GOLD GRAINS IN Fe-RICH THOLEIITIC LAVA FLOWS FROM AMARKANTAK IN THE EASTERN DECCAN VOLCANIC PROVINCE, INDIA

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Abstract: Disseminated microscopic gold grains, measuring 8-12 microns across and posseSsing a fineness of 950 to 960 have been observed in the quartz normative tholeiitic lava flows from the Amarkantak region of the Eastern Deccan Volcanic Province. High temperature of equilibration (1060-1470°C) and very low oxygen fugacity (<5) as determined from the co-existing ulvospinel-magnetite and ilmenite-hAematite pairs are proposed to be the controlling factors for the occurrence of gold in these volcanics.

Lava flows and related intrusives of continental flood basalts generally contain low gold content (Cox and Singer, 1986). Detailed studies on the abundance of Au in basaltic provinces are lacking. However, whole rock analyses of limited samples have shown very low abundance of gold in such rocks (Allmann and Crocket, 1978; Korobeinikov, 1988). Olinikov et al. (1991) have reported very low (0.9-7.5 ppb) Au concentration in Deccan basalts. Olinikov et al. (1993) have studied samples from ten basalt formations of Deccan Trap from Western Ghats in regard to Au concentration. Their study has shown that the average Au value (3.7 ppb) of Deccan basalt is similar to that of Columbia River basalts and Parana basalts, but slightly higher than that of Hawaiian basalts (2.5 ppb). More recently, Banerjee et al. (2000) have reported high Au values (148-231 ppb) from the chrome spinel bearing intrusive picrite that occurs within the olivine-rich Deccan basalts at Limbdi in Saurashtra. In the Deccan Volcanic Province, besides the better-studied and thickest (~1.5 km) lava sequence at Mahabaleshwar, there are several thick, well-exposed lava packages in the north and northeastern parts of the main exposure. The lava flows (Fig.1) in the 900 m thick northeastern sequence, which occurs as an isolated outlier and commonly known as the Mandla lobe of Eastern Deccan Volcanic Province (EDVP), have been recently characterised by Pattanayak and Shrivastava (1999) and Pattanayak (1999). The present work reports the occurrence of gold grains in two lava flows from this lava sequence.

Thirty-eight basalt samples collected (Pattanayak and Shrivastava, 1999) from the lava flows at different sections (Fig. 1b) were studied. Polished samples were prepared following the procedure of Cameron (1961) and carbon coated (<100 Å) in a vacuum coating unit. The Scanning Electron Microscope (SEM) used was Philips Model-515 equipped with a spectrometer capable of detecting X-rays emitted by the specimen during electron beam excitation. The detector is lithium drifted Si (Li) diode which detects the emitted X-rays. The lower limit of detection for all constituent elements was 0.01%. Gold grains were observed only in two samples viz. PLB-F8S8 and SK-F8S8 (Fig.2). Energy dispersive X-ray analysis (EDAX) was carried out in point mode with spot size of 100 nm, at an incident energy of 30 Kev. The analytical data after ZAF correction are given with the spectra (Fig.2).

Two samples (PLB-F8S8 and SK-F8S8) in which gold grains are present are from Flow-28 and Flow-29 (Pattanayak and Shrivastava, 1999; Pattanayak, 1999), respectively. These flows occupy high altitudes >900 m above sea level in the sequence at Badargarhpahar and Amarkantak and lie in 29N magnetic chron (Vandamme et al. 1991). The gold grains are widely dispersed throughout the basaltic host rock (Fig. 2) that shows ophitic to sub-ophitic texture. These basaltic flows are composed of clinopyroxene, calcic plagioclase and iron oxides. Mostly, the gold grains lie within the confines of silicate crystal boundaries. The Au concentration in such grains varies from 96-98%, and Fe concentration is in trace amount (3-4%).

Fe-Ti oxide geothermometry based on coexisting ulvospinel-magnetite and ilmenite-haematite pairs (Powell and Powell, 1977; Lindsley and Spensor, 1982; Anderson and Lindsley, 1985) showed high temperature of equilibration (1060-1470°C) and low value of - $\log fO_2$ (< 5). Olinikov et al. (1993) in their studies on Deccan basalts

