Programme France-Afrique du Sud

de recherches en géosciences

South Africa-France program in the geosciences

Premier colloque d'étape à mi-parcours

Progress at mid-course

'Are we on track ?'

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Premier colloque d'étape à mi-parcours / progress at mid-course 'Are we on track ?'

En présence de / in presence of
Dr. C. Bréchignac, CNRS president
Dr. Dominique Le Quéau, INSU director

9h00 Introduction : Vincent Courtillot – Maarten De Wit

9h20 E. Thébault : The magnetic field over the Southern African continent: from core to crustal magnetic fields

9h40 M. Moulin (PhD), V. Courtillot, F. Fluteau, G. Marsh, G. Delpech : Paleomagnetic results and dating from the Karoo traps.

10h00 L. Carporzen, A. Galdeano, S. Gilder, M. Le Goff, R. Hart, M. Muundjua : Geomagnetic and Palaeomagnetic studies of the magnetic anomalies associated with the Vredefort impact crater, South Africa: a summary and conclusion.

Coffee break

10h40 G. King and the A1 project team: Landscapes, tectonics and hominins in South Africa

11h00 J. Dyment, D. Bissessur, R. Fernandes, N. Villeneuve **:** Origin of lemurs in Madagascar: what to expect from marine and GPS investigations?

11h20 J-J. Jaeger : The origin and early evolution of madagascar mammalian fauna : first results and perspectives.

11h40 P. Philippot, M. Van Zuilen, Y. Teitler (PhD), V. Noel, M. Ader and M. de Wit, The Barberton Barite Drilling Project: a window on Archean microbial metabolisms

12h00 Isabelle Duhamel-Achin (PhD), M. Cuney : Mineralogy and Geochemistry of the Witwatersrand Basin Reefs, South Africa: detrital vs. hydrothermal origin of uranium mineralization, possible sources and constraints for the atmospheric pO_2 level prior 2.2 Ga.

Lunch break

14h00 F. Guillocheau, M. de Wit, G. Dubois, F. Eckardt, B. Linol, C. Robin, D. Rouby: Plateau uplift, epeirogeny and evolution of climate : The Kalahari Plateau, a world class laboratory

14h20 C. Jaupart : Stability of lithosphere and thermal structure

14h40 P. Cartigny : Traçing Conflict Diamonds ?: Yes we can… sometimes. Case studies on diamonds from Central African Craton (RDC and CAR)

15h00 S. Gilder, M. de Wit, S. Roud, R. Egli and S. Koch : Magnetic signatures of diamonds

15h20 J. Besse, S. Satolli, R. Domoney, M. de Wit : Disrupted fun in the Cape Fold Belt : pyrite spoils the paleomagnetic party

Coffee Break

16h00 M. Tredoux, Laure Meynadier, M. De Wit, Capacity building

… *Discussion, perspectives, future*

The magnetic field over the Southern African contient:

from core to crustal magnetic fields

Erwan Thébault

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The secular magnetic field evolutions do not proceed in a regular way all over the Earth. In some regions like Southern Africa, the field has been changing more rapidly than elsewhere. During the last five decades, the Earth's magnetic field has been represented in spherical harmonics from a series of measurements that were generally obtained at magnetic field observatories. Unfortunately, magnetic observatories are not evenly distributed over the Earth and are particularly scarce in its Southern hemisphere. This situation leads to low resolution magnetic field models in space, in particular over the South African continent.

An interesting alternative to address this issue is to apply a regional modelling technique to represent all available magnetic data. We apply such a technique (R-SCHA; Thébault et al., 2006; Thébault, 2008) to represent observatory, repeat station and satellite data at the same time in an attempt to obtain a high spatial resolution main field model for the past 40 years. In addition, we show that by merging satellite and aeromagnetic compilations in this region, we are able to derive a mutli-scale vector lithospheric field model. Such approaches are likely to bring new insights into the nature of magnetic field sources occurring in the Earth's crust at a large variety of spatial scales. This new model may also be compared with the known geology in Southern Africa and standard techniques inherited from the geophysical prospecting. This will provide us with some interesting perspectives to proceed within the framework of the !Khure project.

