Occurrence of gold in association with uranium in Gulcheru quartzite of Cuddapah basin, Gandi–Rachakuntapalle area, Cuddapah district, Andhra Pradesh

Quest for gold in India has continued since ancient times. Gold anomalies are recorded in different geological settings and rock types of Archaean to Recent ages. Association of gold with uranium was first recorded in the lower Proterozoic quartz pebble conglomerates of palaeo-placers of Witwatersrand[1] in South Africa, where substantial quantities of gold were recovered along with uranium. The high density and chemical stability of gold enables it to be mechanically concentrated in river and beach environments and preserved in placer deposits. The prevailing oxygen-deficient physico-chemical environment during lower Proterozoic times enabled uraninite preservation and was responsible for its association with gold.

In peninsular India, exploration for gold was essentially to greenstone belts such as Kolar schist belt, Ramagiri schist belt, Hutti schist belt and others. These investigations were not extended to the Proterozoic basins in the craton on a large scale, though Radhakrishna and Curtis[2] have mentioned potential of lower arenaceous members of the middle Proterozoic basins as good hosts for gold.

Cuddapah basin is the largest of the Purana basins in the South Indian peninsula. It is a crescent-shaped intracratonic basin largely occupied by sediments of middle to late Proterozoic period. The Gulcheru conglomerate and quartzite deposition marks the first depositional event over the basement crystallines, followed by Vempalle limestone, Pulivendla quartzite and Tadpatri shales. Gulcheru conglomerates and quartzite represent the oxygenic depositional

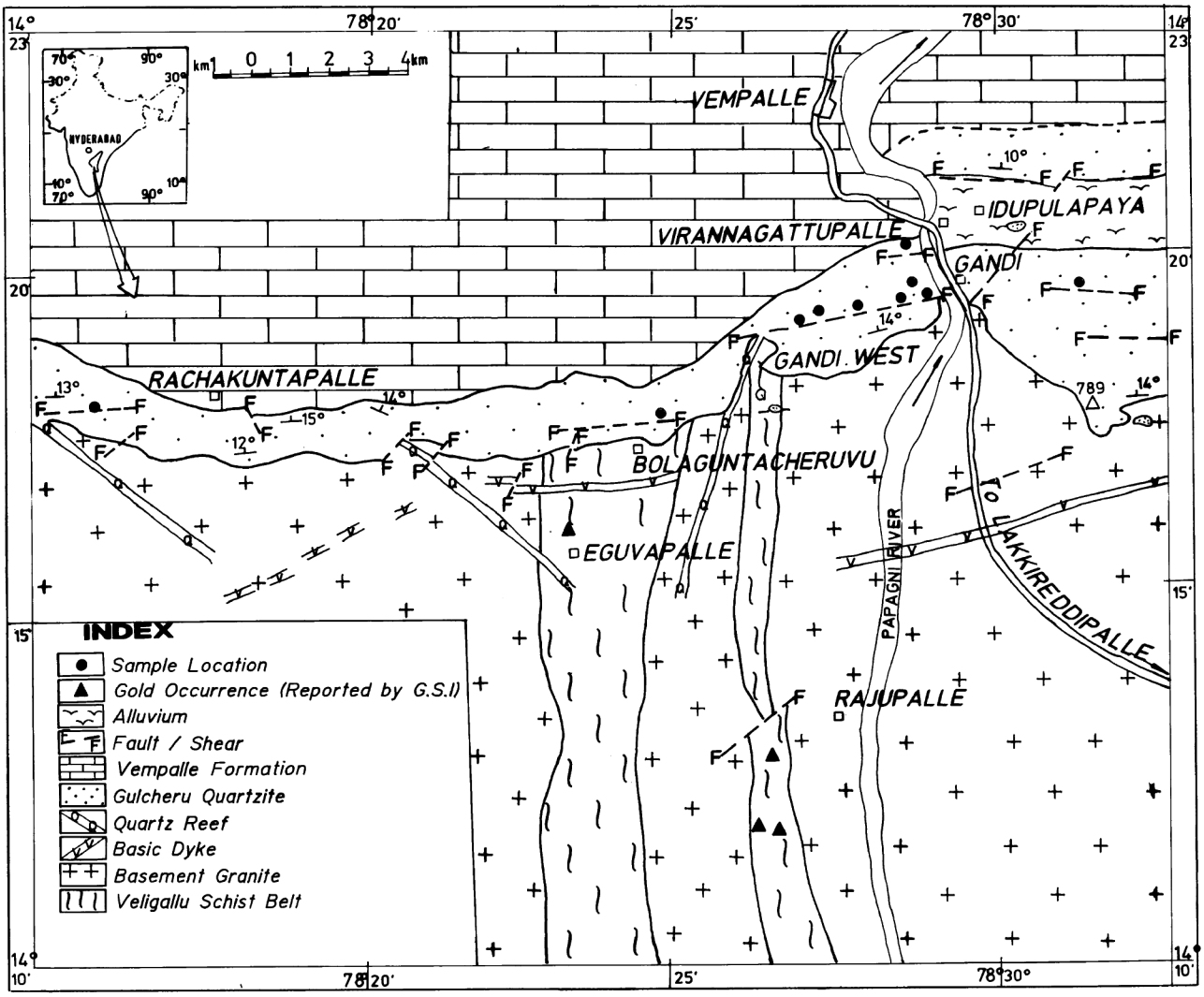

Figure 1. Geological map of Gandi and Rachakuntapalle area.

