(SO_4)(OH)_4 \bullet 5H_2O$				+
Natrojarosite	$NaFe^{3+}_3(SO_4)_2(OH)_6$			+++	+++
Rozenite*	$FeSO_4 \bullet 4H_2O$				+
Sideronatrite*	$Na_2Fe^{3+}(SO_4)_2(OH) \bullet 3H_2O$				+
Szomolnokite*	$FeSO_4 \bullet H_2O$				+
Thenardite*	Na_2SO_4				+

Mineral	Formula	1		2	3
		1.1	1.2		
Phosphates					
Fluorapatite	$Ca_5(PO_4)_3F$	+++			
Silicates					
Aegirine-augite	$(CaNa)(Fe^{3+},Mg,Fe^{2+})Si_2O_6$	+			
Analcime	$NaAlSi_2O_6 \bullet H_2O$		+++	+	
Anorthoclase	$(Na,K)AlSi_3O_8$	++			
Apophyllite-(KOH)*	$KCa_4Si_8O_{20}(OH,F) \bullet 8H_2O$		+		
Augite	$(Ca,Mg,Fe)_2Si_2O_6$	+++			
Biotite	$K(Mg,Fe)_3AlSi_3O_{10}(OH)$	+			
Celadonite	$KMgFe^{3+}Si_4O_{10}(OH)_2$		+++		
Chabazite-Ca	$Ca_2[Al_4Si_8O_{24}] \bullet 13H_2O$		++		
Chamosite*	$(Fe^{2+},Mg,Al,Fe^{3+})_6(Si,Al)_4O_{10}(OH,O)_8$		+		
Chlorites (group)		+++	+++		
Clinoptilolite-Ca*	$Ca_3(Si_{30}Al_6)O_{72} \bullet 20H_2O$		+++		
Clinoptilolite-Na*	$Na_6(Si_{30}Al_6)O_{72} \bullet 20H_2O$		++		
Dachiardite-Ca	$(Ca,Na_2,K_2)_5Al_{10}Si_{38}O_{96} \bullet 25H_2O$		+		
Datolite	$CaB(SiO_4)(OH)$		+++		
Dickite ?	$Al_2(Si_2O_5)(OH)$		+		
Diopside	$CaMgSi_2O_6$	++			
Epidote	$Ca_2(Al_2Fe^{3+})[Si_2O_7][SiO_4]O(OH)$	++	+		
Epistilbite ?	$Ca_3[Si_{18}Al_6O_{48}] \bullet 16H_2O$		+		
Erionite-Ca*	$Ca_5[Si_{26}Al_{10}O_{72}] \bullet 30H_2O$		++		
Erionite-K	$K_{10}[Si_{26}Al_{10}O_{72}] \bullet 30H_2O$		++		
Erionite-Na*	$Na_{10}[Si_{26}Al_{10}O_{72}] \bullet 30H_2O$		++		
Faujasite (series) ?			+		
Ferrisaponite*	$Ca_{0.3}(Fe^{3+},Mg,Fe^{2+})_3(Si,Al)_4O_{10}(OH)_2 \bullet 4H_2O$		++		
Ferroceladonite	$KFe^{2+}Fe^{3+}Si_4O_{10}(OH)_2$		+		
Ferrosaponite	$Ca_{0.3}(Fe^{2+},Mg,Fe^{3+})_3(Si,Al)_4O_{10}(OH)_2 \bullet 4H_2O$		+		
Ferrosilite	$Fe^{2+}_2Si_2O_6$	++			
Fluorapophyllite-(K)	$KCa_4Si_8O_{20}F \bullet 8H_2O$		++		
Gmelinite-Ca	$Ca_2(Si_8Al_4)O_{24} \bullet 11H_2O$		+		
Halloysite-10Å	$Al_2Si_2O_5(OH)_4 \bullet 2H_2O$	++			
Heulandite-Ca	$(Ca,Na,K)_9(Si_{27}Al_9)O_{72} \bullet 26H_2O$		+++		
Heulandite-Na*	$(Na,Ca,K)_6(Si,Al)_{36}O_{72} \bullet 22H_2O$		+++		
Julgoldite-(Fe^{3+})*	$Ca_2Fe^{3+}Fe^{3+}_2(Si_2O_7)(SiO_4)O(OH) \bullet H_2O$		+		
Kaolinite	$Al_2(Si_2O_5)(OH)$				+
Laumontite	$CaAl_2Si_4O_{12} \bullet 4H_2O$	+++	++		
Mesolite	$Na_2Ca_2(Si_9Al_6)O_{30} \bullet 8H_2O$		+++		
Montmorillonite	$(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2 \bullet nH_2O$		+++		
Mordenite	$(Na_2,Ca,K_2)_4(Al_8Si_{40})O_{96} \bullet 28H_2O$		+++		
Muscovite	$KAl_2(Si_3Al)O_{10}(OH)_2$	+			
Natrolite	$Na_2(Si_3Al_2)O_{10} \bullet 2H_2O$		+++		
Orthoclase	$K(AlSi_3O_8)$	++			
Plagioclases (series)		+++			
Prehnite	$Ca_2Al(Si_3Al)O_{10}(OH)_2$		+++		
Sanidine	$K(AlSi_3O_8)$	++			
Scolecite	$Ca(Si_3Al_2)O_{10} \bullet 3H_2O$		++		
Stellerite*	$Ca_4(Si_{28}Al_8)O_{72} \bullet 28H_2O$		+++		
Stilbite-Ca	$NaCa_4(Si_{27}Al_9)O_{72} \bullet 28H_2O$		+++		
Stilbite-Na*	$Na_9(Si_{27}Al_9)O_{72} \bullet 28H_2O$		+		
Thomsonite-Ca	$NaCa_2(Al_5Si_5)O_{20} \bullet 6H_2O$		++		
Titanite	$CaTiSiO_5$	+			
Tremolite ?	$\square Ca_2(Mg_{5.0-4.5}Fe^{2+}_{0.0-0.5})Si_8O_{22}(OH)_2$	+			

Notes:

1. Minerals of volcanic rocks:
1.1. Rock-forming and accessory minerals;
1.2. Minerals of hydrothermal-metasomatic zones, hydrothermal veins, and filling cavities in amygda-loidal rocks;
2. Minerals of concretions from sedimentary rocks;
3. Supergene minerals.

Abundance:

(+++) common;
(++) subordinate;
(+) rare.
(*) minerals identified by the authors;
(?) questionable identification.