Geology and Nickel-Laterite Weathering Deposit in the Southeast Arm of Sulawesi

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Introduction

Nickel-Laterite deposits are derived from ultrabasic bedrock after undergoing prolonged chemical erosion at a greater rate than mechanical erosion. In describing the origin of Ni-laterites, it is logical to proceed from a consideration of the bedrock type and their origin in order to define the occurrence and distribution in space and time, prior to determining favorable weathering environment and detail profiles of its mineralogical and chemical conditions.

Principal occurrences of Ni-laterites in Sulawesi coincide with two northwest trending belts of ultrabasic rock and derived sediments. The first trend is the southwest belts from Sua-sua through Pomalaa and Torobulu to the island of Wawoni. The second trend is the northeast belt runs from Malili and Kolonodale at north end of the arm to Lasolo on the east coast.

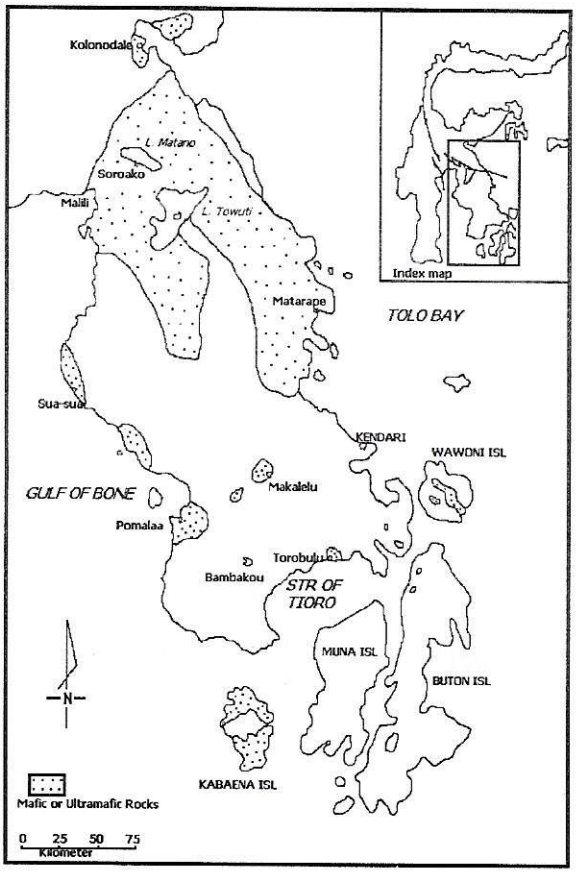

Fig 1: Distribution of mafic and ultramafic rocks in Southeast Sulawesi

Regional Setting

Sulawesi is characterized by the surface occurrence of two major areas in which each is marked by different igneous rock assemblages. Granite and granodiorite associations are widely distributed in the western arc, whereas the absence or scarcity of granitic rocks and the abundance of mafic and ultramafic rocks characterizes the eastern arc.

Large ultramafic complexes are extensively distributed on the east arm and the northern part of southeast arm (Figure 1). The ultramafic intrusions on the east arm occur as slightly curving elongate bodies with their convex side to the north. The strike of these bodies is parallel to the strike of the closing rocks and dominant structural trend in the area.

The southwestern arm comprises of a southeast trending string of plutons with relatively small outcrop area each. The trend starts at Sua-sua on the east coast of the gulf of Bone and continues along the shore to Pomalaa. At Pomalaa, the trend branches; one branch is going east across the peninsula toward Kendari embracing ultramafics near Andowenggo, Makalelu, and Benua. The other branch continues southeast through G. Watumohai and Bombakou to the vicinity of Torobulu on the strait of Tioro. The two branches rejoin at the southeast corner of the peninsula around the strait of Wawoni where there are numerous small ultramafic bodies, both on the Wawoni Island and the mainland.