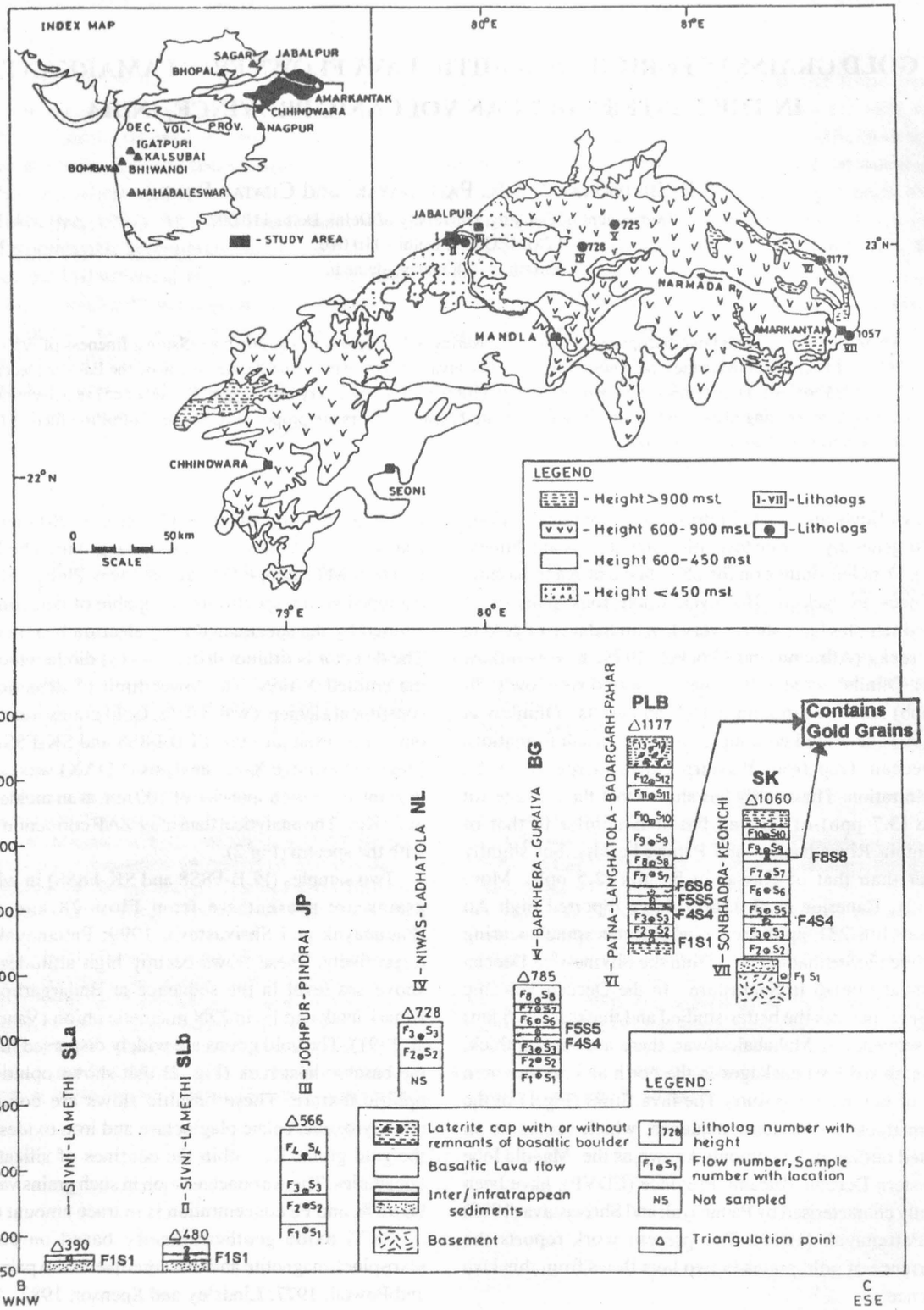

Fig.1. Spatial disposition of Eastern Deccan Volcanic Province at the Mandla lobe: (**a**) Topographic map showing four distinct geomorphic horizons and location of studied lithologs, (**b**) Relative locations of lithologs with sample locations (*after* Pattanayak and Shrivastava, 1999; Pattanayak, 1999).

