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SOURCE AND ORIGIN OF AFRICAN A-TYPE MAGMATISM – A TOMOGRAPHIC SOLUTION

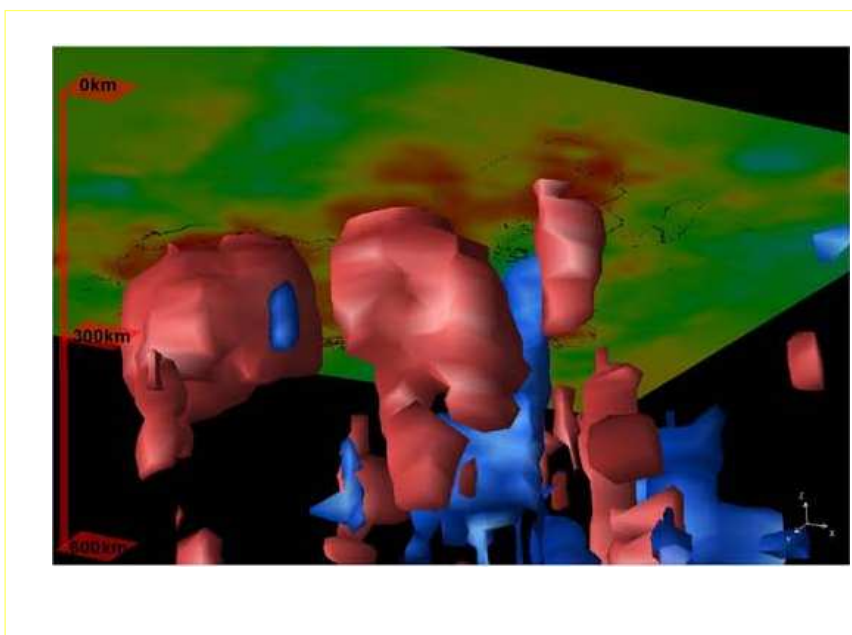
P.Bowden, J-Y Cottin Dept Géologie, Université Jean Monnet, 42023 Saint Etienne

There is still some debate concerning the petrogenesis of African A-type magmatism. For instance, Martin (2006) considers that A-type granites are of crustal origin resulting from fenitization in an extensional environment. However, Bonin (2007) prefers to regard A-type granites as mantle products from parental transitional-alkaline mafic to intermediate magma compositions. This presentation concerns seismic tomography of the African continent (Begg et al., 2009) which can help to identify the structural setting, source and origin of alkaline A-type magmatism.

The basic fabric of Africa cratons consist of Archean cores and Palæoproterozoic reactivated cratonic margins flanked by Pan African fold belts. For the West African, Congo and Kalahari cratons shear wave speeds V_s are higher, indicating that the cratonic mantle is relatively cool (or more dense), depleted in basaltic components, with distinctive keels (lithospheric mantle roots) down to at least ~ 400 km (see Fig below). There are also intermediate to low seismic shear wave velocities in the Pan African fold belts, suggesting less dense material, or higher geotherms with more fertile mantle to shallower depths.

Global seismic tomography and geodynamic models suggest that Africa sits above a major Superswell defined as a continental scale low V_s anomaly in the mantle emanating from the core-mantle boundary (Ritsema et al., 1999). Thus volcanism in Afar, Air, the Hoggar, active rifting in East Africa, and other Cenozoic areas of alkaline magmatic activity in Africa may be linked to the influence of this Superswell.

Cratonic marginal control on Phanerozoic alkaline igneous activity can be well observed from the superimposition of craton depth profiles from seismic tomography, and the surface cartographic location of alkaline magmatic centres in Africa (Woolley, 2001)



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DIAMOND-BEARING GRAVEL ALONG THE LOWER KWANGO RIVER, DRC

De Wit MCJ[°] and Thorose E²

[°]University of Pretoria (dewit@icon.co.za)

²BRC-Diamondcore (Pty) Ltd (ethorose@brc-diamondcore.com)

The first discovery of diamonds along the Kwango River was recorded in 1922 on a Forminière map prepared by Faucett and Young. They sampled river sediments at various points in the lower Kwango downstream from Kasongo Lunda and recovered grades of up to 0.86ct/m³. This was not of interest at the time when new major diamond mining activities were going on at Tshikapa and Mbuji Maye further east. In the 1950s however, there was renewed interest in the area from both Angola and the DRC especially around the town of Tembo where diamonds have since been mined. Large-scale alluvial diamond mines were developed further upstream between Cuango and Cassango in Angola, and exploration stream sampling in the upper reaches of the Kwango River eventually led to the discovery of many kimberlites in the Muongo/Alto Cuilo region of the Lunda Norte Province. These are the only known kimberlites in the Kwango Basin.

