Indicator Mineral Analysis of Stream Sediments Bordering the North American Emerald Mine in Alexander County, North Carolina

Anabel G. Winitsky and Dr. Brittani D. McNamee
Department of Environmental Studies, University of North Carolina at Asheville, Asheville NC

INTRODUCTION

The North American Emerald Mine (NAEM), located in Alexander County, North Carolina, contains V-Cr-bearing beryl deposits that have produced the most valuable emeralds ever found in North America[1], and is the first confirmed location of Cr-bearing spodumene, known locally as hiddenite[2]. These emeralds occur within hydrothermal quartz veins in open cavities, in one of four distinct cavity types identified by Wise and Anderson that run throughout the Inner Piedmont Belts of Western North Carolina[3]. This project further analyzes the NAEM through an analysis of the dense stream sediments sampled from the Wallace Creek and the South Yadkin River, which converge in the southeast and border the mine site. Stream sediments are an excellent source of indicator minerals, which serve to provide geologic context, as they consolidate high density minerals and allow for their convenient recovery[4]. In this application, indicator minerals are used to identify potential emerald cavity locations along the fluvial systems.

METHODS

- Samples were collected using sluicing methods to obtain dense sediments from Wallace Creek and Yadkin River 11/2/2018.
- Glass slides of each sample were prepared with 1.560, 1.600, and 1.650 indicator liquids for visual and optical analysis by SLM and PLM.
- C-coated sprinkle mounts and polished epoxy grain mounts were prepared for visual analysis by SEM and compositional analysis by EDS.
- Polished epoxy grain mounts were further analyzed for compositional data by EMPA.

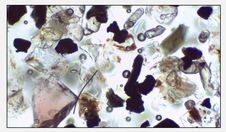

Fig. 6 Stereo photo of Sample 7 in epoxy

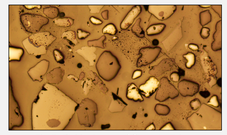

Fig 7: PLM photo of Sample 7 in epoxy

Wallace Creek

Minerals Confirmed Present: Rutile, tourmaline, pyrite, quartz, garnets (assortment, hybrids), plagioclase, amphibole, ilmenite, monazite, sillimanite, zircon

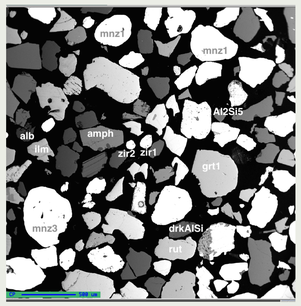

Fig. 1: EMPA image of epoxy grain mount NAEM3

Minerals Confirmed Present: Tourmaline, quartz, garnets (assortment, hybrids), amphibole, plagioclase, orthoclase, ilmenite, monazite, sillimanite, zircon

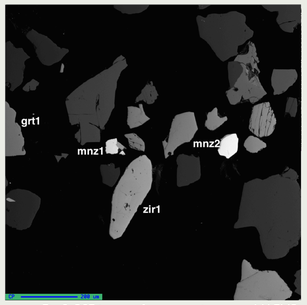

Fig. 3: BSE image of epoxy grain mount NAEM5

Study Area at NEAM

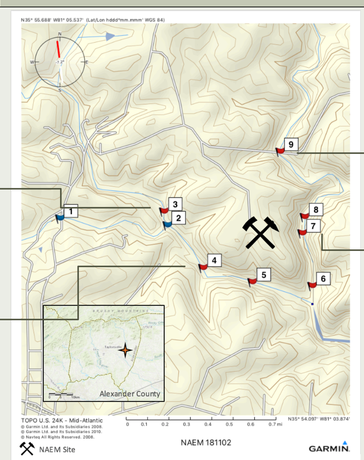

Fig. 5: Sample collection sites along Wallace Creek and Yadkin River bordering the North American Emerald Mine.

The Country Rock: Inner Piedmont Belt of Western North Carolina, middle and upper amphibolite facies metamorphic rocks comprised of deformed gneisses, migmatites and schists intruded by granitic and gabbroic plutons containing quartz, garnet, feldspar, biotite, apatite, titanite, diopside, trace sulfides and zircon[2,5].

