8.0 DEPOSIT TYPES

8.1 *Laterite Deposits*

The laterite deposits at Mada were formed by prolonged tropical weathering of minerals in an ordinary serpentinite. Laterization is largely a chemical process whereby ground water and biological processes interact on exposed serpentinites, resulting in the concentration of certain elements in the soil profile (e.g., Fe, Al, Co, Ni, Cr, Mn) while dissolving and removing other elements (e.g., Mg, Ca, Si). The intensity of weathering is a function of time, climate, and bedrock characteristics (composition, fracturing, etc). Sulfide minerals are typically not common in serpentinites, and did not play a significant role, if any, in the formation of the enriched cobalt-nickel profiles. This minimal sulfide content is in stark contrast to many other cobalt and nickel deposits such as in the African Copper Belt (Zaire and Zambia), Sudbury, Thompson and Raglan (Canada), Norilsk (Russia), Bou Azzer (Morocco), and others, which were formed by magmatic and/or hydrothermal processes wherein the presence of sulfide minerals is of supreme importance.

Iron is less soluble in the lateritic environment, and is enriched in the zone above the saprolite. The degree of iron enrichment and leaching of silica and magnesia results in the eventual formation of limonite layers rich in goethite that eventually collapses under their own weight to form the capping ferricrete breccias and overlying granular laterite zones. Only in the saprolite and transition zones is iron largely in a reduced state. Clay minerals may form from the weathered serpentinites, and adjacent schists at Mada. Secondary silica and nickel minerals may occur in fractured portions of the serpentinite (e.g., opal and garnierite).

Mada, like Nkamouna and the other Geovic laterites, is unusual with respect to the abundance and coarseness of asbolane; the low Ni:Co ratio, the low MgO content of the Lower Limonite, the abundance of kaolinite instead of smectite, and the presence of a well-developed ferricrete breccia horizon sandwiched between the Upper Laterite and Lower Limonite.

These features are consistent with great age and episodic formation of the Mada profile. Weathering of the ultramafic rocks in Cameroon most likely occurred during Cenozoic time, although precise dating is not possible due to the absence of Cenozoic rocks in the region other than very young alluvium. In any case, while the age of laterization is not well-constrained, it suffices to say that the laterite characteristics at Mada suggest a long period of laterization. Encroachment and incision of the Zaire (Congo) River tributaries (e.g., Sangha, Dja and Boumba Rivers) may have lowered the erosional base levels, as reflected in episodic formation and destruction of the ferricrete and other laterite units.

Though unusual by having several distinct features, the Cameroon laterites share similarities with other nickel-cobalt laterites found around the world (e.g., Western Australia, New Caledonia, Indonesia, Philippines, Cuba). The Cameroon deposits are unusual in their low magnesium content, high cobalt to nickel ratio, coarsely aggregated asbolane mineralization, abundance of maghemite, and occurrence of ferricrete breccias. Also significant is the concentration of most of the cobalt mineralization in the lower ferricrete breccia and upper portion of the ferralite zone. In other laterite deposits, cobalt is usually concentrated in the lower-most portion of the ferralite and upper saprolite zones.

The ultramafic rocks that source the Mada mineralization (i.e., sepentinite) originally contained the mineral olivine. The olivine in serpentinites of lower-crust origin typically contain 0.3 to 0.4 percent nickel and near 0.01 percent cobalt, in partial substitution for magnesium in the olivine formula $(Mg,Fe,Ni)_2SiO_4$. Upon serpentinization and weathering of the olivine-bearing rock, cobalt and nickel are released as the olivine is destroyed, but are usually re-captured in other minerals formed at the same time, such as asbolane, nontronite clays, garnierite, and others. Other factors tending to localize mineralization include the permeability of the host rock, foliation and fracturing of the basement rocks, and the water table(s).

The other major constituents of serpentinites, MgO, SiO_2, and FeO, are also released by weathering. The FeO is oxidized to Fe_2O_3 which is highly insoluble, and remains as an iron-rich surficial laterite soil. The MgO and SiO_2 are usually mobilized several meters in the percolating water, and are re-deposited at varying distances as clays, silica, and other minerals. Their specific behavior depends on the chemistry and pH of the interacting water and rock.

Resistant minerals such as chromite and micas if present (e.g., phlogopite and chlorite) tend to remain intact in the weathering profile, and to some degree are concentrated in the weathered residuum, as other constituents are selectively removed. Mafic rocks not containing appreciable amounts of olivine, such as gabbro and pyroxenite, do not normally contain much nickel and cobalt, and thus do not give rise to significant nickel-cobalt enrichment during weathering.

The cobalt-nickel-bearing weathering profile at Mada has been mostly preserved due to the resistant ferricrete breccia cap and low topographic relief. The surface relief over the Mada laterite deposit is not much more than 90 meters (680-770 meters above sea level), except at the outer margins, where active erosion is occurring and surface elevations locally fall below 700 meters, and where quartzite capped ridges exceed 800 meters.

8.2 *Alluvial Deposits*

Neither Geovic nor PAH are aware of any concentrations of valuable metals in streams draining the ultramafic massifs. While some fine-grained magnetite and black MnO concretions were observed in some streams draining the massif, along with chromite, these occurrences are not present in economic concentrations or tonnages. There is no known panning of gold or platinum-group metals in the region.