Paleomagnetic results and dating from the Karoo traps

Maud Moulin[1], Vincent Courtillot[1], Frédéric Fluteau[1], Goonie Marsh[2], Martine Gérard[3], Guillaume Delpech[4], Xavier Quidelleur[4]

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A causal relationship between large igneous provinces (LIP) and mass extinctions (ME) or oceanic anoxia events (OAE) is supported by an increasing data base of age determinations. Although the impact of recent (much smaller) volcanic eruptions on climate is understood as being largely due to injection of SO_2 into the stratosphere, the environmental effects of LIP eruptions remain ill understood. Successful climate modelling requires high-resolution timing of volcanism, i.e. number, volume and duration of peak episodes. Chenet et al (2008, and in revision) have studied the Deccan traps, which correlate with the major KT crisis, combining geochronology (K-Ar), paleomagnetism (secular variation), volcanology (flow types) and analysis of alteration levels between flows (red boles); they have shown that emplacement occurred as a small number of discrete, very large and short-lived.

But mass extinctions are not all alike, in pattern or intensity. Some large igneous provinces are correlated with only minor crises, e.g. the Karoo traps formed near the Pliensbachian-Toarcian boundary (~180 Ma).

Remnants of these traps outcrop over > 2.5 10^6 km^2. Jourdan et al. (2008) find that the Karoo traps were emplaced over some 4 Myr, significantly longer than the Deccan. However, the Karoo province does seem to comprise brief (<1-2 Myr), spatially and temporally distinct magmatic events.

We began our study with the Naude's Nek section (the lower 700 m of the traps), located in South Africa near the southern border of Lesotho. Our first determinations (^{40}K-^{40}Ar Cassignol-Gillot technique) yield ages of 181.2 ± 2.4 Ma, in good agreement with previous studies.

Detailed flow by flow magnetostratigraphy (site-mean directions based on thermal demagnetization) shows that the eruptive sequence can be divided into several volcanic pulses having likely lasted less than ~100 years. Particular attention has been focused on the specially detailed record of the only reversal found in the sequence and identified by van Zijl 50 years ago: 136 m of lava erupted over less than a few thousand years.

Indeed we believe that the duration defining a volcanic pulse may be overestimated during the reversal in response to faster secular variation. In order to strengthen our understanding of the eruptive sequence (the record of the eruptive sequence during a reversal as well as the role of the Karoo traps in the Pliensbachian crisis), we are now investigating another section further to the North, in Lesotho, where the Karoo sequence outcrop is the thickest (almost 1600 m), complementing the full lava pile.

We are currently determining site-mean paleomagnetic directions of the new samples removed at the time of the last field trip in order to complete the northern volcanic sequence.

Geomagnetic and Palaeomagnetic studies of the magnetic anomalies associated with the Vredefort impact crater, South Africa: a summary and conclusion.

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Over the past eight years an extensive body of palaeomagnetic Carporzen et al. [1,2] and geomagnetic data Muundjua et al. [3] have been obtained from the central uplift of the Vredefort meteorite impact crater, aimed at the better understanding of the magnetic anomalies associated with the crater. These studies include 550 palaeomagnetic cores and 316840 new geomagnetic data points from within the central uplift area (Vredefort dome).

The palaeomagnetic data Carporzen et al. [1,2] geomagnetic data Muundjua et al. [3] across the central dome have led to two very different explanations to account for the unusual magnetic signatures associated with the Vredefort crater. Here we summarize the results from these two studies and also describe a recent drilling program (Weiss, Carporzen and others) that was recently initiated to test between these two contrasting theories.

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Landscapes, tectonics and hominins in South Africa

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The relationship between complex and tectonically active landscapes and patterns of human evolution is discussed and we describe how active tectonics can produce dynamic landscapes with geomorphological and topographic features that may be critical to long-term patterns of hominin land use, but that are not typically addressed in landscape reconstructions based on existing geological and paleoenvironmental principles. We describe methods of representing topography at a range of scales using measures of roughness based on digital elevation data, and combine the resulting maps with satellite imagery and ground observations to reconstruct features of the wider landscape as they existed at the time of hominin occupation and activity.