The Cavities: Northeast oriented, sub-vertical fractures in hydrothermic quartz veins precipitating under relatively low pressure conditions within 230°C-290°C where brittle tensional fractures form in folded metamorphic rocks[3]. Emerald bearing cavities recorded by Wise and Anderson identified by presence of quartz, muscovite, dolomite, tourmaline, albite, zircon, monazite, apatite, beryl, rutile, siderite, calcite, and limonite[3].

Yadkin River

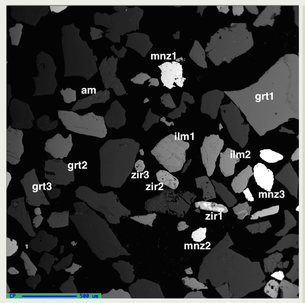

Fig. 2: EMPA image of epoxy grain mount NAEM9

Minerals Confirmed Present: Quartz, garnets (assortment, hybrids), amphibole, ilmenite, monazite, sillimanite, zircon

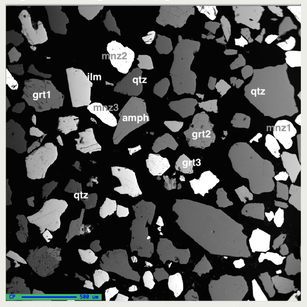

Fig. 4: BSE image of epoxy grain mount NAEM7

Minerals Confirmed Present: Quartz, garnets (assortment, hybrids), amphibole, plagioclase, orthoclase, ilmenite, monazite, sillimanite, zircon

Table 1: Selected zircon compositions from NAEM samples*

	3 ZIR1	3 ZIR2	9 ZIR1	9 ZIR3
Na2O	0	0.018	0.005	0.031
TiO2	0	0.083	0	0.056
CaO	0.012	0.016	0.012	0.027
MnO	0.023	0.041	0	0.022
MgO	0	0.026	0.013	0.002
V2O3	0	0.04	0	0
ZrO2	66.554	66.738	70.109	70.171
Al2O3	0.002	0	0.013	0.022
Cr2O3	0.014	0.027	0.034	0
P2O5	0	0	0	0
FeO	0.191	0.041	0.041	0.137
SiO2	33.203	32.97	29.773	29.531
Total	100	100	100	100

Table 2: Selected illmanite compositions from NAEM samples*

	3 ILM1	3 ILM2	9 ILM1	9 ILM2
Na2O	0	0	0.012	0.013
TiO2	57.111	56.068	36.576	51.479
CaO	0	0.01	0	0
MnO	1.563	0.329	2.315	2.23
MgO	0.481	0.149	0.086	0.318
V2O3	0.357	0.323	0.561	0.415
ZrO2	0	0	0.085	0
Al2O3	0.016	0	0.052	0.008
Cr2O3	0.028	0	0.076	0
SiO2	0.025	0	0.001	0.005
FeO	40.419	43.121	60.235	45.532
P2O5	0	0	0	0
Total	100	100	100	100

Table 4: Selected monazite compositions from NAEM samples

	3 MN1	3 MNZ2	5 MNZ1	5 MNZ2	7 MNZ1	7 MNZ2	9 MNZ1	9 MNZ3
Na2O	0	0	0	0	0	0	0	0
TiO2	0	0	0	0	0	0	0	0
Nd2O3	9.847	9.713	9.318	8.626	9.323	7.956	8.521	9.617
La2O3	12.011	13.389	11.288	12.28	11.878	10.122	12.775	11.793
MgO	0	0	0	0.001	0	0	0	0.016
V2O3	0	0	0	0	0	0	0	0
Pr2O3	4.168	4.656	4.033	4.149	4.286	3.554	4.284	4.133
Ce2O3	31.348	28.558	29.978	29.111	31.321	26.047	29.397	29.293
Al2O3	0	0.013	0.023	0	0	0	0	0.015
Cr2O3	0	0	0	0	0	0	0	0
CaO	1.204	1.124	0.806	1.14	0.793	1.43	1.056	1.098
MnO	0	0	0	0	0	0	0	0
FeO	0.056	0	0.09	0.037	0.019	0	0	0
P2O5	30.225	30.595	31.013	29.406	29.965	28.864	29.516	30.071
SiO2	0.209	0.119	0.231	0.338	0.251	0.292	0.561	0.249
ThO2	7.739	5.954	6.077	9.421	6.647	10.864	9.731	8.449
Total	96.807	94.121	92.857	94.509	94.511	89.204	95.841	94.734

* Reported in normalized weight%.