conditions of Meso-Proterozoic times unlike the conglomerate and arenites of Bababudan formation of Archaean age, where detrital uraninite is preserved[3]. Provenance characterization of Cuddapah basin based on available data suggests basement to the south-west with the north providing the detritus for the lower Cuddapah[4]. The Archaean crystallines forming the basement for Cuddapah sediments consist of granite and greenstones.

Radiometric examination of the crystalline basement in the south-western environments of Cuddapah basin by the Atomic Minerals Directorate for Exploration and Research (AMD), Bangalore indicated significant uranium association with granites, basic dykes, mylonites and cataclasite in fracture/shear zones[5]. Exploration programmes by the Geological Survey of India (GSI) have indicated gold association with greenstones bordering Cuddapah basin. Au value of 4.6 g/t is recorded in sulphide-rich banded iron formation at Errakonda in Veligallu schist belt[6]. Gulcheru quartzites are the results of degradation and transportation of the fertile crystalline basement as well as gold-bearing greenstone belts exposed on the southern, western and northern margin of the Cuddapah basin. Gulcheru quartzite presents all the favourable factors, namely (1) provenance, (2) porosity and permeability, (3) precipitation, and (4) preservation for uranium/gold mineralization. In addition, post-sedimentary tectonothermal activity in the form of post-sedimentary faults and emplacement of basic dykes not only remobilizes the intrinsic uranium and other elements in the sediments but can also contribute through hydrothermal activity. Since gold association was noticed in the provenance area, samples were analysed for gold along with uranium.

During the geological investigations for uranium mineralization associated with quartzite, systematic litho-geochemical surveys were carried out in Gandi area. Several uranium occurrences were located in Gulcheru quartzite having considerable extent and grade, spread along E-W fault sections over 1–4 km length in Gandi[7], Gandi west, Bolaguntacheruvu, Virannagattupalle and Rachakuntapalle, Cuddapah district, Andhra Pradesh. The host rocks are grey-white/brown quartzite with abundant primary structures like cross-bedding, ripple marks and mud-cracks. The petromineralogical studies of mineralized samples of Gandi area reveal the presence of well-indurated and bimodal quartz arenites. The framework clasts are composed of monocrystalline quartz, polycrystalline quartz (chert) and rarely altered feldspar. These are corroded and infiltered by authigenic microcrystalline chlorite and authigenic quartz interlocking adjoining quartz clasts. Matrix (2–4% modal value) is mainly composed of chlorite and clay minerals, whereas the authigenic quartz is the common cement found in these quartzites. Electron microprobe studies confirmed the association of Au and Ag with sulphides. The Au content in galena is analysed up to 0.05%, whereas Ag content in galena is up to 0.09% and in pyrite up to 0.06%. Uranium occurs in the form of fractures filling/veins and interstitial along quartz grain boundaries. The uranium minerals identified are pitchblende, coffinite and uraninite. Significant uranium values have also been recorded in the boreholes drilled in Gandi area, with mineralized intercepts up to 1.043% U_3O_8 for 3.53 m. Gold is generally high in quartzite samples recording high uranium values (Figure 1).

Twenty-two surface samples and 8 core samples were collected from three localities along 30 km tract and analysed for gold. In these samples, gold is determined by atomic absorption spectrometry. The samples are first treated with aquaregia and finally taken in HCl medium. Gold is preconcentrated and separated from the sample matrix by (i) co-precipitation with Te followed by toluene extraction, and also (ii) by adsorption on chitin and leaching with a mixture of thiourea and HCl. The final solution after separation is aspirated into AAS and measured at 242.8 nm, along with calibration standards of 1.235, 2.47 and 3.70 µg/ml of Au.

