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NEWS AND NOTES

Geochronology and Isotope Geochemistry of Uranium Deposits of India

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Introduction

Geochronological studies are one of the very important tool that help in the modelling for the favourability and selecting the geological terrain for uranium exploration in accordance with the existing example. One of the various considerations that apply to the exploration of all types of uranium deposits is "TIMING", without an idea of age of uranium deposit, age of its host and source rocks, the proper exploration strategy cannot evolve (Cuney, 2008). The uranium deposits of Archean and Proterozoic era are important since they contain >75% of the world's uranium resources in the form of Paleo Quartz Pebble Conglomerate (QPC) type, Proterozoic unconformity type and Polymetallic Iron Oxide Breccia Complex (IOBC) type of uranium deposits which occur in distinct time and in specific age group of rocks. Age data along with isotopic signature is very important in establishing Precambrian stratigraphy, petrogenesis and crustal evolution in general and understanding genesis of uranium deposits in particular. World over, fifteen types of uranium deposits have been identified (IAEA, 2022) and out of these Proterozoic unconformity related uranium deposits located in Canada are of highest grade and large tonnage. These deposits occur along the unconformity contact during distinct period that is between Lower and Middle Proterozoic e.g. Cigar lake uranium deposit, Canada, c. 1300 Ma, which has multiple younger remobilisation ages up to 200 Ma, resulting into one of the highest grade uranium deposit, at Mac Arther lake (19% U_3O_8). Present discussion on geochronological (Pb-Pb, U-Pb and Sm-Nd) and isotope geochemical studies on important Indian uranium deposits is aimed to understand its temporal correlation with that of other deposits of the world and also have an idea about the source rock.

Geochronology and Isotope Geochemistry of Indian Uranium Deposits

Uranium Deposits along Singhbhum Shear Zone (SSZ)

First and oldest metamorphite type uranium deposit discovered in India is located along Singhbhum Shear Zone (SSZ). U-Pb and Sm-Nd ages of uranium mineralization obtained on uraninite, from parts of SSZ are (i) c. 1600 Ma from Narwapahar, Bhatin, Surda and Rakha mines (Rao et al.,1979) and (ii) c. 1600 Ma from Jaduguda (Pal et al., 2013) and (iii) from Banadungari/Singridungari 1616 ± 54 Ma (U-Pb Concordia) and of 1686 ± 180 Ma (Sm-Nd isochron age) with ε_{Nd} = -6.7 ± 1.3 (Krishna et al., 2017). The ε_{Nd} of -6.7 indicate source of uranium from a enriched crustal source of around 2200 Ma age and is comparable with the age of Soda granite.

Uranium Deposits in the Environs of Cuddapah Basin

- *Tummalapalle:* The strata bound uranium-mineralisation in southwestern part of the Cuddapah basin is unique in the sense that no such strata bound uranium deposit hosted by carbonate rocks is reported from any other part of the world. Uranium mineralisation is hosted by impure phosphatic dolostone of the Vempalle Formation of the Papaghni Group. It extends from Chelumpalli in the northwest to Maddimadugu in the southeast over a belt of 160 km. The Pb Sequential Leaching (PbSL) in carbonates can be applied with great ease due to high and variable U/Pb ratios in these rocks. Pb ratios obtained, on leachants, using HCl (1M and 2.5 M HCl), Residue (R-left over after leaching) as well as on Whole Rock (WR) samples from uranium mineralized /non-mineralised dolomites from Tummalaplle. The Pb-Pb (PbSL) study define isochron ages as **1930 ± 6 Ma** and **1999 ± 7 Ma** respectively indicating that the deposition, diagenesis, dolomitisation and syn-diagenetic uranium mineralization might have taken place in the time span of c. 1900 to 2000 Ma in Vempalle Formation (Rai and Pandey, 2015). Essentially, a syndiagenetic origin is contemplated for this dolostone hosted mineralisation. This is similar to the age of initial deposition, diagenesis and late dolomitisation in an interval of 100 to 150 Ma, reported from Wittenoom and Carawine Dolomite of Hemersley Group, Western Australia.

  Based on model μ_1 = 8.3 to 9.4, $\varepsilon_{Nd\ (1900\ Ma)}$ = -2.45 to -7.67 and initial $^{87}Sr/^{86}Sr$ ratio of 0.7074 (at 1900 Ma), for Tadpatri and Vempalle dolostone samples, it can be inferred that basement crustal rocks of eastern Dharwar craton of 2200-2700 Ma may be the main probable provenance rocks for sediments and uranium apart from intrinsic uranium in the dolostone.

  In $^{204}Pb/^{206}Pb$ vs. $^{208}Pb/^{206}Pb$ plot, the Cuddapah carbonates are broadly collinear with the available data on K-feldspars and granites from the eastern part of Dharwar craton (Zachariah et al., 1999).