Migmatite basement at the Francois Josef Falls near Tembo is covered by coarse-grained conglomerates of possible Mesozoic age just below the falls. Stratigraphically this is overlain by basal gravel units of Cretaceous Kwango Group and the Calondo Formation in the DRC and Angola respectively, which are diamond-bearing and contain abundant agates. In places these sediments contain kimberlitic indicator minerals, since the intrusion of the Cretaceous kimberlites, such as those at Alto Cuilo, was contemporaneous with the sedimentation of the Calondo Formation. Importantly, the distribution of these minerals in the post-Gondwana units, including diamond, reflects of the development of the Congo Basin.

The Kalahari sediments, which rest on a Late Cretaceous surface, consist of sands and locally derived gravels with a distinctive silicified sandstone layer also referred to as the 'grès polymorphe'. Boulders of this silicified unit found within the recent alluvium of the Kwango are instrumental in trapping diamonds.

The secondary diamond deposits along the Kwango River in the DRC are associated with gravels in the terraces and flats, but diamonds are also recovered from recent sediments within the river. The granitic basement forms an irregular floor characterised by gravel-filled troughs and potholes, whereas the overlying Mesozoic sediments produce planar depositional surfaces.

The François Josef falls near Tembo mark a major change in the river gradient. Over the length of the falls the river descends by some 8.5m per kilometre (170m over the 20km stretch). Here and upstream from the falls around Nzasi-Muadi, the Kwango River cuts through the crystalline basement and passes between a narrow, steep-sided bedrock controlled valley containing economic diamond grades in narrower channels. Below the falls and over a distance of 100km the river drops by approximately 20m or roughly 0.2m per kilometre. Here the Mesozoic and Cretaceous sediments form the base, and the river is wider and has a gentle gradient with more extensive flats and terraces with broader and shallower palaeo-channels. This geomorphic change has a pronounced effect of the type and economic value of the alluvial diamond deposits. Over the post-Gondwana cover sequences the trapping of diamonds appears to have been controlled by silcrete boulders derived from the Kalahari. Here the gravels are generally thin (<30cm) and overlain by fluvial quartz sand/silt varying between 1 and 15m. Ground geophysics in the form of Resistivity Surveys identified high-conductivity areas that were interpreted as waterlogged or clay-rich features and therefore possible palaeo-channels. A subsequent Airborne Electromagnetic survey was flown over some of the flats flanking the river and was able to highlight some channel features below the cover sands. Subsequent drilling and pitting over the flats and terraces were able to confirm some of these features as channels.

A first-pass assessment of the diamonds recovered from some of the deposits between Tembo and Kasongo Lunda indicates that the Kwango in the DRC forms part of a distributary system in which the diamonds decrease in size in a downstream direction. There are some points however where the river narrows with an increase of silcrete boulders, which have had a positive impact on diamond grades and sizes. Presently however the secondary diamond deposits below the falls are sub-economic.

MINERAL PROVENANCE ASPECTS OF THE BLACK REEF CONGLOMERATE IN THE EAST AND (FAR) WEST RAND AREAS

Gauert, C.D.K., and Roettger, S.