High concentration of gold values up to 13, 2.15 and 1.11 ppm is recorded in uraniferous quartzites in Gandi West, Gandi and Rachakuntapalle and among these, Gandi west is the most promising block, where uranium mineralization occurs as lensoidal bodies in cross-bedded white/grey quartzite spread over 4 km long E-W fault section. Silver analysed up to 8 ppm in Gandi West. Besides, anomalous content of Mo, V, Ni, Co, Cu and Pb is reported along with uranium in Gulcheru quartzite. Gold is associated with sulphides in banded iron formation, amphibolites and metapyroxenites of Veligallu greenstone belt. In these lithologies, auriferous sulphides like arsenopyrites and pyrites occur as stringers and knots[6]. These rock types, apart from granitoids and basic dykes, form the source for the sediments constituting Gulcheru quartzite sequence. Possibly, gold is released in detrital form during mechanical weathering and also in solution during chemical processes. Gold taken into solution by means of reaction with ferric sulphate and ferric chloride may be reprecipitated around sulphides as tiny particles[2]. The possibility of contribution of gold from the greenstones to sediments is also evidenced by higher

Table 1. Chemical data of uraniferous Gulcheru quartzite

Oxide/element	Gandi core samples (n = 8)	Gandi West (n = 15)	Bolaguntacheruvu (n = 4)	Rachakuntapalle (n = 1)	Virannagattupalle (n = 2)
U_3O_8%	0.667–4.583	0.229–1.970	0.008–2.420	0.012	0.041–0.111
Au (ppm)	< 0.25–2.150	0.30–13.00	0.30–0.40	1.11	< 0.25
Ag (ppm)	< 0.25–0.530	0.94–8.00	0.27–2.34	< 0.25	0.35–2.08
Mo (ppm)	< 25–45	< 25–7352	< 20–168	< 25	110–460
Ni (ppm)	33–47	< 25–43	< 25–50	80	< 10
Co (ppm)	< 25–31	< 25–130	< 25–30	< 25	< 10
V (ppm)	60–337	26–395	< 25	289	110–130
Cu (ppm)	< 25–159	< 25–44	< 25–49	288	265–715
Pb (ppm)	1165–2812	260 – > 10000	552–3551	2230	230

concentration of trace elements like Cr, Co, Ni and Cu (Table 1). Enrichment of uranium and gold is seen in samples from the proximity to fault zones emplaced. Association of gold with uranium in the sediments can be attributed to fertile provenance, prevalence of reducing environment indicated by redox sensitive elements like V, Mo and Cu, in addition to uranium.

Their further enrichment in the quartzite in close proximity of fault zones suggests possible remobilization. This is supported by the presence of basic dyke along E-W fault zones in the Gulcheru quartzite and the associated uranium mineralization in the basic dyke at its contact with the grey quartzite, as encountered in the borehole. An extraneous contribution of the gold mineralization due to magmatic activity indicated by basic dyke emplacement cannot be ruled out.

The geological setting, the nature of sedimentation, fertile provenance area and the geochemical signatures suggest the potentiality of gold mineralization in the Gulcheru quartzite.

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Record of genus *Hausmannia* Dunker from the Upper Gondwana of Bairam-Belkher area, Amravati district, Maharashtra and Betul district, Madhya Pradesh

In the foothills of Satpura at Bairam-Belkher area (21°22′–73°37′, 21°22′–77°31′) of Amravati district, Maharashtra and Betul district, Madhya Pradesh, a good exposure of Upper Gondwana sediments crops out as an inlier in widespread basaltic province. This lithounit is overlained by the Lametas followed by the Deccan Trap and Alluvium. The basement Archaean Gneiss is, however, exposed in the east of the study area at a distance of about 30 km. The Gondwana succession is about 100 m thick arenoargillaceous sediments showing profused assemblage of well-preserved mega plant remains in dark-brown to black clay horizons. However, this locality could draw the attention for megafloral remains in the recent past only[1–3].

The pioneer workers have only made a casual remark on the locality, regarding its stratigraphic set-up and lithological characteristics. The age was also a debatable matter as earlier it was with Mahadeva[4], while later with Kamthi and (?) Mahadeva[5]. In addition, it is also assigned Upper Triassic age and equated with Pachmarhi and Maleri[6,7]. Lately, on the basis of pollen and spore assemblage the Neocomian–Aptian age has been suggested[8]. Recently, a huge assemblage of plant megafossils has been recovered by Srivastava *et al.*[1,3] which shows more affinity with Lower Cretaceous assemblages of other reported localities.

The present report of *Hausmannia* is significant because it is a very rare species from the entire Upper Gondwana of the Indian subcontinent. It is recorded from the clay pockets which are lenticular in shape and interbedded with medium- to coarse-grained, parallel- to cross-bedded sandy horizons. The clay is brown to black in colour, occasionally showing bedding planes.

Pteridophyta
Filicales
Dipteridaceae
Hausmannia Dunker

Lamina sessile, 5 cm long and 1.5–8.5 cm broad, leathery, wedge-shaped divided into two symmetrical halves by a median sinus, obtuse, entire. Venation diverge and subdivide dichotomously. From these veins there arise secondary veins almost at right angles, which again divide to finer tertiary veinlets. These tertiary veinlets ultimately join to form rectangular meshes (Figure 1).

The above specimen can be very well compared with four species described from the Bhuj, Rajmahal and Jabalpur formations. The present specimen is clearly distinct from *H. dichotoma*[9] in its