

Ultramafic xenoliths from Nosy Be island (Madagascar)

M. LUSTRINO¹, L. MELLUSO², V. MORRA²,
R. VANNUCCI³, A. ZANETTI³

¹Dip. Scienze della Terra, Univ. La Sapienza, Roma, P.le A. Moro, 5, 00185 Roma, Italy
(michele.lustrino@uniroma1.it)

²Dip. Scienze della Terra, Univ. Federico II, Via Mezzocannone, 8, 80134 Napoli, Italy

³CNR CSCC, Via Ferrata, 1, 27100 Pavia Italy

Mafic alkaline volcanic rocks from Nosy Be are associated with ultramafic xenoliths subangular to subspherical in shape and with an average dimension of 4-5 cm. The ultramafic xenoliths show a typical four phase mantle assemblage with olivine (Fo = 91.2 to 80.7 mol%; present as large crystal, often deformed with kink bands), orthopyroxene (enstatite; Wo_{3.1-0.9}En_{89.1-86.7}Fs_{11.0-8.2}, with Mg# and Cr# ranging from 89.0 to 91.6 and from 21.7 to 1.4, respectively), clinopyroxene (diopside to endiopside; Wo_{49.7-31.4}En_{62.1-41.2}Fs_{10.9-0.04}, with Mg# and Cr# ranging from 93.4 to 79.1 and from 68.2 to 0.5, respectively; sometimes spongy, probably in relation of incipient partial melting) and spinel (occurring both as interstitial phase and as vermicular to holly leaf-shaped crystals; Al₂O₃ (55.39 to 42.83 wt %) shows negative correlation (R² = 0.97) with Cr₂O₃ (18.5 to 6.06 wt %); Mg# and Cr# range from 52.7 to 80.6 and from 6.9 to 61.3, respectively).

The xenoliths are harzburgite, wehrlite, cpx-poor lherzolite, lherzolite and dunite. Modal clinopyroxene content ranges from 36 % (wehrlite) to 0.7 % (harzburgite).

All but one sample show concave upward chondrite-normalized REE patterns. The LREE/HREE ratio ranges from enriched values (La/Yb_(N) = 8.48) to composition typical of clinopyroxene in equilibrium with depleted source (La/Yb_(N) = 0.11). The most LREE-enriched clinopyroxene (La 20x chondrite) is found in harzburgite; in this case the LREE enrichment is coupled with a ΣREE extremely low (Sm to Yb below 5 x chondrite). This feature could be related to a previous melt extraction, responsible for the low ΣREE, followed by the reaction with a LREE-rich metasomatic agent. Clinopyroxene associated with low-MgO olivine (Fo 80.9-81.3) can be distinguished from clinopyroxene in equilibrium with mantle olivine on the basis of the highest ΣREE (~50 compared to < 35).

Liquids in equilibrium with clinopyroxene have been calculated on the basis of literature KDs. Primitive mantle-normalized diagrams of such melts evidence a relatively uniform signature, with positive peaks at Nb (71 to 250 x PM) and troughs at Zr (7 to 26 x PM) and Ti (1 to 8 x PM). Clinopyroxene associated with low-MgO olivine can be distinguished on the basis of the absence of trough at Ti and for the overall higher concentration in trace elements. The calculated melts closely match the geochemical composition of the host basanites, thus suggesting genetic relationships between lavas and wehrlitic nodules. These latter are thus hypothesized to be high pressure cumulates

Crystal dissolution kinetics: Is there light at the end of the tunnel?

A. LUTTGE, R.S. ARVIDSON, M.S. BEIG, AND
T.A. FEWLESS

Department of Earth Science, Rice University, Houston, TX, USA; aluttge@rice.edu

Mineral dissolution kinetics have been studied by various experimental and analytical techniques, e.g., in flow-through, column and batch reactors using single crystals and mineral powders. Rates have been determined indirectly via measurements of solution chemistry or directly by atomic force microscopy techniques and recently also by vertical scanning interferometry (VSI), with and without microbial control. If we include theoretical approaches like *ab initio* calculations and Monte Carlo simulations, the "hunt" for the "true" dissolution rates is occurring on a large range of scales, i.e., from the quantum mechanical and molecular scale up to the macroscopic world.

This effort has led to a large pool of dissolution rates that may be internally consistent within the same laboratory but are often not transferable to different experimental conditions, or even natural systems. Some key problems have been identified: e.g., the quantification of the correct (reactive) surface area, the establishment of a quasi steady state, the ΔG dependence, or even the formation of new phases on the reacting mineral surface. However, a comprehensive fundamental understanding of mineral dissolution kinetics is just beginning to evolve (e.g., Lasaga and Luttge, 2001; 2002; Oelkers, 2001) and that discussion continues today.

In any case, we can distinguish and quantify processes that lead to bulk removal; i.e., etch pit-based rates, "global" crystal surface retreat, rates of step movement, microbially-controlled surface destruction rates, and bulk dissolution rates obtained from mineral powders. How do all these different rates relate to each other? We base our discussion of this question on our VSI dissolution studies of (alumino)-silicates, carbonates, sulfates and other minerals. We will show that different analytical and observational techniques lead necessarily to different dissolution rates for the same crystal specimen, causing us to ask: what is the "true" dissolution rate?

References

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