Dept. of Geology, University of the Free State, Bloemfontein, R.S.A., gauertcdk@ufs.ac.za

Keywords: Black Reef, geochemical Au fingerprint, provenance, West and East Rand

The base of the Black Reef Formation in South Africa is a rather unique gold-, uranium- and PGE-bearing conglomerate horizon, in places highly economic. Henry and Master (2008) identified shortcomings in our understanding of the genesis of Au mineralization and their provenance. Therefore, various selected profiles of the conglomeratic Black Reef have been investigated for the exact mineralogy and geochemistry of the mineralization, its economic potential, and the alteration products of envisaged late-stage hydrothermal events. Methods included litho-geochemistry for sediment provenance studies, geochemical fingerprinting of Au using EMPA, SR- μ -XRF, TOF-SIMS and μ -PIXE for Au provenance, ongoing microthermometry of ore and gangue minerals to geochemically characterize alteration associated with Au remobilisation.

The heavy mineral assemblage contains chromite, sphalerite, chalcopyrite, galena, uraninite, cassiterite, tourmaline, Ni-Co-sulpharsenides such as cobaltite, gersdorffite, and free gold. Detectable traces in gold by EMP analyses comprise Fe, S, U, Th, Ni, Cu, Pb, Cd, As, and Bi, possibly from micro-inclusion (Fuchs & Gauert, 2010). Gold shows a good correlations ($r \geq 0.5$) with Ag, Hg in EMPA measurements;

LA-ICP-MS measurements show a reasonably well correlation of Au aggregates with Ag, Mn, Rh, Ag, Cu, Te, Os, Ir, Pt, Pb; Whole rock ICP-MS measurements confirm the good correlation ($r \geq 0.75$) of Ag, As, Fe, Ge, Ni, S, Sb, Se, Tl with Au (Gauert et al., 2010).

Among those elemental relationships Sn, Sb, Pd, and Pt possibly combined with Mn, Cu, Se, Pb, Se, Ir, Os, Ru, and Tl appear the most effective element combination for distinction of Au sources due to their moderate variation in repeated LA-ICP-MS measurements, whereas As, Zn, Ag, U, Pb, as well as Ni and Cu are probably less suitable because of their abundance in surrounding pyrite.

Synchrotron micro-XRF gives good spatial and compositional resolution of Au-Ag particles, trace element quantification is ongoing. Qualitative TOF-SIMS technique identified Ag, Sb, Na, Ca, and Bi in Gold. LA-ICP-MS analyses indicate low fineness of Au, Cr, Ni, Cu, As and Pb as traces and detectable Pd, Sn and Sb; as well as high Ni, Co, As, Cr and detectable Zn, Mn, Ti, Se, Pt, Ru, Pd in neighbouring pyrite. Discriminant diagrams based on immobile major and trace elements show ferruginous clastic BR sediments to have chemical features of ocean island arcs of mixed felsic to mafic source of predominantly post-Archean origin.

A similar heavy mineral content of Black and Witwatersrand Reefs supports a similar provenance whereas occurrence of concretionary pyrites with unradiogenic Pb isotope composition as well as less abundant Ni-Co-Fe-sulpharsenides in Witwatersrand reefs speak against a common source.

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PLATINUM GROUP-MINERAL OCCURRENCES IN ALASKAN TYPE MAFIC-UTRAMAFIC ROCKS IN NORTH EAST AFRICA (YUBDO, ETHIOPIA & AKAREM, EGYPT)

Mogessie, A.¹ & Helmy, H.²

¹Institute of Earth Sciences, Department of Mineralogy and Petrology, University of Graz, Universitaetsplatz 2, A-8010, Austria; mogessie@uni-graz.at

²Department of Geology, University of El Minia, Egypt; Hassan.helmy@yahoo.com

Keywords, Platinum, Yubdo, Akarem, Ethiopia, Egypt

The ultramafic complexes of the East African Orogen (EAO) in western Ethiopia lie along a line stretching for more than 100 kms towards NNE and these include among others, the well known Yubdo mafic-ultramafic body which is covered by thick laterites, Daleti and Tulu Dimtu in the north east. Although these bodies have been considered to belong to an ophiolitic belt representing a suture for the closure of the East and West Gondwanaland, detailed geological, petrological, geochemical and Platinum group-element geochemistry have shown that the belt represents an Alaskan Type mafic-ultramafic rocks comparable to those of the Urals (Mogessie et al., 2000). The Yubdo mafic-ultramafic body consists of several Platinum group-minerals mainly tetraferroplatinum, isoferroplatinum, tulameenite and a series of Osmium-Iridium phases included within the Iron-Platinum alloys. Based on microscopic study and Electron microprobe analyses two types of PGM (platinum-group-minerals) mineralization are documented: 1) in placer deposits and 2) in fresh and serpentinised ultramafic rocks, from bore holes. The PGM in the chromites of the fresh rocks show Pt₂Fe compositions while the PGM in the serpentinized zones and the placer deposits show isoferroplatinum (Pt₃Fe) and tulameenite compositions.