We illustrate these methods to sites in South Africa, where relatively stable topography facilitates reconstruction, and demonstrate the presence of previously unrecognized tectonic effects and their implications for the interpretation of hominin habitats and land use. South Africa has advantages compared with East African Rift were reconstruction is more difficult where dramatic changes have occurred since the time of hominin occupation, and where fossils are often found in places where activity has now almost ceased so that the present landscape is a poor analogy for the past. However, we suggest that original, dynamic landscape features can be assessed by analogy with parts of the Rift that are currently active and indicate how this approach can complement other sources of information to add new insights and pose new questions for future investigation of hominin land use and habitats. This approach was originally proposed by Maurice Taib, but never previously explored.

Origin of lemurs in Madagascar: what to expect from marine and GPS investigations?

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In the *Khure* proposal (project A5), we reminded that "*the colonization of Madagascar by lemurs and others mammals from Africa requires either the crossing of land bridge or the transportation on natural rafts. The second hypothesis, also known as the "sweepstakes model", has been suggested to be very unlikely on the base of statistical calculation (Stankiewicz et al., 2006). Therefore, the "episodic emergence of inter-channel islands along the Davie Fracture Zone during the end of the Mesozoic and early Cenozoic [may have] played a significant role in facilitating this colonization process (Stankiewicz et al., 2006).* "

The Davie Ridge is a sub meridian bathymetric ridge that marks the transform motion of Madagascar during its drift away from Africa in the Mesozoic. In 2003, the newly built R/V Beautemps Beaupré of SHOM (*Service Hydrographique et Océanographique de la Marine* – the French hydrographic survey) carried out a bathymetric survey of Europa, Bassa de India and Juan Nova islands in the Mozambique Channel (these islands are part of the "*Iles Eparses*" district, a French Territory). This ship, equipped with a multibeam echosounder of the latest generation, also surveyed a part of the Davie Ridge. We obtained these data from SHOM, processed and analyzed them. In this area, the ridge is as shallow as 500 m. As expected for the trace of a transform fault, it exhibits a strongly asymmetric shape, with a gentle slope toward Africa and a steep scarp, more than 1000 m high, facing Madagascar. This scarp is affected by a number of small gullies, which can be interpreted as the trace of erosional flow on the slopes of a subaerial structure. This observation therefore suggests that at least parts of the Davie Ridge were emerged for some time during its history.

In order to extend this partial bathymetric survey, we submitted two proposals to a call issued by TAAF (*Territoire des Terres Australes et Antarctiques Françaises*, a French authority based in Reunion Island in charge of the "*Iles Eparses"*) to valorise scientifically a rotation of R/V Marion Dufresne in the '*Iles Eparses*". Our first proposal aimed to carry out marine geophysics work, including a significant extension of the Davie Ridge bathymetric (and geophysical) survey. This could have been a mean to confirm that parts of the Davie Ridge were indeed subaerial during its history.

Beyond the evidences for emersion and subsidence of parts of the Davie Ridge, constraints on the age of the subsidence are also required to link (or not) the marine geophysical observations to the paleontological constraints. The subsidence can be explained by the facts the Davie Ridge area is in the continuation of the East African Rift, exhibits a strong seismicity, and may therefore be part of the plate boundary between Nubia and Somalia. Whether this plate boundary is diffuse and extends over a wide area, i.e. Mozambique on land and the whole Mozambique Basin at sea, or is restricted to narrower zones of focused deformation such as the Davie Ridge, is unclear and has consequences on the subsidence of the ridge. To further investigate this question, our second proposal aimed to install GPS stations on Juan Nova and Europa islands, each located on a different side of the Davie Ridge. To make such an experiment possible and useful, we allied with two partners: Portuguese colleagues who operate a wide GPS network over Africa, including 3 stations in Mozambique and 2 in Mauritius, and colleagues from Reunion Island, who also operate stations in the area (Reunion, Comoros).

The first proposal was unfortunately turned down because TAAF could not operate the marine geophysical equipment of R/V Marion Dufresne. The second one was accepted. The Portuguese partners provided the instruments and University of Reunion helped for the logistics. The stations were installed in April 2008 in a quite difficult environment – no power, no external connection, only 7 people residing on each island. The *gendarme*, who is also in charge of radio transmission and electronics, will play an essential role in maintaining the stations and collecting the data. Help of TAAF to transmit the data every couple of month and to allow regular visits to the station will also be crucial. First result of this experiment is not expected before several years.