Ultrabasic Rocks And Mesozoic Sediment

Geologically the southeast arm of Sulawesi is complex. Intimately mixed ultrabasic rocks and Mesozoic sediment of Middle Miocene subduction melange of eastern Sulawesi rest against the presumably pre or early Triassic metamorphic complex of eastern Central Sulawesi. The rocks have been further deformed by the development of the major faults and secondary fractures within the area. The various

rock types have responded differently to this deformation.

The Mesozoic rock areas of the Matano Lake and its surrounding are part of the largest Mesozoic rock complex in eastern Sulawesi. On the east coast, the Mesozoic outcrops, which are found in north of Kolonodale and south of Bahodopi, are also part of greater Mesozoic rock complexes. In northeast of Matano Lake and east of Towuti Lake, the Mesozoic rocks are exposed generally as disconnected elongated bodies within the large ultrabasic massif of Verbeek Mountains. In Soroako area, the Mesozoic sediment is thrusted over the ultrabasic. Koolhoven (1932) divides the Mesozoic into Upper and Lower Matano Beds and assigns them in Cretaceous age.

The occurrence of serpentinite at the contact between Mesozoic sediments and ultrabasic rocks has been observed in the western and southern parts of Soroako area and at the southern limit of the Mesozoic complex in the south of Wasuponda. In both areas, the Mesozoic sediments are thrusted over the ultrabasics. The ultrabasic rocks of the Lakes Area are massive, and as a general rule, harzburgites and lherzolites are serpentinized in varying degrees. The unserpentinized peridotites of Soroako and Matano areas and the completely serpentinized peridotites at the periphery of the ultrabasic bodies are some exceptions. Basic and intermediate rocks are conspicuously lacking from this part of Sulawesi and occur only in the form of occasional dikes.

At both Pomalaa and Soroako, undoubted molasse-type conglomerates and greywackes are found over considerable areas. They are, at least in their coarse fractions, of totally ultramafic derivation. The conglomerates tend to have a porous sand matrix that is often filled by supergene silicate precipitates (including garnierite). The boulders or cobbles tend to be well rounded, imbricated ellipsoids commonly partly serpentinized and almost invariably serpentinized around their margins. The sand fractions in greywacke are mostly subrounded serpentine particles or partly serpentinized pyroxenes and amphiboles with occasional grains of picotite. The pore space is filled by isotropic serpentine.

It has been suggested that the mature appearance of the molasse conglomerates which have odd mineralogy of which would not normally support lengthy mechanical abrasion in the process of transport, can be attributed to a prehistory of preparation as tectonic breccia fragments. Conglomerates and greywackes at Pomalaa are very thoroughly consolidated and provide the impression of substantial age in comparison to those along the base of the fault scrap along the north shore of Matano Lake which are virtually unconsolidated.

The Laterite Profile

In general, the following zones may be recognizable in a lateritic weathering profile. The basal zone weathered rock or saprolite is often followed above by a quartzose zone of mixed soft saprolite and limonite characterized by abundant quartz veinlets and boxwork. Above this, the zone of nickeliferous clayey limonite is topped by an "iron-capping" of colloform goethite. In practice, the above members usually are not all present. Iron-capping is normal restricted to exceptionally flat plateau areas that are well removed from sites of active mechanical erosion. The limonite layer is often reduced to less than a meter; it contains evidence of mechanical transport.

The quartzose boxwork "horizon" is extremely variable in development and may be completely absent. It occasionally outcrops on the shoulder or crests of hills. Outcrops of ultrabasic rock on the shoreline of Matano Lake are usually strewn with "boulders" of silica boxwork. Saprolite is the only member of the residual profile invariably present. The somewhat ideal sequence above is, of course, frequently complicated by features of sedimentary origin as described in the previous section.

In general, the mineralogy of each zone is listed in Table 1. The saprolite zone contains both fresh and weathered bedrock minerals, supergene minerals apparently precipitated by solutions, which are derived from higher levels in the profile, and limonite as the first newly formed residual mineral. The supergene veinlets minerals comprise garnierite, asbolite, and quartz. In some coastal laterite deposits, colloform magnesite and opaline silica occur in this zone.

