

## OSMIUM AND OXYGEN ISOTOPIC INVESTIGATION OF THE J-M REEF, STILLWATER COMPLEX

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The J-M Reef is a platinum-group element (PGE) enriched horizon within the Banded Series of the Stillwater layered mafic intrusion. The isotopic composition of Os is an ideal tracer of the PGE and, in conjunction with the ( $^{18}\text{O}/^{16}\text{O}$ ) systematics of the dominant silicate minerals, can be used to determine the processes by which the horizon formed.

Previous work on the G-chromitite horizon from the Ultramafic Series lower in the complex established its probable initial ( $^{187}\text{Os}/^{186}\text{Os}$ ) to be 0.895, with a (Re/Os) of  $\sim 0.007$ . The present-day ( $^{187}\text{Os}/^{186}\text{Os}$ ) of one whole-rock sample from the J-M reef is  $1.9403 \pm 0.0077$  ( $2\sigma$ ). If the reef had the same initial osmium isotope ratio as the chromitite, it should have a (Re/Os) ratio of  $\sim 0.65$ . Alternatively, influx of new magma with a different isotopic composition may have occurred between these horizons.

The  $\delta^{18}\text{O}$  of mineral separates from the same J-M reef sample (bronzite  $\delta^{18}\text{O} = 5.8 \pm 0.1$ ; plagioclase  $\delta^{18}\text{O} = 6.2 \pm 0.2$ ) yields an equilibrium temperature of  $\sim 1200^\circ\text{C}$  and a calculated melt  $\delta^{18}\text{O}$  of 5.9, in agreement with data for the rest of the complex reported by Dunn (1986, *J. Petrol.* 27:987-997). These values of  $\delta^{18}\text{O}$  are typical of mafic igneous systems and indicate that no significant upper crustal contamination (high  $\delta^{18}\text{O}$ ) or subsolidus reequilibration has occurred.

The preliminary data indicate that the osmium and oxygen isotopic systematics record magmatic events. Further osmium isotopic measurements on mineral separates will define the initial ( $^{187}\text{Os}/^{186}\text{Os}$ ) of the reef horizon and thus provide constraints on the evolution of the Stillwater magma chamber.

## No 25242

## RISING MELT ZONES: ORIGIN OF THE VOLCANIC-ARC TO WITHIN-PLATE MAGMATIC TRANSITION IN IGINIMBRITES DURING EXTENSIONAL STAGES OF OROGENIES

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Silicic ash-flow tuffs in the Mogollon-Datil volcanic field, southwestern New Mexico, preserve chemical signatures recognized worldwide as characteristic of a progression from volcanic-arc to within-plate tectonics. Normalized trace-element plots for pre-30 Ma rocks display trends similar to volcanic-arc granites from Jamaica, while post-30 Ma rhyolites mimic trends found in within-plate granites from the Sabaloka complex, Sudan. Passively emplaced plutons and domino-style faulting indicate that the 30 Ma chemical transition occurred several million years after the initiation of extension and ductile thinning in the lithosphere.

Trace-element and Sr-isotope values for the pre- and post-30 Ma volcanic suites are, respectively: Rb = 113-175 & 181-240; Sr = 150-408 & 8-43; Y = 22-34 & 48-96; Zr = 142-284 & 212-436; Nb = 17-22 & 24-42; Ba = 1212-1445 & 30-436; ( $^{87}\text{Sr}/^{86}\text{Sr}$ )<sub>o</sub> = 0.70712-0.70872 & 0.71775-0.73407. These distinct chemical suites reflect melt-zone migration from upper mantle to lower crust as extension progressed, coincident with mantle diapirism and within-plate basaltic andesite volcanism. Pre-30 Ma rhyolites contain an upper-mantle component, modified by assimilation of lower crust and fractional crystallization. After 30 Ma, silicic ignimbrite compositions reflect feldspar-buffered melts, characteristic of the lower crust. The volcanic-arc to within-plate transition is a global phenomenon of orogenic belts; our results indicate the petrogenetic link.

