CORUNDUM INCLUSIONS IN DIAMONDS - DISCRIMINATORY CRITERIA AND A CORUNDUM COMPOSITIONAL DATABASE

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INTRODUCTION

THEORY

- Corundum contains sites appropriate for hosting HFS elements and transition metals
- Corundums contain quantities of trace elements measurable by ICPMS and SIMS
- These elements are fractionated in widely differing fashions in different mantle and crustal settings
- Trace elements could therefore provide a means of discriminating diamond-associated corundums from those grown in other settings
- Corundum is resistant to weathering
- Corundums empirically observed to be associated with diamond in many alluvial settings
- Corundum occurs as syngenetic inclusions in diamonds from Juina, Brazil (Watt et al., 1994; Hutchison, 1997; Harte et. al., 1999; Hutchison et al., 2001)
- Corundum has potential as an exploration tool

OBSTACLES

- Published data on trace elements in corundums generally very sparse (Schreyer et al., 1981; Kerrich et al., 1987)
- Corundum is a very common mineral particularly in heavy mineral separates - diamond associated corundums are likely to be in the minority even in diamondiferous settings

SOLUTIONS - CURRENT RESEARCH

- Expansion of database of ruby and white corundum inclusions from Juina
- First recorded occurrence of sapphire as inclusion in diamond.
- Collection of corundums for additional settings: granitic emplacement, amphibolite-facies, granulite-facies rocks, synthetic origins and from kimberlite drill cores
- Establishment of analytical methodology
- Establishment of compositional database
- Implementation of selection criteria for rapid EDS-type mineral identification

CORUNDUM INCLUSIONS IN DIAMOND

JUINA INCLUSIONS

- Samples from the Rio Vinte e Um and the Rio Cinta Larga and its tributaries the Rio Mutum, Igarapé Porcão, Rio Juininha and Rio Juina-Mirim.
- Inclusions were recovered by fracturing in a purpose built steel anvil.
- Three inclusions of ruby - one 60 µm grain being a composite with a high (10wt%) Al_2O_3 pyroxene, Fig. 1, within the same diamond as a syngenetic inclusion of ferropericlase ((Mg,Fe)O
- One 300 ì m intense blue sapphire inclusion
- Two white corundums

DEPTH OF ORIGIN

- Association of ruby, high alumina pyroxene and ferropericlase suggests an origin within the lower mantle of ~720 – 820 km depending on ambient temperature (Hutchison et al., 2001).
- White corundum and sapphire were not associated with other mineral grains - hence their depth of origin unknown.
- However inclusion study and measurement of nitrogen characteristics (Hutchison et al., 1999) in run-of mine production diamonds are compatible with the majority of diamonds being of transition-zone and lower-mantle origin.

ADDITIONAL SAMPLES

- White corundum from the Rockford s-type felsic granite, Tallapoosa County, Alabama (3640) - Drummond et al. (1988)
- Light brown corundum from granite intruding felsite dyke, Sacatan Mountains AZ (12976) - Larrabee (1969)
- Carmine corundums (PHN20(2)) recovered from kimberlite drill cores, Forte à la Corne, Canada- possible diamond provenance, unusual colouration and compositional zonation.
- Claret coloured corundums var. ruby associated with clinozoisite from Kenya (9997), Tanzania (PHNz)
- Ruby from high-grade Proterozoic orthoamphibolites, Bamble Sector, Norway (1855) - Nijland et al., (1993)
- High-grade granulite-facies hosted corundum from 800°C reaction zone (Osanai et al., 1996) associated with ultramafic intrusion (HIGO) Kyushu, Japan
- Metsomatised corundum (91-38) from garnet sillimanite phlogopite gneiss, Rauer Group - (Harley, 1998)
- Four samples from claystone protolith high grade granulites hosted in TTG orthogneisses / monzodioritic gneiss, Vestfold Hills, Antarctica - Harley (1993); Snape and Harley (1996)

- Synthetic corundum (SYNCOR) manufactured commercially (chromite + Al <=> Cr-corundum + Cr)
- Synthetic gem ruby (BURM) from Burma