The origin and early evolution of Madagascar mammalian fauna: First results and perspectives

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The mammalian fauna of Madagascar is very peculiar : It contents neither large herbivore nor large carnivore and is constituted by a few disparate endemic families as lemurians, Nesomyid rodents and the carnivorous Cryptoprocta. These peculiarities clearly correspond to insular evolution during a long isolation period. It is therefore crucial to understand how this mammalian fauna evolved in Madagascar, from which ancestors and from which geographic origins. Unfortunately, in the absence of fossil record, the only indication derive from indirect methods like molecular phylogeny and biogeographic analysis. But these methods have strong limits which can be easily demonstrated. Therefore, our objectives is to find lower Tertiary fossil mammals to contribute to unravel this problem. Until today, not any mammalian fossil older than late Pleistocene and Holocene has been discovered so far. We have realized a first survey of the lower tertiary deposits of South Madagascar, between Tulear and the southern extremity of that island. We have discovered several bone layers which testify of the good preservation of fossil bone. But most of the time, the remains belonged to aquatic vertebrates as turtles or crocodiles.However these fossils testifies the occurrence of fluviatile channels that may contain mammal remains. But the field work in those areas is highly dependant on the security conditions which are unfortunately impredictable. During the last fieldwork, we discovered two Pleistocene karst fissure fillings that yield the oldest recordsof Pleistocene micrommals so far discovered in Madagascar, including lemurians and numerous rodents.

The Barberton Barite Drilling Project (BBDP): Tracking microbial metabolisms in the Early Archean geological record

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Current summer 2008, we completed a diamond drilling of ~200m of sedimentary and volcanic rocks from the Barberton Greenstone Belt in South Africa. The sequence investigated is part of the 3.250 billion years old Mapepe Formation at the base of the Fig Tree Group. This succession is well exposed in the Barite Valley Syncline, where it consists of shallow-water clastic and chemical sedimentary rocks underlain by hydrothermally-altered komatiites and black chert veins of the Mendon Formation.

The goal of this drilling operation was to obtain a representative sequence of the hydrothermally-altered komatiites, black cherts, jasper deposits, and bedded barite. This sequence represents a conspicuous assemblage of rock types that is typically seen in Early Archean seafloor hydrothermal settings. For instance, the Chert-Barite Unit of the Dresser Formation in the Pilbara Craton of Western Australia represents a very similar sequence of rock types. Two drill cores of this 3.49 Ga Chert-Barite Unit have been studied in great detail (Pilbara Drilling Project; *Van Kranendonk et al., 2008; Precambrian Research, 167, 93–124*), and led to the recognition, among others results, of several traces of sulfur-based early life (*Philippot et al., 2007, Science, 317, 1534-1537*). The origin of carbonaceous matter in black chert veins and carbonate beds in this unit suggests the presence of several additional forms of metabolisms (photosynthesis, methanogenesis; *Van Zuilen et al., 2009; Geobiology, in review*) in this ancient seafloor setting. At present it is not clear whether the Chert-Barite Unit in Australia represents a unique, semi-closed basin, or represents a typical seafloor environment that was ubiquitous in the Early Archean. In this respect, it is of great value to obtain a new drill core from a similar stratigraphic sequence that was located some 1000 km away from the Pilbara terrane during deposition.

A stratigraphic log of the BBDP drill core has been performed current fall 2008 (*Philippot et al., 2009; Palevol, in press; http://www.ipgp.fr/pages/020613.php*). During spring 2009, a preliminary petrographic study using scanning electron (SEM) and electron microprobe (EPMA) analysis of representative mineral assemblages has been performed as part of a Master degree *(Noel, 2009*). In addition, the origin and nature of organic matter has been evaluated in the different rock types using a combination of *in situ* Raman spectrometry microanalysis and bulk carbon stable isotope analysis. Important results are presented here.

Mineralogy and Geochemistry of the Witwatersrand Basin Reefs, South Africa: detrital vs. hydrothermal origin of uranium mineralization, possible sources and constraints for the atmospheric pO_2 level prior 2.2 Ga.

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The Archean Witwatersrand Basin, lying on the Kaapvaal Craton in South Africa, hosts the oldest Au-U paleoplacer-type deposits. For the past 50 years, the detrital or epigenetic origin of the mineralization in the quartz pebble conglomerates (reefs) has been highly debated. This work provides a comprehensive mineralogical (petrography and SEM) and geochemical (whole-rock composition, EMPA and SIMS in minerals) characterization of the uranium ores within the different reefs of the basin.