## No 24302

## Pb/Sr/Nd ISOTOPIC EVIDENCE FROM MANTLE XENOLITHS AND RELATED BASALTS FOR MID-CENOZOIC N. AMERICAN ARC PETROGENESIS AND MANTLE Pb SYSTEMATICS

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Mantle-derived websterites from La Olivina, Mexico (160 km SW of Big Bend Nat. Park) occur in two varieties; allotropic (A-Type) and equigranular (E-Type). Isotopic compositions of acid-washed CPX suggest A-Type samples ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.70292$ ,  $\epsilon_{\text{Nd}} = +5.7$ ,  $^{206}\text{Pb}/^{204}\text{Pb} = 19.31$ ,  $^{207}\text{Pb}/^{204}\text{Pb} = 15.60$ ) formed as precipitants from host basanite-associated magmas, while E-Types ( $^{87}\text{Sr}/^{86}\text{Sr} = 0.7041$ ,  $\epsilon_{\text{Nd}} = +2.0$ ,  $^{206}\text{Pb}/^{204}\text{Pb} = 18.68$ ,  $^{207}\text{Pb}/^{204}\text{Pb} = 15.63$ ) formed from mid-Cenozoic calc-alkaline magmas found near La Olivina. The websterite-basalt associations are supported by CPX REE modelling. The E-Type samples provide evidence that the isotopic signature of the voluminous calc-alkaline suite is fundamentally subcrustal, a much debated hypothesis (Ruiz and Patchet, 1988; Cameron and Cameron, 1985). The Pb compositions of the E-Types indicate incorporation of a slab-derived pelagic component. The unusual Pb compositions of the A-Types and basanites require the presence of a HIMU component underlying the region.

Acid-washed CPX from Cr-Diopside peridotites and orthopyroxenes at La Olivina show enriched and depleted LREE patterns. One third of the

samples contain trace phlogopite or amphibole, evidence for metasomatism. Isotopic compositions of CPX from 5 samples show no correlation with either modal metasomatism or REE pattern. A phlogopite-bearing lherzolite has the lowest Sr composition (0.70220), while a LREE depleted sample has the highest composition (0.70328). Although the single amphibole-bearing lherzolite analyzed has a low Pb composition ( $^{206}\text{Pb}/^{204}\text{Pb} = 18.33$ ,  $^{207}\text{Pb}/^{204}\text{Pb} = 15.53$ ), Pb compositions are similar in the four other samples ( $^{206}\text{Pb}/^{204}\text{Pb} = 18.93-19.25$ ,  $^{207}\text{Pb}/^{204}\text{Pb} = 15.59-15.61$ ). The similar, but slightly lower, Pb values of the A-Type websterites and host basanites suggest a genetic relationship or isotopic exchange. The lack of coherence between the isotopic systematics and the evidence for enrichment/depletion in the lherzolites implies a multistage history for the La Olivina mantle.

## No 20850

## ABUNDANT MOISSANITE FOUND IN FUXIAN DIAMOND PIPE, LIAONING, CHINA

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Kimberlite diatremes occur in northeastern China along the NE-SW trending Tanlu fault zone within the Sino-Korean Craton. Diamonds are found in two major areas near Mengyin, Shandong, and three clusters of kimberlite bodies at Fuxian, Liaoning. Moissanite (SiC) occurs as a rare accessory in all these localities.

An unusual hand specimen from Pipe 50 near Fuxian contains hundreds of dark blue moissanite occurring in aggregates coated and held together by a milky, vesicular substance. This overgrowth was also identified as moissanite by SEM/EDS and X-ray diffraction techniques. Individual crystals range from minute to several mm in size. Several crystals are covered by an orange rim decorated with numerous hexagonal flakes of red hematite. Embedded within these orange coats are inclusions of corroded blue moissanite.

The blue crystals as well as their rims show similar crystal structures on X-ray precession photographs. They are composed of the basic 6H polytype structure (6-layer, hexagonal) in syntactic coalescence with type 15R (15-layer, rhombohedral). Amount of the latter is estimated to be 30% by volume based on relative intensities of X-ray reflections. There are also less than 5% type 4H and about 3% type 4H. According to a structure-temperature study of synthetic silicon carbide (Knippenberg, 1963), the temperature of formation of the Fuxian specimen may be about  $2400^\circ\text{C}$ . Petrologic studies of kimberlites in this area also indicate very high temperature and deep source of origin. This is perhaps the major reason why moissanite is such a rare mineral in other rock types.