The comparison of the analytical data and textures of the PGM showed that the original PGMs are magmatic droplets collected by chromites, later released and recrystallized during the alteration of chromites by hydrothermal fluids. The findings of relatively large PGM grains in the serpentinized zone; and a diorite intruding the ultramafic body in the borehole section are strong evidence for hydrothermal fluid to be responsible for the remobilization, transport and the growth of the nuggets. The association of Pt and Au in both the primary and placer nugget formation indicate that the same fluid is responsible for the remobilization of precious metals in Yubdo. The mineralization is sulphide poor and enriched in magnetite and chromite compared to the second Alaskan-type mafic-ultramafic body we have identified in the Arabian Nubian shield in Egypt

Concentrically zoned mafic ultramafic intrusions (Gabbro Akarem, Genina Gharbia and Abu Hamamid) in the northern part of the Arabo-Nubian Shield are located along deep fracture zones perpendicular to the Red Sea rift. These complexes have many petrological features typical of Alaskan-type complexes even though they are Precambrian in age. Unlike typical Alaskan-type complexes, Gabbro Akarem contains sub-economic Cu-Ni-PGE mineralization. Massive and disseminated sulfide ores (pyrrhotite >> pentlandite > chalcopyrite) are hosted in the ultramafic core rocks. Merenskyite, michenerite and Pd-rich melonite are the only platinum-group minerals (PGM) noted in the massive sulfide ore. The IPGE (Ir, Os, Ru) contents of the massive and disseminated ores are very low (generally <2 ppb). The Pt and Pd contents are similar in both disseminated and massive ore. The type of PGM, PGE geochemistry and the generally high Pt+Pd/Te ratio suggest high potential of PGE mineralization in the intrusion.

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THE MERENSKY REEF INTERVAL AT DWARSRIVER 372 KT, EASTERN BUSHVELD COMPLEX.

Rose, D.H.¹, Knoper, M.¹, Viljoen, K.S.¹, & Rajesh, H.M.¹

¹ Department of Geology, University of Johannesburg, South Africa; derekr@postgrad.uj.ac.za

Keywords: Merensky reef, Mineral chemistry, PGE mineralization, Eastern Bushveld Complex

The Two Rivers Platinum (TRP) Mine which occurs within the farm Dwarsriver 372 KT currently exploits only the UG-2 chromitite for its PGE mineralization although the Merensky reef also occurs within this area. TRP is located approximately 25 km due south-west of Steelpoort in the north-western part of Mpumalanga. This current study thus focuses on the Merensky reef (MR) within the farm Dwarsriver 372 KT, on the southern sector of the Eastern limb. In this contribution the MR is taken as the interval bounded by a basal and an upper chromitite stringer, which in this case is a pyroxenite.

It has long been accepted that the Rustenburg Layered Suite of the Bushveld Complex formed as a result of multiple magma injections into the main Bushveld chamber. In testing the validity of this premise certain minerals, such as orthopyroxene, plagioclase, chromite and olivine can be used to document the chemical changes that the crystallizing magma underwent during fractional crystallization. These minerals act as the proxies from which the indices of fractionation, such as the %En and Mg# in orthopyroxene, %An in plagioclase, Cr# in chromite and %Fo in olivine can be computed to determine the cryptic variation of these mineral phases within a specific stratigraphic section or profile, in this case the MR and the associated lithologies of the MCU. The chemistries of the minerals that act as proxies for fractionation have historically been sourced largely from the Western limb. Given that there is a dearth of mineral chemistries for the lithologies of the MR particularly those in the southern sector of the Eastern Bushveld, this study aimed to contribute to the data base of the mineral chemistry for orthopyroxene, plagioclase, chromite and to a limited extent olivine. In so doing once the MR was delineated by petrographic studies on drill core, samples were taken at 30 cm intervals throughout the MR interval including 2 m at most into the footwall and hanging wall lithologies, depending on the amount of drill core available for an intersection. A total of five drill core whole MR intersections were sampled which covered the four different reef facies types from which a total of 76 thin sections were prepared. These samples were subsequently analyzed with a CAMECA SX 100 housed at SPECTRAU, University of Johannesburg. Overall the MR orthopyroxene ranges from En_{85.83} at the base and decreases to En_{71.27} with stratigraphic height. The overall MR plagioclase compositions are much more variable than those of the MR orthopyroxene and range from An_{89.02} to An_{34.92}.

