V21C-9 1045h

The Effects of Fe/Mg Ratio and Pressure on Carbonate Stability and Melt Compositions in Peridotitic Assemblages

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We have determined the effects of Fe/Mg ratio and pressure on the composition and stabilities of magnesite and dolomite in peridotitic compositions. Fe is preferentially partitioned into olivine relative to magnesite and ordered dolomite (K_D = 0.45 - 0.5). Increasing Ca/Mg ratio in disordered carbonate produces increased Fe/Mg ratio in this phase coexisting with olivine (K_D = 0.75 - 1.4).

The effect of Fe/Mg ratio on the reactions 1) dolomite/calcite + opx = cpx + olivine + CO_2 and 2) dolomite + opx = magnesite + cpx is small. We find that reaction 1) is displaced to slightly lower pressures (1 kb) and reaction 2) to slightly higher pressures (2 kb) in natural composition relative to CMS.CO_2. We also find a stability field of magnesian calcite in lherzolitic assemblages at ~16-28 kbars and 750-1000°C.

Initial carbonate melts produced in peridotite have Ca/(Ca+Mg) of about 0.7. Carbonate melts with higher Ca/(Ca+Mg) ratios are stable in wehrlites and carbonatite metasomatism.

V21C-10 1100h

Uranium Series Disequilibria Generated by Peridotite Partial Melting: Constraints From Partitioning Studies.

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Alkaline earth, Pb and actinide partition coefficients have been measured for olivine-, orthopyroxene- and clinopyroxene-melt pairs using SIMS. Bulk partition coefficients for spinel peridotites in equilibrium with basaltic melts are dominated by the presence of cpx (D_U=1.0x10^{-3}; D_{Th}=1.5x10^{-3}), and hence U behaves more incompatibly than Th.

These results demonstrate that the partial melting of a spinel peridotite will produce silicate melts with (^{230}Th/^{238}U) ratios between 0.65 and 1, and cannot therefore be the cause of the (^{230}Th/^{238}U) ratios in excess of unity observed in MORB, or the high Th/U ratio of the crust compared with the mantle. Nor can the (^{230}Th/^{238}U) ratios of MORB be explained by the presence of hydrous phases in the MORB source or by extraction of a carbonate melt in equilibrium with spinel peridotite.

Preliminary garnet-melt experiments indicate that U is much more compatible than Th. (^{230}Th/^{238}U) ratios of 1.4 as observed in MORB can be generated if melts are extracted from the garnet stability field with melt porosities of 0.25% or less.

The Ra bulk partition coefficient for spinel and garnet peridotites are estimated to be approximately 1x10^{-8}. (^{226}Ra/^{230}Th) ratios of 2 can be generated by partial melting of peridotite only if the porosity during melting is less than 2x10^{-4}.

The U/Pb ratio of the mantle cannot have been raised by cpx-melt partitioning during melt extraction, as Pb is more compatible than U in cpx-melt pairs.

V21C-11 1115h

Partitioning of U-Th-Pb and other incompatibles between augite and carbonate liquid at 1200°C and 55 kbar

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Recent investigations of OIB and MORB indicate that members of the U- and Th-series decay chains may fractionate from each other during basalt petrogenesis [1]. In particular, (^{230}Th/^{238}U), (^{231}Pa/^{235}U), (^{226}Ra/^{230}Th) activity ratios are greater than unity in many MORB (equilibrium implies unity). This is particularly surprising considering the assumed extreme incompatibility of these elements in simple igneous processes. One possible solution to this problem is for MORB genesis to have been initated by very low-degree partial melts. These melts, enriched in fractionated incompatible elements, could then be used as fluxing agents in the MORB source region. Carbonate melts, which are less viscous and presumably more mobile than silicate liquids, have been suggested as good candidates for the postulated low-degree partial melts [2]. Earlier we have shown that carbonate liquid/silicate liquid partitioning can fractionate elements that are otherwise subequally incompatible [1]. Here, we show that partitioning between augite and carbonate liquid is insufficient to produce the observed fractionations of U- and Th-series nuclides.

Incompatible-element-doped starting materials were as in [1]. The sample was loaded into a graphite capsule and taken to pressure and temperature (1200°C, 55 kbar), using the multi-anvil techniques of [3]. The sample remained at (P,T) for 2.5 hours and then quenched. The mounted and polished charge was analyzed for major and minor elements using the electron microprobe and then analyzed for trace elements using the Edinburgh Cameca ims4f ion microprobe, using 77 ev filtering. Elemental concentrations were calculated by normalizing to the ^{30}Si peak and by using the electron microprobe results. Preliminary partition coefficients are given in Table 1 along with our earlier results for carbonate liquid/silicate liquid partitioning [1]. Partition coefficients are typically precise to ~ ±20% relative. D(aug/sil. liq) is calculated from the first two columns and may be compared with directly measured values [4] for D(Th) of 0.0015 and D(U) of 0.0010. Our values are slightly higher but are consistent with the observation that D(Th)/D(U) is relatively constant at 1.5.