## No 13570

## PETROLOGY AND OXYGEN ISOTOPE GEOCHEMISTRY OF BRASILIANO-AGE SHOSHONITIC TO ULTRAPOTASSIC PLUTONS OF NORTHEAST BRAZIL.

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Silica saturated and oversaturated peralkaline magmas were widely intruded into the Cachoeirinha-Salgueiro Fold Belt (CSF; a  $20,000 \text{ km}^2$  SW-NE trending Precambrian belt) between 450-510 and 660 Ma. The nepheline-normative plutons are sodic-potassic to ultrapotassic syenites forming multiple syenitoid lines and two dike swarms of  $\sim 50$  dikes each aligned along the southern boundary of the CSF. The plutons of the main syenitoid line change to quartz monzonite with shoshonitic affinities to the north.

The silica-saturated plutons are very high in K, Sr, and Ba, high in P and Ti, and low in Zr and Nb. MORB-normalized element concentration diagrams show positive Ce, Y, and Sm anomalies, and negative Nb and Ti anomalies. Alkali-pyroxenite inclusions are high in K, P, Ba, Sr and REE contents suggesting an anomalously enriched mantle source.

MORB-normalized concentration diagrams for shoshonitic compositions show negative P, Ti, and Nb anomalies and positive ones for Zr and Rb. Both groups show similar REE patterns, with LREE enriched and HREE depleted and variable Eu anomalies.

Whole-rock  $\delta^{18}\text{O}$  estimated from pyroxene separates are +6.5 to +8.3 permil (SMOW) suggesting differentiation from a mafic magma with some crustal contamination. Whole-rock  $\delta^{18}\text{O}$  values for the oversaturated group and shoshonitic granitoids of +8 to +10 permil infer either more crustal interaction or a different source.

The intrusion of the peralkaline plutons seems to follow major sigmoidal fault zones, and may be related to pull-apart processes along these zones associated with the Patos-Aurora and Pernambuco transcurrent lineaments. The 2 b.a.-old Serra de Itiuba syenite in Bahia shows similar geochemical characteristics, suggesting that anomalous mantle existed since Early Proterozoic times.

## No 13070

## LAMPROITE IN BRAZIL

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The first description of the occurrence of a lamproite in Brazil was recorded by Leonardos (1986) in Western Minas Gerais. Within this general region are a large number of other igneous intrusions that include kimberlites and major carbonatites whose ages are similar - 80

to 07 m.y. In view of the controversy regarding the petrogenetic relationship of carbonatite, kimberlite and lamproite magmas, detailed study of the rocks in this area of Brazil may provide a unique insight into answers for this controversy.

Two individual composite intrusions, Limeira and Indaia about 1½ km apart, consist of a large kimberlite intrusion and an associated smaller lamproitic one. Petrographically and mineralogically the Limeira and Indaia lamproites are comparable. Olivine macrocrysts occur randomly in a fine grained groundmass that consists of a felty aggregate of thin laths of clinopyroxene in which larger perovskite, spinel, apatite and rare-Mg ilmenite occur. Both lamproites contain flow textured elongated clasts of partially recrystallized glass. Prominent in the Indaia rock are pleochroic reddish-brown titanium micae that poikilitically enclose clinopyroxene and spinel. This texture is not observed in the associated kimberlites but is characteristic of madupitic lamproites.

Chemical analyses of the bulk rocks trace elements and constituent minerals are similar from each intrusion and comparable with lamproites from elsewhere, particularly madupite from the Leucite Hills, Wyoming (Armstrong, 1967). These chemical features will be presented in detail.

## No 13072

## MANTLE XENOLITHS IN THE HOMESTEAD KIMBERLITE PIPE, WELKOM, SOUTH AFRICA

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The Homestead or Kaalvallei kimberlite pipe near the gold mining town of Welkom, O.F.S., South Africa was worked for diamonds for a short period at the turn of the century. Recently, the pipe has been reopened and revealed a plethora of both peridotite and eclogite xenoliths. The kimberlite is important as it is one of the most northerly xenolith-bearing localities of a group of possible Type II kimberlites, which includes the Star Mine near Theunissen, and provides an insight into a hitherto unknown portion of the lithosphere/asthenosphere of the Kaapvaal craton.