The second part of this study focused on the platinum group minerals (PGM) associated with the chromitite stringers of the MR. Previous studies on the MR at Dwarsriver have focused on the platinum group element (PGE) grade distribution based on whole rock assays. This method although useful in giving an indication of the PGE present within the rock does not render useful information of the actual distribution and textural relationships of the PGEs within the PGM. In ensuring maximum extraction of the PGE from the PGM it is useful to determine the size frequency distribution along with the mineralogical associations of the PGMs with other minerals. Up until now the acquisition of such data was both operator and time intensive. The advent of automated SEM-based image analysis techniques such as the Mineral Liberation Analyzer (MLA) has dramatically reduced the time required to acquire data pertaining to the geometallurgical properties of ores of interest. For this study the aims were thus to determine the PGM assemblage present within the basal and upper chromitite stringers and also to establish the mineralogical associations of the PGMs with other minerals as well as the grain size distribution of the PGM. In so doing a total of 25 thin sections covering the basal and upper chromitite stringers were prepared from 12 diamond drill core Merensky reef intersections and were analyzed using an FEI 600F MLA housed at SPECTRAU. Results show that sperrylite, isoferroplatinum, cooperite, laurite, maslovite as well as an unidentified phase (PtPdNiS) (which is most probably braggite) are the most common PGMs within the basal and upper chromitite stringers. The average grain size distribution of the PGMs is approximately 40 µm. These PGM have a strong affinity for base metal sulfides (BMS) of approximately 31 %, although modally the BMS make up 2.04 % at most.

RECOGNIZING MAGMATIC CONDUIT DEPOSITS BY GEOLOGICAL SETTING

Steenkamp, N.C.¹

¹ Department of Geology, University of Pretoria, South Africa, 0002; steenkamp.nc@gmail.com

Keywords: conduit, magmatic, mafic, sulphide deposits

Magmatic conduits are being recognized as exploration targets for Cu-Ni-PGE deposits. In the present work, an overview of known conduit related Cu-Ni-PGE deposits is presented. It is suggested that conduit deposits share some common geological traits that enhanced prospectivity for economic Ni-Cu-PGE sulfides. Using these geological characteristics it should be possible to evaluate the prospectivity of other magmatic conduit hosted intrusions.

Magmatic Cu-Ni-PGE deposits such as the Uitkomst Complex (South Africa), Kabanga (Tanzania), Noril'sk-Talnakh (Russia), Jinchuan (China), Voisey's Bay (Canada) and Sally Malay (Australia) tend to be hosted by magmatic conduit structures. By reviewing published literature and comparing the geological setting of variably mineralized conduit deposits it is attempted to identify proxies that may point to intrusions of enhanced prospectivity. Many properties of Cu-Ni-PGE deposits have been summarised earlier, but this presentation focuses on conduit deposits only and excludes genetically unusual deposits such as Sudbury (astrobleme-related) and large layered intrusions.

This presentation highlights the following commonalities: 1) Intrusions are found in the vicinity of prominent crustal sutures, providing a zone of weakness into which the magma intrudes. 2) The intrusions are frequently located along the margins of Archean cratonic blocks, emplaced within Proterozoic sedimentary sequences. 3) Deposits vary in age but many were emplaced during the Proterozoic. 4) Many of the intrusions have been deformed during emplacement orogenesis. 5) Most deposits show indirect (isotopic signatures) or direct evidence (presence of xenoliths) for crustal contamination. 6) Deposits are frequently associated with high-volume magmatic events. 7) Most intrusions are sill-like or chonolitic 7) Dynamic "feeder systems" result in distinct metamorphic aureoles around the bodies.