Fig. 1 Composite inclusion of ruby with high-Al pyroxene 60µm

ANALYTICAL METHODS

- Major and minor element concentrations by EPMA, Universities of Edinburgh and Arizona
- Homogeneous $La_9Al_{15}XO_{36}$ glass doped with twenty elements as 2000 ppm atomic manufactured using levitation laser vitrification and characterised by laser ICPMS and EPMA for SIMS standardisation
- Absolute concentrations of twenty-one elements were measured by SIMS, Univ. Edinburgh for Juina samples with the exception of the small composite ruby, ASU for other samples - Al measured at mass 13.5
- Absolute concentrations of twenty five elements by laser ICPMS, ANU - 23s burn-in time

RESULTS

- Sapphire characterized by low Cr relative to Fe and Ti.
- Red corundums dominated by relatively high Cr to Ti.
- White corundums have relatively high Ti and Cr.
- Corundums from similar geological settings show very similar compositions and are easily distinguishable from those of differing origin.
- Rubies from Norwegian, Tanzanian & Kenyan amphibolite-facies rocks compositionally indistinguishable (Fig. 2)
- Corundums from metasomatised zones associated with contact metamorphism from Arizona and Japan are very similar - characterised by unusually high abundance of mobile Y, Zr and Nb.

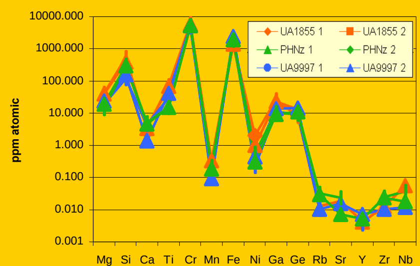

Fig 2. Concentrations of trace elements from Norwegian, Tanzanian & Kenyan amphibolite-facies rubies

- Two distinct compositional zones identified in carmine corundums from Forte à la Corne - broadly high and low-Ca
- Concentrations in these zones indistinguishable from similar zones in SYNCOR
- With the exception of slightly more Fe and less Si, similar concentrations found in synthetic gem ruby BURM.
- Forte à la Corne corundums are likely to be contaminant introduced during the drilling process.

JUINA SAMPLES

- Juina sapphire inclusion exhibited much larger ratios of Ga and Ge to HFSE elements compared to otherwise similar corundums.
- White corundum inclusions are particularly rich in Ge, exhibiting up to ~750 ppm for one analysis.
- Ruby inclusions are distinguished from synthetic rubies in particular by their homogeneity from otherwise similar natural corundums by over an order of magnitude higher Ni (20 – 100 ppm compared to < 2 ppm, Fig. 3).

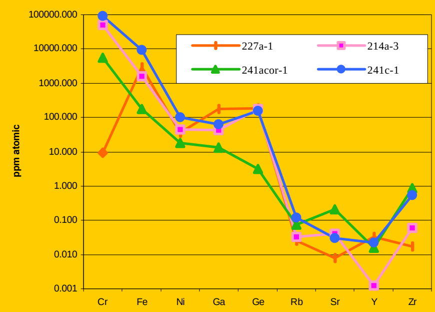

Fig 3 Concentrations of trace elements from syngenetic inclusions of corundums in Juina diamonds

CONCLUSIONS

As corundum occurs syngenetically with diamond and its hardness and chemical stability lend it to survival in conditions more extreme than other diamond-associated minerals, potential exists for corundum to be used as a tool for diamond prospectivity. We have demonstrated with a small sample set that minor and trace element compositions of corundum show strong similarities amongst corundums from related geological yet varied geographical settings. At the same time, identifiable differences occur between corundums from differing geological settings and in particular corundum inclusions in diamonds are shown to be distinguishable from other samples. In this case, all inclusion corundums; namely sapphire, ruby and white corundum are particularly identifiable by high Ni concentrations 20 – 100+ ppm; an order of magnitude greater than Ni in other samples.

As corundum is a common accessory phase in rocks from a range of geological settings, it is envisaged that corundums with a diamond association may be significantly outnumbered by those from non-diamond bearing country rocks. It is possible however that Ni concentrations may often be high enough to be detectable by rapid energy dispersive spectrometry (EDS) such as being developed the CSIRO and ICPMS. It is therefore envisaged that corundum could be used as a useful tool to compliment conventional indicator mineral techniques.

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