Fifty-two peridotites and a similar number of eclogites have been examined from this pipe. The peridotites are garnet-bearing lherzolites (40%), harzburgites (20%), pyroxenites (35%), and wherlites (5%). Coarse grained granular and mosaic-porphroclastic rocks are present, with both olivine and orthopyroxene forming neoblasts in the latter type of xenolith.

Olivines  $F_{0.90}$  to  $F_{0.94}$  have low  $TiO_2$  contents ( $< 0.03$  wt%). Orthopyroxenes ( $E_{0.90}$ - $E_{0.95}$ ) show differences in  $Al_2O_3$  between granular rocks (Av. 0.68) and mosaic ones (Av. 1.30). Clinopyroxenes have  $Ca/(Ca+Mg)$  values of 0.47 and 0.33 for granular and mosaic xenoliths respectively.  $Cr_2O_3$  contents are within the ranges noted from cpx in xenoliths from Southern Africa. Garnets vary in color from wine-purple to black, generally the lighter colored garnets contain less  $Cr_2O_3$  than the darker ones.  $TiO_2$  contents differ between the granular ( $< 0.01$ ) and mosaic (Av. 0.3) xenoliths.

Geothermobarometry suggests high- and low-temperature suites of peridotite xenoliths similar to localities in other parts of the Kaapvaal craton. The high-temp peridotites reflect an origin in the upper asthenosphere whereas the granular, low-temperature, depleted xenoliths reflect lithospheric conditions.

## No 23067

## PETROLOGY AND GEOCHEMISTRY OF PROTEROZOIC HIGH-Mg DIKES FROM THE VESTFOLD HILLS, ANTARCTICA

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The oldest undeformed mafic dikes in the Vestfold Hills of the East Antarctic shield are characterized by relatively high  $SiO_2$  (51-57%),  $MgO$  (7-14%), Cr and Ni (up to 1600 ppm and 417 ppm respectively) and low  $TiO_2$  (0.49-0.70%). The suite was emplaced at ca 2400 Ma, directly following an amphibolite-granulite facies tectonothermal metamorphic event at ca 2500 Ma. Chondrite-normalized plots of incompatible trace elements, major element ratios, and phase compositions divide the high Mg suite into three distinct subgroups. Based on dike intersections, the oldest of these chemical groups (I) is oliv+opx phyric, the intermediate group (II) is oliv+opx phyric, and the youngest group (III) is opx phyric. Whole-rock trace-element characteristics of chilled margin samples and zoning trends in the opx phenocrysts prohibit these subgroups from being related by crystal fractionation and previous isotopic studies preclude crustal contamination as a significant source of chemical variations. Major- and trace-element evaluation also indicate that two of the chemically distinct subgroups (I, II) were derived from primitive liquids extracted from separate "chondritic" upper-mantle sources leaving olivine + orthopyroxene residues. Superimposed upon the chondritic characteristics is evidence for selective trace element enrichment, coupled with a relative depletion in Sr, suggesting enrichment through a "wall-rock" reaction-type process within a plagioclase-bearing lherzolite. Comparison of an estimated parental liquid composition ( $Mg_{75}$ ) with experimental melting studies indicates magma extraction took place at pressures of ~10 kbar, consistent with the geochemical signature indicating partial melting within a plagioclase-bearing mantle. This also constrains the thickness of the continental crust to  $\leq 35$  km at the time of magma genesis. Phenocryst matching experiments indicate emplacement of the suite at pressures of 7-8 kbar.

## LOWER TO MIDDLE JURASSIC VOLCANICLASTIC ROCKS IN THE BEARDMORE GLACIER AREA, TRANSANTARCTIC MOUNTAINS, ANTARCTICA

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Lower to Middle Jurassic volcaniclastic rocks of the upper part of the Falla Formation and the Prebble Formation are the uppermost strata of the Devonian to Jurassic Beacon Supergroup in the Beardmore Glacier region. The volcaniclastic rocks are disconformably overlain by up to 520 m of flood basalts of the Middle Jurassic Ferrar Group.