The earliest uranium reefs correspond to the Dominion Group conglomerates deposited from 3.09 to 3.07 Ga and showing the highest U (78-3454 ppm with mean at 817 ppm), Th (29-1498 ppm with mean at 527 ppm), Rare Earth Elements (ΣREE=94-10234 ppm with mean at 3431 ppm) and other high field strenght elements (HFSE) concentrations. Uranium ore is mainly within heavy mineral beds as abundant well-rounded uraninite grains up to 200 µm wide associated with pyrite, titanium oxides, chromite, almandine-family garnet, ferro-tantalite, zircon and monazite. Subsequent hydrothermal deposition of colloform pitchblende, microcrystalline (U,Th)-silicates and urano-titanates have been observed.

In the younger Central Rand Group reefs, deposited from 2.91 to 2.71 Ga, uranium distribution is more scattered and mineralization is generaly represented by very fine grained uraninite disseminated within carbonaceous matter seams or nodules with pyrite, gold, secondary galena and (U,Ti)-silicates re-deposited on kerogen after alteration of primary uraninite. The Central Rand Group conglomerates have lower U (2-394 ppm / mean 140 ppm), Th (4-91 ppm / mean 22 ppm) and REE (ΣREE=47-607 ppm / mean 150 ppm) concentrations which is relevent of the abundance and nature of U-bearing accessory minerals, primary but also secondary redeposited after hydrothermal alteration.

Major and trace elements in uraninite have been analyzed by electron and ion microprobes (CAMECA SX100 and IMS-3f). In primary grains, the high Th content in uraninite (up to 9.31 wt% ThO_2) shows that it has crystallized from high temperature magmatic proccesses. Moreover, the variation of Th contents between individual uraninite crystal are characteristic of their ultimate derivation from various types of granitic source. The Witwatersrand uraninite compositions range between the fields of peraluminous leucogranites (low Th) and S-type granites from the partial melting of metasediments (high Th). REE patterns are also characteristic of magmatic uraninite: high ΣREE (~ 10^4 chondrites), weak fractionation of the REE with a flattened bell shape pattern and a negative Eu anomaly corresponding to early plagioclase fractionation in the magmatic source.

The geochemical signature of the uraninites from the Witwatersrand Basin demonstrates their derivation from granites/pegmatites enriched in U, and their mechanical accumulation in paleoplacers. Granitoids sufficiently enriched in uranium able to crystallize uraninite have to have existed as soon as 3.1 Ga. This work further support the anoxic character of the Earth atmosphere during uraninite-bearing reef deposition.

Plateau uplift, epeirogeny and climate changes: The Kalahari Plateau, a world class laboratory

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The Kalahari Plateau is a 1000-1500 m high plateau that stretches ~2500 km from southern to central Africa. The origin of this plateau and its margins are not well understood but can be traced back to peneplanation near sea-level during the continent-wide end-Paleozoic Gondwana glaciation (~300 My), followed by extensional intracontinental tectonics during the Late Permian-Triassic (Karoo rifts and basins) and continental break-up during the the Late Jurassic – Early Cretaceous (formation of the Atlantic and Indian Oceans). The peneplain was also affected by extensive volcanic activity: three large flood basalt events (the Karroo, 170-180 My; the Etendeka, 132 My; and the Aghulas (100-90 My) and two punctuated episodes of kimberlite emplacement (around 120 My and 90 My). The goal of this project is to quantify the growth of this major topographic feature of the Earth – the very long wave length Plateau topography, and the associated rates of uplift over the last 300 My, in order to understand the dynamics of Africa's surface processes (erosion, transport, sedimentation), climate change, hydrology, and biological evolution in response to landscape evolution. Main results:

1. **The southern Africa passive margins as a record of the Kalahari plateau uplift.**
The sedimentological and sequence stratigraphic studies of wells and seismic lines of the passive margins of South Africa (provided by the South African Petroleum Agency) confirms a Late Cretaceous age for the main events of sediment dispersal from Kalahari plateau. This is diachronous: it started between 115-95 My around the coastlines and ended at 80 My for most of the Plateau. This sediment dispersal controls the growth of two main catchments (pre-Orange and a pre-Limpopo) and the products of erosion fed a large deep-sea fan located along the Agulhas fracture zone. Fission track dating conforms that enhanced episodes of cooling and (assumed) uplift occurred at between 160-138 and between 115 and 90 Ma. Whilst the interplay between uplift and erosion/sediment transport has not yet been adequately addressed, at least 5 km of rocks were eroded during the Cretaceous, and that during the Cenozoic the amount of total denudation decreased dramatically by at least an order of magnitude, approaching the very low present-day denudation rates determined by cosmogenic nuclide data.