Broadly, we always observe that Th is more compatible in augite than is U. This result is not in the correct sense to explain the observed enrichments of (^{230}Th/^{238}U) in MORB. We also note that U and Pb are either subequally incompatible or that U is more incompatible, depending on the composition of the liquid. This result does not support the hypothesis of [5] that U is more compatible than Pb during oceanic basalt petrogenesis. We conclude that augite is not the phase primarily responsible for the fractionation of U- and Th-series nuclides during OIB and MORB petrogenesis.

References: [1] Jones J.H. et al. *Lunar Planet. Sci. XXIII*, pp. 627-628. [2] McKenzie D. (1985) *E.P.S.L.* **79**, 81-91. [3] Walker D. (1991) *Am. Min.* **76**, 1092-1100. [4] Beattie P. (1992) This volume. [5] Meijer A. (1985) *Geophys. Res. Lett.* **12**, 741-744.

Partitioning Between Augite and Carbonate/Silicate Liquid

Element	D(aug/carb. liq)	D(carb. liq/sil. liq)	D(aug/sil. liq)
Nb	0.0059	0.52	0.0031
Mo	0.0090	5.8	0.052
Ba	0.00057	1.8	0.0010
Ce	0.030	1.0	0.030
Pb	0.0055	0.61	0.0034
Th	0.0093	0.28	0.0025
U	0.0048	0.35	0.0017

V21D CA: 317 Tues 0815h
Precambrian Terrane Analysis (*joint with T*)

Presiding: **A Kroner,** Inst. Fur Geowissenschaften; **R Van Schmus,** Univ of Kansas

V21D-1 0815h INVITED

Possible Terrane Identification in the Early Archean Barberton Greenstone Belt, South Africa, Using Single Zircon Geochronology

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Many stratigraphic and age relationships in the southern part of the Barberton greenstone belt (BGB) remain unresolved due to strong deformation including thrusting, nappe stacking and strike-slip faulting. A relatively undisturbed sequence from the lower Onverwacht Group (~3.48-3.45 Ga), followed by the upper Onverwacht (~3.42-3.3 Ga), the Fig Tree Group (~3.26-3.23 Ga) and the Moodies Group (>3.22 Ga) was established by single zircon dating using various techniques, but the position of the Theespruit Formation is still uncertain, although a published zircon age of <3.45 Ga suggests it to be younger than the Komati rocks. Using the single zircon evaporation technique we obtained remarkably uniform ^{207}Pb/ ^{206}Pb ages of 3547±3 Ma for felsic rocks mapped as Theespruit in the Steynsdorp Anticline of the southeastern BGB, some 100 Ma older than all other dated greenstone units. These rocks were intruded by the 3510±3 Ma old Steynsdorp tonalite pluton containing zircon xenocrysts as old as 3553±4 Ma. A 3.2 Ga old granite plug intrusive into Theespruit metavolcanics contained a 3702±1 Ma old zircon xenocryst, the oldest so far measured in the Barberton-Swaziland area and testifying to the presence of very ancient crust in the region. Another felsic unit mapped as Theespruit at the confluence of the Theespruit and Komati Rivers was dated at 3511±3 Ma and is thus younger than the rocks discussed above but still significantly older than the Komati Formation. The Theespruit felsic metavolcanics have Nd model ages not exceeding 3.55 Ga, thus ruling out derivation of these rocks from much older crustal material.
The above zircon ages extend the history of the BGB back to ~3.55 Ga and show that previous regional correlations of lithologies in the southern BGB are probably incorrect. We suggest that the area of the Steynsdorp Anticline constitutes the oldest nucleus of the BGB onto which successively younger units were tectonically and magmatically accreted. We also speculate that the mafic-felsic volcanic units of the southern BGB may perhaps represent distinct oceanic plateaux, rather than ocean floor material, which amalgamated between 3.55 and 3.42 Ga ago. Our data support the concept that the BGB consists of a number of discrete, fault-bounded terranes, and that large-scale lithological correlations are therefore not justified.

V21D-2 0830h INVITED

Three Dimensional Isotopic Mapping: An Example From the Early-Middle Archean Narryer Gneiss Complex, Western Australia

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Typically polymetamorphosed, multiply deformed and often poorly exposed early Archean regions present a challenge to terrane analysis. Single zircon dating provides precise and accurate ages enabling lithologically similar gneisses with ages differing by ≥ 20 Ma to be distinguished with absolute confidence. Combined zircon ages and Nd isotopic data allow the assessment of both the age distribution and juvenile vs. crustal older crustal contribution for each gneiss generation. Viewing this data on a regional scale enables recognition of collages of terranes which can be inferred to be separated by tectonic boundaries; boundaries which unless the region has almost complete exposure, are unlikely to be directly observed because they are in some cases less than 20 m wide.