Analysis of new stratigraphic, petrographic, and geochemical data indicates that two distinct volcaniclastic sequences are present. The lower sequence, up to 156 m thick, consists of fluvial sandstone and rhyolitic to high-silica rhyolitic distal airfall tuff which increases in abundance upward. The upper sequence is up to 375 m thick and consists of one or more of the following: dacitic to rhyolitic proximal airfall tuff, volcanic-sedimentary debris flow breccia, coarse basaltic tuff and pyroclastic breccia, and fine to coarse volcaniclastic sedimentary rocks. The tuffaceous beds in the lower sequence are interpreted to be Plinian airfall deposits from distal dacitic to rhyolitic volcanoes and those in the upper from proximal dacitic to rhyolitic and basaltic volcanoes, and possibly include phreatomagmatic eruptions.

The rhyolitic to high silica rhyolitic tuffs in the lower sequence, and the dacitic to rhyolitic tuffs in the upper, have typical calc-alkaline chemistry; tuffs in the upper sequence differ from those in the lower in having markedly higher transition metal contents. The basaltic pyroclastic rocks have geochemical characteristics similar to the overlying flood basalts. Basaltic and silicic volcanism overlapped in Prebble time; these rocks constitute a bimodal volcanic province.

The volcanic activity was associated with a change in tectonic setting from a foreland basin in which the Beacon was deposited to an extensional regime related to the initial stages of break-up of Gondwanaland.

## No 21927

## COMPLEX PETROGENETIC MODELING USING SPREADSHEET SOFTWARE

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Spreadsheet software, such as LOTUS 1-2-3, has previously been shown to be readily adaptable for modeling the basic petrogenetic processes of partial melting and fractional crystallization. More complex models have been proposed to represent the continuous nature of magmatic petrogenesis where material may be repeatedly removed and/or added to the magma chamber. Spreadsheets have been created for open system fractional crystallization models (r.t.f.- periodically refilled, periodically tapped, continuously fractionated, and a.f.c.- assimilation-fractional crystallization) and for dynamic melting. These processes have been used to explain variations in elemental ratios and REE patterns within igneous suites that had previously been attributed to variations in source composition.

R.t.f. and a.f.c. models involve a single spreadsheet. Variables used are the parent magma composition, composition and proportions of material(s) added, proportion crystallizing, mineralogy of crystallizing portion, and the proportion removed. The process can be followed through any number of cycles. Examples of material that could be added are additional parent magma, mantle partial melts, previously erupted flows, and upper or lower crust.

Variables for the d.m. model are the source composition and mineralogy, mineral melting proportions, and the fraction melted and the melt fraction removed for each cycle.

The advantages of using the spreadsheet models are the large number of elements and variables that can be involved and repeatedly changed with rapid recalculation. REE or multi-element plots can be viewed and printed at any stage.

## No 27260

## RESISTANCE WELDING TECHNIQUES FOR SEALING PRECIOUS METAL CAPSULES\*

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An important aspect of preparing samples for high-pressure, high-temperature experimentation is sealing volatile components inside precious metal tubes. Bulk composition changes due to loss of volatiles during the sealing process are potentially detrimental to such studies. Resistance welding techniques provide two key advantages in alleviating this problem: (1) electrodes can be shaped to make line seals on flattened tube ends and (2) sealing can be accomplished with short-duration current pulses that minimize heating of the tube contents. In addition, after optimum welding parameters have been determined, reliable welds can be made routinely without a high level of operator skill. This methodology contrasts with both gas-torch and arc-welding methods, which require that the source of heat be continuously moved with skill along the crimped end of the tubing.

A potential disadvantage of the resistance welding method is that the weld cannot be inspected visually as is done routinely in gas-torch and arc-welding. For this reason, selection of appropriate weld parameters (electrode force, current, and duration of current pulse) is critical for achieving leak tight, high strength welds. To test the integrity of welds produced by our resistance welding apparatus, high internal pressures were applied to thin-