2. **Mapping the planation surfaces.**
We compiled a database of sediments and weathering profiles associated with the planation surfaces. The field study of the Eocene marine sediments of South Africa and a quantitative geomorphological study indicate that most of the retreat of the Kalahari plateau escarpment happened before 50 My. Mapping of the palaeo-marine cliffs and marine planation surfaces lead to a quantification of an Oligocene uplift of up to 500 m.

3. **How old is the infilling of the Kalahari desert?**
Drillings results from the Kalahari Desert (NW Botswana) are new and still tentative: three periods of weatherings have identified (pre-Karoo, pre- and post-80 My kimberlites, and Neogene?). An unknown Karoo accumulation and a carbonate lake (Tertiary?) were discovered. The post-kimberlite laterite records humid conditions on top of the Kalahari Plateau after 80 My. Aridification is younger (prossibly around 25 My).

The formation of the Kalahari plateau is at least a five step process (1) 350-300 My Dwyka glaciations, (2) ~ 250 My – formation of the Cape Fold Belt and related intracratonic Karoo rifts, (3) 160-140 My, (4)120-90 My, (5) 90-80 My, (6) 40-35 My-eastern part of the Plateau. The next step will be the characterisation and the modelling of the relief growth through the past 300 My, and monitor its related geomorphic and climate changes.

Traçing Conflict Diamonds ?: Yes we can… sometimes.
Case studies on diamonds from Central African Craton (RDC and CAR).

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Diamonds known as *conflict diamonds*, otherwise known as *blood diamonds*, originate (mostly) from the war zones of Africa, and specifically from areas controlled by forces or factions opposed to legitimate and internationally recognized governments, and are used to fund military action in opposition to those governments, or in contravention of the decisions of the United Nations Security Council. On December 1, 2000 the UN General Assembly unanimously adopted a resolution defining the role of conflict diamonds with the intent of cutting-off the sources of funding for rebel forces and to help shorten the wars and prevent their recurrence through breaking the link between the illicit transaction of rough diamonds and armed conflict. The questions asked to scientists is/was : Can we help to recognise them ? And, potentially, which systematic(s) can/should be used

Our approach is two fold.

(1) using the geochemical characteristics of diamonds for which a substaintial (although incomplete) database exists, identify if conflict diamonds can display at least one unusual geochemical characteristic that can be used to recognised them. It is of course better but not a prerequisite if the technique is quick, cheap and non-destructive.

(2) developing the potential of new tools and, in particular, to develop the potential of diamond magnetic properties. The present abstract focusses on the first aspect.

Furthermore, (most importantly ?) before any attempt is made to trace conflict diamonds, some fundamental questions remain to be discussed. Recognising a diamond population on the basis of their geochemical characteristics indeed assumes that these (size, shape, color, deformation, paragenesis, C-isotopes etc…) would not change through time as the kimberlite (or placer) is being mined. There is yet no data to address such a possibility.

We have undertaken a geochemical and magnetic study of diamonds from Republic Democratic of Congo (the primary kimberite) and Central african Republic (placer deposits containing diamonds derived from the above kimberlites).

The samples include both so-called coated diamonds (a gem diamond surrounded by a coated of fibrous/opaque structure) and gem diamond. The coated is related to kimberlite volatiles (ie the coat has the age of the kimberlite) whereas cores are much older and usually are of Archean in age (ie > 2.5 Gy).

