McSwiggen & Associates

Applications

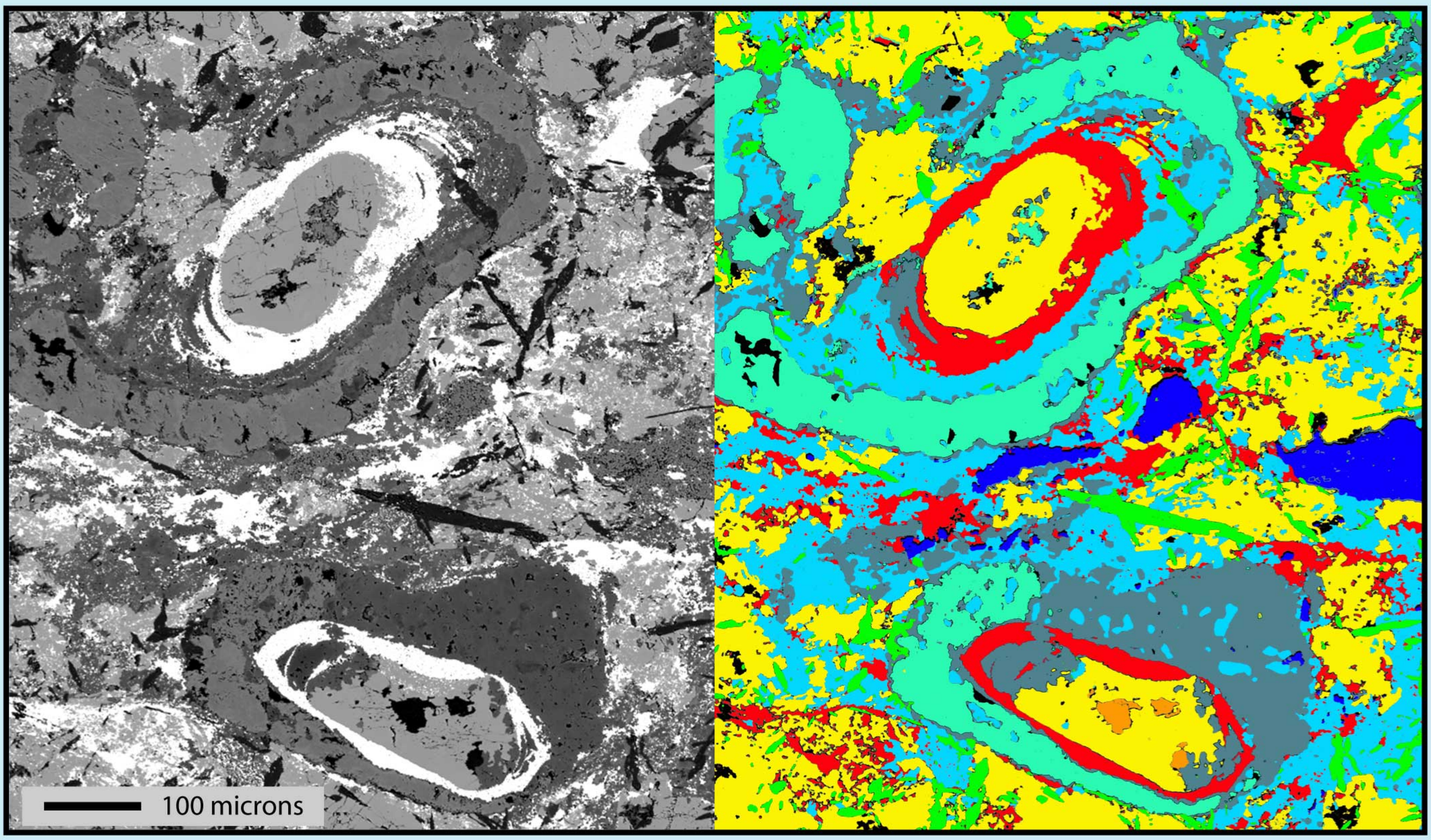
Mineral Characterization: Cuyuna Iron Range

The Cuyuna iron range of east-central Minnesota has traditionally been considered a Lake Superior-type iron-formation. However it is unique in the Lake Superior region due to the high manganiferous content of its iron ores. Recent investigations have also identified the presence of such minerals as aegirine, barite, Ba-feldspar (hyalophane), and tourmaline. This association with the iron-formation implies that there were hydrothermal or exhalative processes underway during the deposition of the iron-rich sediments. This in turn has significant implications for mineral exploration in this part of Minnesota, suggesting the possibility of sediment-hosted, submarine exhalative Pb-Zn-Ag deposits.