- *Lambapur:* It was discovered in the year 1990 along the NW margin of Cuddapah basin and classified as unconformity proximal deposit (classified as stratiform structure-controlled by IAEA, 2022), which consist of flat ore lenses that occur along structures parallel to the unconformity that separates the brecciated granite (Archean K–U–Th enriched granites) and Mesoproterozoic Srisailam Formation (Banganapalle quartzite). This type of uranium mineralisation was established in India, for the first time. Lambapur mineralisation has close resemblance to the high grade and large tonnage Proterozoic unconformity type uranium deposits from the Canada and Australia except for its grade and host rock. The 5 fractions from two uraninites separated from mineralised quartzite core samples (Srisailam Formation) gave Sm-Nd isochron age of **1330 ± 74 Ma** (modified after Pandey et al., 2009) which indicates time of primary uranium mineralisation. The ε_{Ndi} = -12, shows that source of uranium is from enriched crustal rocks approximately 1200 Ma older, than the mineralization age, most probably basement granite of c. 2500 Ma age or equivalent rock may be the source of uranium for Lambapur uranium deposit.

The Pb ratios obtained on two uraninite grains, from mineralised quartzite core by PbSL using 4MHCl (3 leach fractions for 10 minutes each) and 8N HNO_3 (one leach fraction by 8N HNO_3). The $^{206}Pb/^{204}Pb$ ratios up to ~25000 indicate very high radiogenic value as compared to common lead value of 17.21. The Pb-Pb isochron ages (PbSL) 549 ± 17 Ma and 548 ± 43 Ma (Pandey et al., 2009) indicate the time of remobilisation. This younger event recognised at c. 500 Ma might have helped in enriching the uranium deposit at Lambapur due to effect of younger Pan-African event.

- *Gandi:* Granite related uranium mineralisation (IAEA, 2022) both basement granite hosted as well as sediment hosted (Gulcheru Formation, the oldest member of the Cuddapah Supergroup) occurs along the southern margin of the Cuddapah basin. The Gulcheru quartzite, affected by structural disturbances like faults and abundance of reductants like sulphides, holds promise for the better grade and easily leachable uranium mineralisation.

  Three uranium mineralised quartz arenite from Gulcheru Quartzite were analysed for U-Pb isotopic studies and Concordia plot define upper intercept age of c. 1334 ± 9 Ma (modified after Pandey et al., 2009) which may be the time of primary uranium mineralisation whereas lower intercept age of 441 ± 21 Ma (modified after Pandey et al., 2009) may be the age of remobilisation. These ages are similar to that of Lambapur Poterozoic unconformity related uranium mineralisation and later remobilisation.

Uranium Mineralization in Bhima Basin

- *Gogi:* The uranium mineralization is classified as granite related (IAEA, 2022) and occurs along the E-W Gundahalli-Gogi-Kurlegere (GK) fault in the brecciated impure limestone of Shahabad Formation. Pb isotope ratios obtained on six uranium mineralized core samples of brecciated limestone from two borehole cores (GGL-4 and GGL-5) from Gogi uranium deposit define Pb-Pb isochron age of 1305 ± 39 Ma (modified after Pandey et al., 2009). The age of uranium mineralization in Gogi (Bhima Basin) is same as that of Lambapur and Gandi (Cuddapah Basin). Sustained exploration in this geological domain has established another uranium deposit at Kanchankayi.

Uranium Mineralization in North Delhi Fold Belt (NDFB)

- *Rohil:* Exploration is being carried out in various sectors of the ~200 km long "Albitite Line" in Rajasthan and Haryana and resulted in metasomatite type uranium deposits(IAEA, 2022) at Rohil and Jahaz areas in Khetri sub-basin of North Delhi Fold Belt (NDFB) in Rajasthan. Khetri sub-basin is a rift related one and contains graben filled argillites, volcaniclastics and carbonates which were metamorphosed to amphibolite facies and belong to Delhi Supergroup comprises of lower Alwar Group (arenaceous) and upper Ajabgarh Group (calcareous-argillaceous).

  Uraninites from Borehole core samples from main five ore lodes from Rohil uranium deposit and from ore zones were studied. The age of metasomatite type uranium mineralization at Rohil is well constrained based on convergence of Pb-Pb, U-Pb and Sm-Nd ages on uraninites as c. 830 Ma (Pandey et al., 2022). The $\varepsilon_{Nd\ (830\ Ma)}$ = -14 indicates source of uranium from crustal rocks around 1400 Ma older than the age of uraninite (c.830 Ma). This indicates that rocks of Palaeoproterozoic age i.e. metasediments of Delhi-Aravalli Supergroup or basement granite gneiss, are the main contributors for the uranium in the NDFB.

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