We will show that the diamonds under investigation are unique from their N-contents (which are unusually high, average is 1000 ppm), making possible to recognise diamonds from those areas (however C-isotopes or N-aggregation are not symptomatic). We will also show that available evidence is compatible with the fundamental assumption that the kimberlite yields diamonds with homogeneous geochemical characteristics –not with the depth within the crust – but at least with depth within the continental lithosphere (~150-250 km). From that evidence, we suggest that diamond populations are actually homogeneous within the continental lithopshere and therefore within the kimberlite.

Magnetic signatures of diamonds

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In 2000 the UN General Assembly adopted a resolution defining the role of conflict (blood) diamonds with the intent of cutting-off the funding sources of armed forces through illicit transaction of rough diamonds. However, no one has yet mastered a non-destructive technique that can fingerprint these precious stones. Because diamonds sometimes contain opaque, iron, and chromium-bearing sulphide or oxide inclusions, perhaps diamonds can be characterized magnetically. Our preliminary findings show that the magnetic properties of diamonds are indeed unique as fingerprints. Our findings can also potentially yield information concerning diamond genesis by exploiting the fact that magnetic characteristics are highly sensitive to composition, oxidation and strain.

Petrogenesis of Sanukitoids : Example of the Bulai Pluton, Central Limpopo Belt, South Africa

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The word sanukitoid refers to Archaean high-Mg dioritic, granodioritic and monzogranitic plutons. These magmatic rocks display geochemical features of both Archaean TTG (fractionated REE patterns, strong HFSE- depletion) and modern BADR series (calc-alkaline differenciation trend, high LILE contents). Their transitional characteristics are not only compositional, but also temporal; indeed sanukitoids were reported in almost all Late Archaean terranes, where they emplaced at Archaean-Proterozoic boundary (2.5 Ga). Consequently, sanukitoids are considered as the result of the petrogenetic and geodynamic changes that took place at the end of the Archaean. In NE South Africa, the 2.6 Ga old Bulai pluton is a calc-alkaline granodioritic pluton intruded into the granulitic Limpopo Belt. It shares several petrographic characteristics with sanukitoids : it is a hornblende- and biotite-bearing porphyritic granodiorite, associated with monzodioritic enclaves and both mafic and granitic dykes. Whole-rock major- and trace-element analysis show high LILE contents (K2O > 3 wt. % ; Rb 60-200 ppm ; Ba 600-2600 ppm) and fractionated REE patterns (25 < (La/Yb)N < 80; with La > 80 ppm). However it slightly differs from typical sanukitoids by lower Ni and Cr contents, Mg# and higher SiO2 contents and K2O/Na2O. In Harker's plots, data draw linear trends for both major and trace elements, over a wide range of compositions, from 47 up to 74 wt. % SiO2. In case of fractional crystallization or of partial melting, this would imply that the composition of the cumulate or of the residue remained constant throughout the whole process, which is unlikely over a so large range of SiO2. Consequently, such long linear is better explained by mixing processes. The calculated poles of the mixing are : i) an acid one represented by a granitic dyke (SiO2 = 74 wt.%) and ii) a mafic one, whose composition is close to that of monzodioritic enclaves (SiO2 = 47 wt.%). The SiO2-rich pole is assumed as generated by melting of the surrounding TTGs. On the other hand, the mafic pole would represent the primitive sanukitoid magma : monzodioritic enclaves and basic dykes are the richer, not only in Fe, Mg, V, Ni and Cr but also in both REE and incompatible trace elements thus precluding a cumulative origin. Modeling shows that this pole can have been produced by partial melting of a mantle peridotitic source, which was previously enriched in LREE and LILE. In addition, the Nb/Y ratios of these magmas points to a metasomatic agent that would be a TTG-like slab melt rather than a fluid. These results are in good agreement with previous studies focusing on the petrogenesis of sanukitoids which identified a peridotitic source metasomatized by slab-derived melts. They also enhance the role of mixing with crust-derived magmas, which seems to be a key process in the genesis of many sanukitoid suites. We interpret the genesis of the Bulai sanukitoids in terms of decreasing TTG production in course of time. This interpretation is based on the effective melt/rock ratio of Rapp et al. (1999): during Archaean times, due to high geothermal gradients, great volumes of TTG magmas were produced such they were not all consumed in reaction with mantle peridotite. At the Archaean-Proterozoic boundary, due to cooling of the Earth, TTG magmas were produced in smaller amounts and totally consumed by reaction with peridotite, which subsequent melting gave rise to sanukitoids.