The composition of the deposits shows some common features: 8) Host rocks are mafic/ultramafic intrusive consisting of a largely gabbroic to noritic upper part and a peridotitic lower section. Some have very small mafic parts, e.g. Kabanga. This may reflect intrusion of olivine-pyroxene crystal mushes but this is not due to in-situ fractionation. It rather results from a flow of magma from an underlying, fractionating chamber. 9) A magma capable of crystallizing a substantial amount of olivine. 10) Deposits formed from high Mg magma types. The location and paragenesis of the ore body also share some common traits, such as: 11) The massive sulphides tend to be located at the base of the intrusives or around the periphery of tube-like bodies. 12) Analyses of samples, including silicates and sulphides, directly above massive sulphides usually show elevated Ni values because of disseminated sulphides above the massive sulphide deposit. 13) Silicates higher in the sequence well above the deposits are often depleted in Ni.

It was also recognized that certain factors influence the formation of the deposits. These include: 14) Addition of sulphur from adjacent country rock. 15) A dynamic flow-through system is required in order to generate the high R-factor conditions necessary to upgrade the sulfides. In order for the sulphide mineralization to become enriched in platinum group elements, the sulfides need to continuously interact with the intruding magma, without being removed from the system. It has been suggested that the sulphide minerals are localized in flow-dynamic or structural traps in the conduits, e.g. widening of the conduit, or exits of the conduits into a sub-chamber, or a bend in the conduit leading to a reduction of the flow rate of the magma. Finally, it is important to recognize the importance of tectonic activity, post-dating the intrusion, in bringing the deposit to minable depths. Another possibility is that tectonism causes roof collapse, which would filter press magmas up structures, perhaps even sulfide liquids. This could explain the occurrence of sulfide veins separated from the silicate rocks.

LIBYAN DESERT GLASS: FORMATION BY METEORITE IMPACT OR AIRBURST?

Koeberl, Christian^{1,2}

¹ Department of Lithospheric Research, University of Vienna, Althanstrasse 14, A-1090 Vienna, Austria; christian.koeberl@univie.ac.at

² Natural History Museum, Burgring 7, A-1010 Vienna, Austria.

Keywords: impact craters, Libyan Desert Glass, airburst, meteorite

Libyan Desert Glass (LDG) is an enigmatic type of natural glass that is found in an area with an extension of several thousand square kilometers. Literature values on the extent vary between about 2000 and 6500 km². This area, or strewn field, is located between sand dunes of the southwestern corner of the Great Sand Sea in western Egypt, near the border to Libya. Therefore, the name "Libyan" Desert Glass is not entirely correct, given today's geographical boundaries, but refers to the traditional name of the desert. P.A. Clayton was the first to travel the region in the early 1930s and to collect glass samples that were used to provide the first detailed scientific description of the glass and its occurrence. In addition, R. A. Bagnold visited the LDG area in the 1930s. The inaccessibility of the LDG area was the reason for a relative paucity of visits to the location. In the 1970, samples were collected for petrographic work. In addition, two impact structures exist just over the border in Libya, about 100 km west of the LDG strewn field: the B.P. and the Oasis impact structures, which are of interest because of a possible connection with the origin of the LDG. Recent work seems to indicate, though, that the source rocks at BP and Oasis, while similar, are not identical to those of the LDG.

Macroscopically, the glass is irregularly shaped with signs of sand abrasion and other erosion features; buried parts are often more severely eroded, possibly due to humidity. The fission track age of LDG has been determined to be about 29 Ma. LDG is a very silica-rich natural glass with about 96.5-99 wt.% SiO₂, and shows a limited variation in major and trace element abundances. So far rather few trace element studies of LDG exist, but the available data (for example, those for the rare earth elements) indicate abundances and interelement ratios that are typical for upper crustal rocks. Most glass fragments, which can weigh up to several kilograms, are small, yellowish-translucent to white-opaque; a few are dark brown, green, or even appear black.