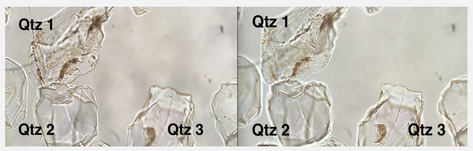

Fig. 7: Quartz sediments with beck lines moving from the mineral (left) to the RI liquid (right)

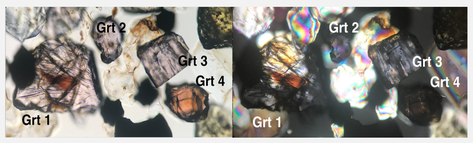

Fig. 8: Garnet sediments showing coloration (left) and isometric extinction (right)

Fig. 8: Bill Miller sluicing in Wallace Creek, 11/2/2018.

Fig. 9: Bill Miller sluicing in Yadkin River, 11/2/2018.

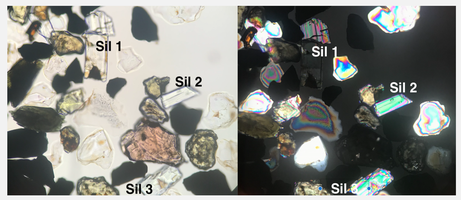

Figure 9: Sillimanites in field (left) showing parallel extinction (Sil 1, right) and lack thereof (Sil 2 and Sil 3, right)

Figure 10: Single rutile crystal seen with a stereo light microscope.

CONCLUSION

This work further characterizes the indicator minerals of the host rock and within the four cavity types present at NAEM site. Specimen location is correlated to previous research to determine presence of cavities in river path/deposition area.

- Quartz, assorted garnets, amphiboles, ilmenite, sillimanite, monazite and zircon were found in all samples
- Garnets vary with almandine, spessartine, grossular hybrids common throughout samples.
- Zircons vary in trace element presence throughout samples.
- Monazites (Ce, La, Nd, Th) had consistently higher La and lower Nd (averaging 11.7:8.9 w/w%), inverse to ratios previously found in emerald cavities by Wise and Anderson[3] throughout samples.
- Ilmenites with higher Cr, and V present in Yadkin River.
- Tourmaline presence in sample 5 may indicate cavity presence which may have come from previously explored mine site.
- Rutile and tourmaline presence in 3 may indicate cavity presence along Wallace Creek north of mine site.

FUTURE RESEARCH

Research is ongoing. Future research may include:

- Continuing SEM and EDS analysis with a focus on detection of Cr/V-beryl and Cr-spodumene.
- Spindle stage analysis of individual crystals to further confirm and determine indicator minerals present.
- Bulk phase analysis to determine relative mineral concentrations in the fluvial systems.
- Further EMPA analysis for more complete compositional data and comparative analysis.

REFERENCES

1. Speer, W. E. (2009). North Carolina famous for north America's largest emeralds. Mining Engineering, 61(6): 83-87.
2. Charles Palache, S. C. Davidson, E. A. Goranson (1930). The hiddenite deposit in Alexander County, North Carolina. American Mineralogist, 15 (8): 280–302.
3. Wise, M. A., Anderson A.J. (2006) The emerald- and spodumene-bearing quartz veins of the Rist emerald mine, Hiddenite, North Carolina. The Canadian Mineralogist, 44 (6): 1529–1541.
4. McClenaghan, M.B. (2005). Indicator mineral methods in mineral exploration. Geochemistry Exploration Environment Analysis. 5(3): 233-245.
5. Wise, M. A. (2009). Chabazite in spodumene-bearing alpine-type fissure veins from hiddenite, North Carolina, USA. Mineralogy and Petrology, 96(3-4): 213-220.

ACKNOWLEDGEMENTS

We would like to thank the following individuals and organizations for their contributions: Bill Miller for his assistance with the project and sample collection, Bob Bodner at the Virginia Tech Department of Geosciences for his assistance with the project, the UNCA Environmental Studies Department for use of their facilities and equipment, the UNCA Undergraduate Research Center for their support of and grant funding for this project, and the Florida center for Analytical Electron Microscopy at the Florida International University, with a special thanks to Tom Beasley, the center's technician, for his assistance with microprobe analysis.