Using combined U-Pb zircon geochronology and initial Nd isotopic compositions of more than 50 samples, the Narryer Gneiss Complex can be divided into terranes which show different early to middle Archean histories. 3300-3730 Ma gneisses occur in a ≤ 100 km wide terrane, which is bounded on both sides by terranes containing 2920 and 3000 Ma gneisses. The first rocks common throughout the region are 2730-2750 Ma granite sheets and neosomes in migmatites, the emplacement and formation of which is interpreted to coincide with assembly of the terranes. In several episodes in the late Archean (between 2680 Ma and 2620 Ma), granites were emplaced throughout the region. Regardless of whether these granites have intruded the 3300-3730 Ma or 2920 Ma and 3000 Ma gneisses, their initial Nd isotopic compositions show that they all can have been generated by partial melting of the 2920 and 3000 Ma group of gneisses with little or no input from older Archean gneisses. Furthermore a few of the granites that intrude the 3300-3730 Ma gneisses contain inherited 2920 Ma zircons. This suggests that 2920 Ma and 3000 Ma gneisses continue *under* the ancient 3300-3730 Ma gneiss terrane and were the dominant source of the late Archean granite *throughout* the entire region. Thus, there is no evidence that the 3300-3730 Ma gneiss terrane extends into the deep crust and instead, we interpret it as an allochthon emplaced over a middle Archean terrane, during or just prior to, intrusion of copious late Archean granite.

V21D-3 0845h

U-Pb and Sm-Nd investigation of terranes in a continental collisional belt, Borborema Province, northeast Brazil

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The Borborema Province of NE Brazil is a major continental fold belt formed about 600 Ma (Brasiliano Orogeny) during assembly of Gondwanaland; it is the western counterpart to the coeval Pan-African central African fold belt. The Borborema Province comprises abundant 550 to 600 Ma post-tectonic granitic plutons emplaced into a gneissic and migmatitic complex. This complex includes recognizeable supracrustal rocks with intercalated metavolcanics, older basement to the supracrustal rocks, and pre-Brasiliano plutons. The province may be divided into several fault-bounded subprovinces. Much of the gneiss and migmatite may have formed during the Brasiliano orogeny, but much more of the gneiss and migmatite probably formed during older orogenies, such as the 2.1 Ga Transamazonian orogeny. Supracrustal rocks probably represent several sedimentary and volcanic cycles, ranging in age from 2100 Ma to 600 Ma, but for the most part their depositional ages are poorly known.

We have begun a program of U-Pb zircon geochronology, Sm-Nd analyses for crustal residence ages [T(DM)], and mineral ages to define the architecture and tectonothermal history of the Borborema Province. In particular, we wish to determine if faults bounding subprovinces represent major sutures between diverse crustal blocks amalgamated during formation of Gondwanaland and to define the pre-collisional histories of the subprovinces. Preliminary results show at least two depositional or volcanic cycles: ca. 1750-1800 Ma in the NW and ca. 1000 Ma in the SW part of the province; 750-970 Ma granitic plutons locally intrude the younger sequence and ca. 1750 Ma granitic plutons intrude the older sequence. We have also identified 2.15 Ga Transamazonian orogenesis in the basement of the northern part of the province, where Sm/Nd data suggest that the crust initially formed in the Late Archean. We anticipate that continuing studies will allow definition of principal crustal blocks, crust-forming events, depositional cycles, plutonic episodes, and tectonic episodes, in much the same way that current U-Pb and Sm-Nd studies are providing better resolution within the Grenville Province.

V21D-4 0900h

Conventional and Single Zircon Evaporation Constraints on the Distribution of Archean Crust in the Penokean Orogenic Belt of Central Wisconsin

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The Penokean Orogenic Belt (POB) in Wisconsin is bounded to the north and the south by Archean terranes. The Eau Pleine Shear Zone (EPSZ) marks the southern boundary between a volcanic-plutonic complex (Wausau-Pembine terrane) to the north and the Marshfield Terrane to the south (Sims et al. CJES 26:2145-58). Delineation of the extent and involvement of Archean crust in the POB is hampered by the limited outcrop area, placing increased importance on detailed petrological and geochronological studies.

Conventional U/Pb analyses of zircons from a lineated granite intrusive into banded gneiss at Thorp, WI are all discordant with a poorly defined upper intercept age of 2293 ±257 Ma, and a lower intercept age of ~472 Ma. Single grain evaporation on three visually identical zircons give a range of ages, which in large part explain the conventional results. One grain gives consistent Pb7/6 ages at all three evaporation steps of 1848±3.9, 1852±6.7 1846±5.3 Ma (total 119 ratios). These ages are in good agreement with previous studies. The other two grains all show complex age distributions with increasing ages with higher evaporation temperatures, ranging from 2678±4.8 to 3237±12 Ma, indicating at least two zircon populations in the granite; a pristine Penokean population and inherited zircons that were assimilated during emplacement into Archean crust, possibly with overgrowths. The evaporation ages are minimum ages, yet these are the oldest ages yet reported for any rocks in Wisconsin, suggesting the presence of older Archean crust in the region that may approach ages found in the Minnesota River Valley. Despite the fact that conventional analyses were done on 100-200 µg sized samples, the conventional analyses give meaningless upper intercept ages. The data are also important in defining the northward extent of the Marshfield terrane and in refining the trace of the EPSZ.

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