The origin of LDG has been the subject of a controversy, which - in the view of some researchers - is still not settled. However, the majority of workers favor an origin by impact. There are, however, some differences to "classical" impact glasses, which occur in most cases directly at or within an impact crater. Evidence for an impact origin includes the presence of schlieren and partly digested mineral phases, lechatelierite (a high-temperature mineral melt of quartz), and baddeleyite, a high-temperature breakdown product of zircon. The dark-colored specimens have brown to black to grayish-bluish layers or inclusions or schlieren. Some of those are partly digested minerals, possibly from the target rocks, whereas others have been shown to contain a distinct meteoritic component. The platinum-group elements are enriched in these layers, up to almost 1% equivalent of a chondritic component. In addition, the osmium isotopic composition of such layers was shown to contain a meteoritic component, which was confirmed by recent chromium isotopic studies. Furthermore, the presence of shocked quartz in rocks of the area in which the LDG occurs has been reported in the literature, and confirmed in our work. Over the past years, an airburst origin for the LDG has been suggested as an alternative to the "hard impact" model, partly due to the lack of an impact crater. This would require that superheated air melts the surface of the target, and a small fragment of the impactor might make a small crater. However, the observations mentioned above are difficult to reconcile with an airburst model, because it requires physical mixing between meteoritic and crustal matter, which seems unlikely in the case of an airburst. In addition, airburst should occur more frequently than impacts, and the lack of similar "airburst-produced" glasses over the world is not easy to explain.

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UNUSUAL HIGH ENRICHMENT OF IRIIDIUM IN CHROMITITE FROM KATPHAL CHROMITE MINE, ORISSA, INDIA

P.V.Sunder Raju^{1,2}, R.K.W.Merkle²

¹National Geophysical Research Institute, Hyderabad- 500007, India (*Council of Scientific and Industrial Research*) email address: perumala.raju@gmail.com

² Dept.of Geology, University of Pretoria, Pretoria- 0002. South Africa.

The Sukinda ultramafic field forms part of the metamorphosed Precambrian shield of the Indian Peninsula. Dismembered chromiteferous ultramafic bodies occur sporadically in an area of 420² km around Sukinda within latitudes 20°.53' and 21°.05' and longitudes 85°.40' and 85°.53' (Banerjee, 1972; Page et al 1985). The ultramafic rocks are orthopyroxenites, dunites, and chromitite. The Katpal body lies ~ 12 km towards SW in the same strike direction as Sukinda ultramafic field at (latitude 21°.01' N and longitude 85°.43'E.). At Katpal, chromitite bodies are brecciated (Sarkar et al., 2001) and similar to the Nuasahi massifs (Mondal and Baidya 1997), from which PGE mineralisation is reported (Auge et al., 2004). The regional stratigraphic sequence in Katpal from the bottom upwards, is orthopyroxenites, silicified serpentinite, talc schist, chlorite schist, iron ore group, chromitite seams, with laterite and soil cover (Mondal et al, 2001). In the Sukinda ultramafic field, chromite ore is present as massive, spotted, laminated, and friable types (Chakraborty et.al 1984), while at KUB, chromite is lumpy, brecciated and in layered form. At KUB, chromite mining is discontinued because it's uneconomical and the ore body is lensoid which makes mining unpredictable. The chromitite have unusual Platinum group elements with high contents of Ir and Os in whole rock analyses. The chromites were investigated using isotope dilution technique followed by Dynamic Reaction cell ICPMS and Laser Ablation ICP-MS. The results obtained from HPA-ID show platinum and Iridium contents (~1120 ppb and Ir 7000 ppb). The following three phases are prominent: Ru-S (laurite), Os-Ir-Ru-S (Ruarsite), As-Os-Ir-Ru (Omeiite). In the Bushveld complex (BV) metamorphosed ultramafic rocks are given least importance for their sparse PGMs content. This study provides avenues to relook the BV complex for the unusual type of PGM (might have not observed frequently before) in any metamorphosed ultramafic rocks. In future it might be worth looking for such PGE occurrences as well elsewhere also.

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