The silica boxwork zone appears to be chiefly the leached equivalent of the supergene veinlets that is found deeper down in the voids between the veins in limonite. Asbolite or lithiophorite is often prominent in this zone. Generally, in the fieldwork, black powdery phases are referred to as asbolite or wad and usually denoted "Mn" in field notes. The term lithiophorite on the other hand is only used after X-ray diffraction identification.

ZONE	MINERALOGY
Iron-Capping	Concretionary Nickeliferous-Aluminous Goethite (M), Hematite (t m), Chromiferous Picotite (m A).
Limonite Zone	Nickeliferous-aluminous goethite (M), Lithiophorite (m), Talc (t m), Tremolite (t m), Chromiferous Picotite (m), Ferro-nickel alloy (t), Quartz (t m), Maghemite (t m), Gibbsite (t).
Silica-boxwork	Same assemblage as Saprolite and Limonite but with Quartz (A M), Lithioporite (Wad) (m), Opal (t m), Magnesite (t m).
Saprolite	Supergene Vein Minerals Garnierite (t m), Quartz (t A), Asbolite (t), magnesite. Weathered Primary Minerals Nickel-iron bearing serpentine (t M), Maghemite (t m), Nickeliferous chlorite (schuchardite) (t m). Neo-formed Weathering Products Nickeliferous-Limonite. + Unaltered residual bedrock minerals.
Bedrock	(t A), Chromiferous picotite (m), Serpentine (m M), Magnetite (t m), Talc (t m), Tremolite (t m).
Peridotite	Olivine (m M), orthopyroxene (m A), clinopyroxene

KEY:
M – major phase
A – abundant phase
m – minor
t – trace

Table 1: The mineralogy of each zone in a lateritic weathering profile

The limonite zone is largely a fine-grained nickeliferous aluminous goethite. All the least stable bedrock minerals, i.e. the ones with relatively high magnesium or alkali to silicon ratios such as serpentine and olivine, have been leached out.Primary talc, tremolite, chromian spinels, and oxidized magnetite or ferronickel alloy can persist at this level, but pyroxenes are rare. In gross mineralogy the ironcapping is similar to the underlying limonite, differing chiefly in relatively small amounts of residual bedrock minerals and in the concretionary pisolitic or wormy-textured coarse-grained goethite. Cr-spinels appear to have begun to dissolve and convert to limonite with networks of hematite grains, and grains of hematite are also found in some coarse-grained goethite.

Figure 2 shows general of the chemical constitution and classification of bore hole sample from Soroako area. The bedrock is mixture of serpentine and lenses of very highly but irregularly serpentinized lherzolite between shear zones containing fine grained slickensided serpentinite. Shear zones commonly form the boundary between relatively highly or slightly weathered saprolite or higher up between limonite and saprolite. The saprolite here is largely nickeliferous serpentine with up to 4 % Ni, with minor limonite, asbolite, talk, quartz, two pyroxenes, maghemite, and picotite. The limonite zone is dominantly finer goethite. Talc and quartz are detected here as well as minor amounts of lithophorite and hard pisolites of goethite. The extremely fine grain size of most limonitic mud makes attempt to separate the major constituents very difficult. Iron capping is totally absent at this location as it is on all hilltops in this region. Concretionary goethite (pisolites) in the form of nodules described above is minor features only.

In current understanding, the ultramafic rocks and superincumbent laterites of Southeast Sulawesi are still rather vague. This is in part a result of the great physical size of the exploration area, aptly illustrated by the enormous outcrop in Figure 1 and by the inherent diversity of types of bedrock and laterization history.
Immature ultramafic-derived breccias, conglomerates, and graywackes are commonly the hosts of laterite profiles, although these tend to be relatively thin. Wide variation in the degree of consolidation of conglomerates suggests, however, that they may be widely variable in absolute age. Those north of Matano Lake, for example, are being virtually uncemented and those of Pomalaa are strongly consolidated.

