Geochemistry and mineral exploration

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Mineral exploration is a multi-disciplinary team effort, in which conceptual geological thinking and traditional geological field work play leading roles. Geochemistry, when properly integrated into the process, is a key component for exploration, from initial targeting through to resource definition.

Anglo American's base metal discovery track record over the past decade (including ten significant discoveries) illustrates this point, where so-called conventional geochemical techniques played an important role in many of those discoveries.

Stream sediment geochemistry in areas of well developed topography, and soil geochemistry in areas of residual soil profiles are very effective techniques and played a role in the discoveries of the Morro Sem Boné Ni-laterite deposit, Brazil, and the Boyongan Porphyry Cu deposit, Philippines. In areas of thicker and/or transported overburden, surface geochemistry is unreliable, and Anglo American has preferred the more direct approach of drilling through the cover and sampling the base of regolith or top of bedrock (as used in the discoveries of the Gergarub Zn-Pb VMS deposit, Namibia, and the Sakatti Ni-Cu-PGE deposit, Finland). In addition to surface media geochemistry, lithogeochemical methods have been used in regional reconnaissance, and more locally for detecting distal effects of mineralisation, particularly around blind targets.

Fast and relatively cheap multi-element analysis by ICP-MS and computer software to aid interpretation have been the most significant technological advances over the last twenty years. More recently, portable XRF technology has enabled real-time decision-making in the field.

Anglo American actively supports geochemistry-related R&D through engagement with several key research centres globally (e.g., CODES and MDRU), and funding of PhD students. Strategic alignment of research objectives with the long term needs of industry is a key challenge, as is the gap in undergraduate teaching in applied exploration geochemistry at universities.

The fate of Archean primary crust and the transition to subduction

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Petrological data and thermal models indicate Archean mantle potential temperatures (T_p) were up to 240°C hotter than at present, but with a similar variation (~100°C). Higher T_p generated thick MgO-rich ultramafic primary crust (PC) and highly residual lithospheric mantle (LM). Subduction and plate tectonics were unlikely. The preserved volume of PC is low suggesting that most is missing, which we address by modelling the equilibrium mineral assemblages for a range of metamorphosed (hydrated) PC compositions and complementary residues for a Moho T of 1000°C. We use calculated compositions of primary melts and complementary residues of high-MgO non-arc basalts as proxies for the secular change in composition of PC and LM. The density of LM decreases slightly with increasing T_p, whereas that of PC increases dramatically. The base of PC with MgO >21–22 wt%, produced at T_p >1600°C, was unstable at crustal thicknesses >45 km (>1.5 GPa), even when fully hydrated. Archean low-MgO eclogites and TTGs were derived from basaltic compositions and require that the PC was fractionated. Although the thermal structure of the mantle in the Hadean and Eoarchean is poorly constrained, heating from radioactive decay exceeded surface heat loss in the interval before 3.0 Ga and Archean geodynamics was probably variable, controlled by the spatial range in T_p. This regime was likely dominated by delamination/convective downwelling of PC that may have partially melted to produce basalt or refertilized the underlying mantle causing additional melting and crustal thickening. The resulting magmatic additions form plateau-like crust. Archean continental crust is dominated by TTGs. Collision of plateaux and/or plateaux overriding PC lithosphere was responsible for inducing melting to generate this TTG crust. Post 3.0 Ga tectonics was dominated by the onset of subduction, plate tectonics and a transition to the supercontinent cycle, consistent with the dominance of secular cooling since 2.5 Ga, and the rare occurrence of paired metamorphism and scarcity of eclogite in orogenic belts from the Mesoarchean to Paleoproterozoic. The onset of subduction may have triggered an overturn of the LM, as evidenced by T_{RD} model ages for the LM.

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