Unraveling the paragenetic sequence of these rocks, and understanding the processes by which they were deposited, is difficult due to the complexity of the mineral associations. Below is a backscattered electron image and mineral map of a sample from an aegirine-rich unit in the Trommald Formation — the principal iron-formation of the Cuyuna North range. The mineral map was constructed from individual element maps collected simultaneously with the backscattered electron image on a JEOL electron microprobe. The two images show the complexity of the mineral textures. The prominent features in the mapped area are two spheroidal structures, which have been described in the literature as oolites, but which have physical attributes similar to oncolites. The upper feature has a core of mostly rhodonite which is surrounded by hematite. That in turn is surrounded in succession by the Ba-feldspar, hyalophane, and then by the Mn-carbonate, rhodochrosite. The coatings of hyalophane have an enigmatic paragenesis, but must represent periods of barium, aluminum, and silica depositions on pre-existing grains. The fact that the hyalophane coating surrounds a hematite coating and is in turn surrounded by

Backscattered Electron Image

Mineral Map



aegirine - $NaFe^{3+}Si_2O_6$
hyalophane - $(K, Ba)Al(Si, Al)_3O_8$
K-feldspar - $KAlSi_3O_8$
hematite - Fe_2O_3
calcite - $CaCO_3$
rhodonite - $MnSiO_3$
rhodochrosite - $MnCO_3$
kutnahorite - $CaMn(CO_3)_2$

McSwiggen & Associates ◆ 2855 Anthony Lane South ◆ Suite B1 ◆ St. Anthony ◆ MN ◆ 55418 ◆ 612.781.2282

rhodochrosite, indicates that these phases or their precursors were deposited from a very complex and changing aqueous solution.

Below are quantitative electron microprobe analyses of selected minerals shown in the previous images. The hyalophane is a feldspar in which Ba has substituted for the K. In the samples, the feldspars contain from trace amounts of BaO to over 13 weight percent. The aegirine is a Na-rich pyroxene. It occurs in many different textural settings in these rocks and often occurs compositionally near its ideal end-member, though there are some substitutions with MnO and CaO. Rhodonite is a Mn-silicate, which in these rocks contains up to a few percent FeO, MgO, and CaO. There is a wide range of carbonates in these rocks, most of which are low in Mg, and fall predominantly within the ternary $CaCO_3$-$MnCO_3$-$FeCO_3$. In the upper member of the Trommald Formation, the carbonates are mostly rhodochrosite, kutnahorite and Mn-rich calcite. In the middle and lower members, the carbonates are more iron-rich and tend to be either manganiferous siderite or ferroan kutnahorite.

The abundance of manganese oxides on the Cuyuna North range has long proved to be an enigma. However, the occurrence of aegirine and hyalophane in the iron-formation, as well as associated barite and tourmaline within the stratigraphic section, suggests that the protoliths of these rocks have a significant exhalative hydrothermal component.

References:

McSwiggen, P.L., Morey, G.B., and Cleland, J.M, 1994a, The origin of aegirine in iron-formation of the Cuyuna Range, east-central Minnesota: Canadian Mineralogist, v. 32, p589-598.

_____ 1994b, Occurrence and genetic implications of hyalophane in manganese-rich iron-formation, Cuyuna iron range, Minnesota, USA: Mineralogical Magazine, v. 58, p. 387-399.

_____ 1995, Iron-formation protolith and genesis, Cuyuna Range, Minnesota: Minnesota Geological Survey Report of Investigation 45, 54p.

	K-feldpars	Hyalophane	
SiO_2	64.54	53.93	57.73
Al_2O_3	18.35	21.06	20.35
Na_2O	0.31	0.50	0.40
K_2O	16.48	10.66	12.44
BaO	0.14	13.31	9.22
Total	99.82	99.46	100.14

	Aegirine		
SiO_2	53.41	52.82	52.50
TiO_2	0.05	0.02	0.00
Al_2O_3	0.22	0.40	0.41
Cr_2O_3	0.03	0.04	0.00
Fe_2O_3*	28.19	31.28	32.95
FeO*	0.77	1.89	1.36
MnO	3.14	0.65	0.09
MgO	1.03	0.00	0.09
CaO	3.02	1.43	0.18
Na_2O	10.94	12.14	12.79
K_2O	0.00	0.02	0.01
Total	100.80	100.69	100.39

* Fe_2O_3 /FeO ratio determined from stoichiometry

	Rhodonite		
SiO_2	46.45	46.95	45.77
TiO_2	0.00	0.00	0.02
Al_2O_3	0.02	0.01	0.01
Cr_2O_3	0.00	0.03	0.04
FeO	0.00	0.00	2.81
MnO	50.59	49.90	47.03
MgO	0.69	1.60	1.20
CaO	1.83	1.88	3.38
Na_2O	0.01	0.01	0.00
K_2O	0.01	0.00	0.01
Total	99.60	100.38	100.27

	Rhodochrosite		Kutnahorite	
CaO	1.84	2.86	23.79	30.06
MgO	0.40	0.51	1.10	0.93
FeO	0.00	0.00	0.00	0.00
MnO	60.06	58.36	35.10	29.08
X_{CaCO_3}	0.037	0.057	0.448	0.553
X_{MgCO_3}	0.011	0.014	0.029	0.024
X_{FeCO_3}	0.000	0.000	0.000	0.000
X_{MnCO_3}	0.952	0.928	0.523	0.423

Quantitative electron microprobe analyses (reported as weight percent) of selected minerals in the Trommald Formation, Cuyuna iron range.