Relatively mature detrital sediments (clay, sand, etc.) of both ultramafic and other origin may have any age relation to laterite. Lateritic materials are found both below and interbedded with such sediments. Absolute dating of the stages of sedimentation and laterization are hindered by the frequently unfossiliferous nature of the sediment. This might be an interesting subject for cautious paleontological investigation.

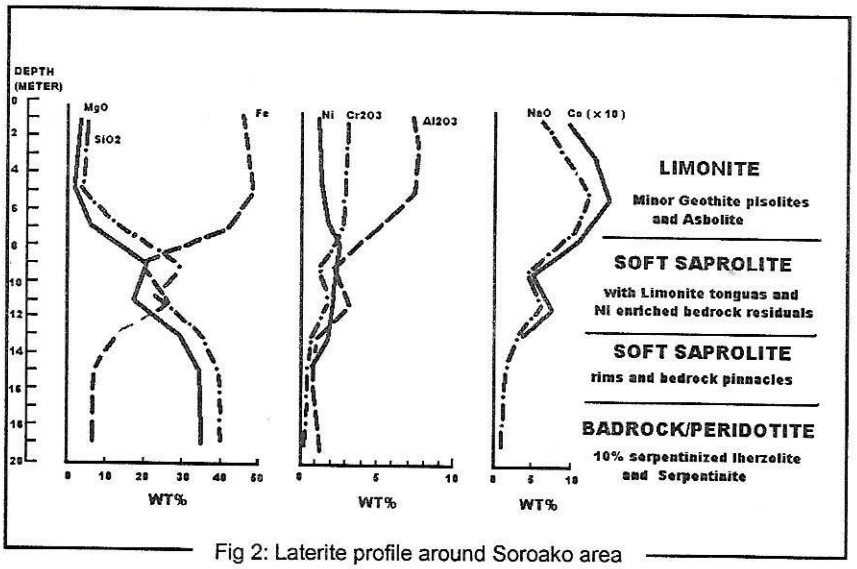

Fig 2: Laterite profile around Soroako area

However, because there has been no research for microfossils, pollen, etc. made internally since it seems to have little direct relation to the primary focus of nickel exploration.
Knowledge of the bedrock is hindered by the interesting deposits over it, although it can be inferred from the petrology to identify its major bodies as up-thrusted fragments of upper mantle peridotite. The relative timing of somewhat mature land surface for laterization and sedimentary events is only partially known.

Conclusions

In summary, the rocks within the southeast arm of Sulawesi area range from pre-Mesozoic crystalline schists to Late Tertiary and Quaternary sediments. Major part of the area is covered by melange of ultrabasic rocks and Mesozoic sediments. It is believed that subduction on a westward dipping benioff zone east of Sulawesi has been going on from Cretaceous to Early Miocene period (Hamilton, 1970). The halting of this subduction around Middle Miocene (as a result of the buoyant Banggai Islands entering the subduction zone, Hamilton, 1970) started an isostatic rebound which eventually brought the subduction melange consisting of ultrabasics and intimately associated Mesozoic sediments to the surface. The uplifting is still continuing as is evidenced by elevated coral reefs all along the coasts of East and Southeast Sulawesi.
Most of the laterite investigated appears to be in-situ residual laterite bearing a strong resemblance mineralogically to other activity developing laterite profiles in such places as Southeast Sulawesi. It is typical of equatorial laterites in its relatively slight development of ironcapping and siliceous horizons.

The saprolite zone mineralogically and chemically is zone of rapid removal of alkaline earth elements by leaching, residual concentration of ferric iron, alluminium, and chromium, and supergene enrichment of nickel, cobalt, and manganese in leached primary hydrated silicates such as serpentine, talc, and chlorite, and newformed saponite or garnierite. The mineralogy of the in-situ sections is also compatible to a relatively high stability under the profile leaching conditions of more siliceous silicate minerals. This is apparent in Soroako profile for example as residual concentration upward in the profile; the same tendency is seen the neo-formed minerals (quartz and garnierite) are both more siliceous than serpentine. The quartz boxwork persists upward to a higher in the profile than the garnierite.

References

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