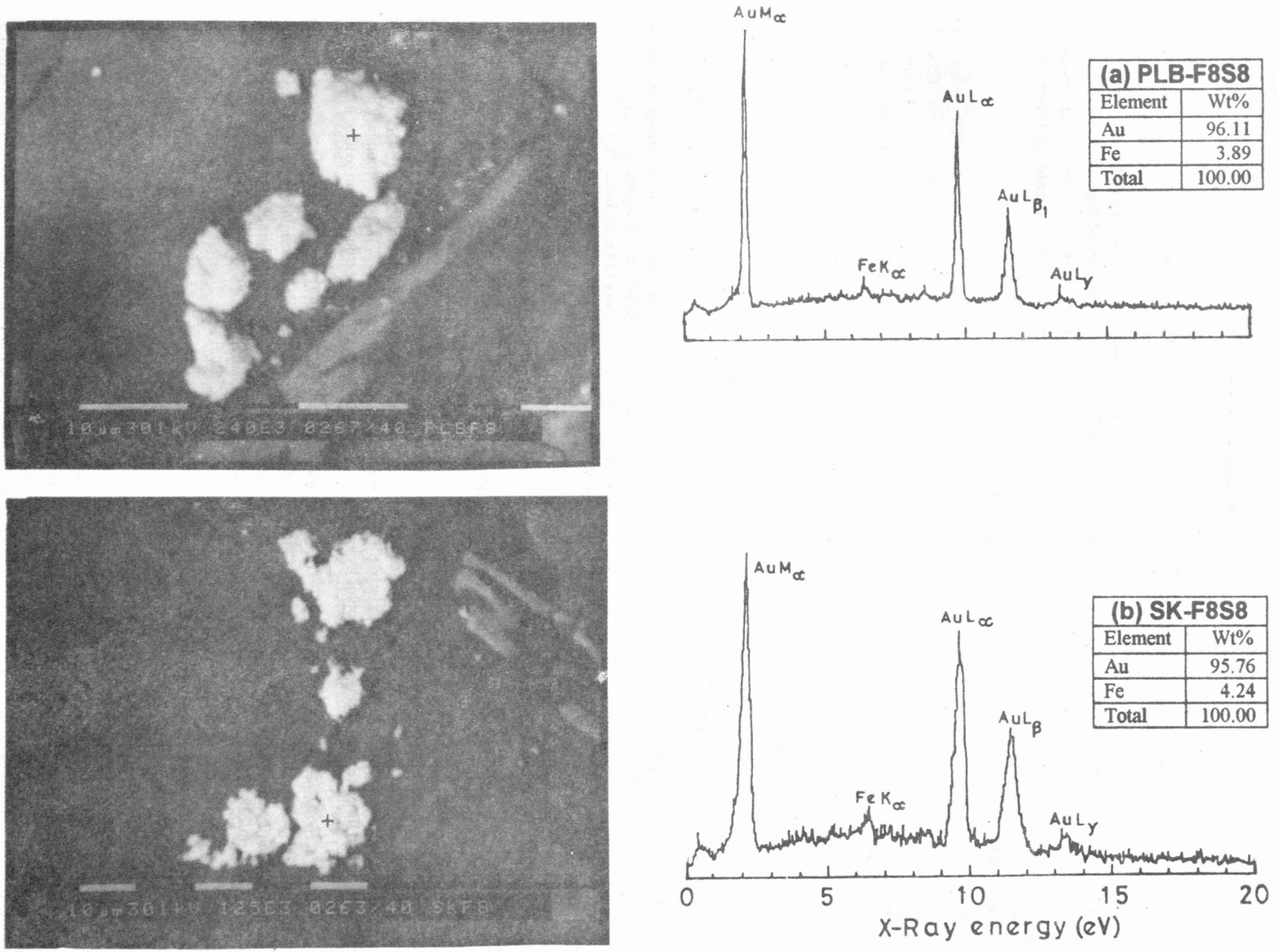

Fig.2. SEM photomicrographs of native gold grains with EDAX spectra and spot analysis data (in wt.%) for samples (**a**) PLB-F8S8 and, (**b**) SK-F8S8. The symbol + represents the spots for which the data are given in tables.

of Western Ghats were of the opinion that magmatic differentiation, fractionation and parent liquid have had little influence on the variation of gold concentration. They stressed that the tholeiitic lava flows with signatures of crustal contamination show high concentration of Au compared to uncontaminated primitive lava flows. The field observations in Amarkantak show that the outcrop of granitic gneiss lies at the base of the lava flow sequence at 790 m a.s.l. The native gold occurrence in the 28th (SK-F8S8) and 29th (PLB-F8S8) Flows (Pattanayak and Shrivastava, 1999; Pattanayak, 1999) of the EDVP at Amarkantak could be attributed to the processes of crustal contamination (where the contaminant is granitic basement), governed by high temperature and low oxygen fugacity of the basaltic magma. The $^{87}Sr/^{86}Sr$ ratio in lava flows in the southwest of Jabalpur range from 0.70413 to 0.70686, the Rb/Sr ratio from 0.001 to 0.04 and $\varepsilon_{Nd(t)}$ range from 0.3 to 4.9 (Peng et al. 1998). They have postulated that these lava flows are chemically similar to those of Khandala, Poladpur and Ambenali Formations. Such an attempt at correlating the flows of Mandla lobe is significant for arriving at a scientifically sound conclusion on the genesis of flows in the Mandla lobe. This is a primary consideration for the flow sequence exposed at the east and southeast of Jabalpur around Amarkantak before any other process is considered for concentration of gold in Flow-28 and Flow-29.

Acknowledgements: JPS acknowledges Department of Science and Technology, New Delhi for project grant (ESS/CA/A6-07/91) and SKP to Council of Scientific and Industrial Research, New Delhi for JRF-SRF (NET) during this work.

References

ALLMANN, R. and CROCKET, J.H. (1978) Gold. *In:* K.H. Wedephol (Ed.), Handbook of Geochemistry: Element La(57) to U(92). Springer-Verlag, Berlin, v. II/5, pp. 79-A.1-79-O.9.

ANDERSON, A.T. and LINDSLEY, D.H. (1985) New (and final ?) model for the Ti-magnetite/ilmenite geothermometers and oxygen barometers. Trans. Geophy. Union, v.66, no.18, p.416 (abs).

BANERJEE, A.C., RAJ, DES and ROYCHOWDHURY, MANAS (2000) Gold and PGM contents in a subvolcanic Deccan picrite of Saurashtra, Gujarat. Jour. Geol. Soc. India., v.56, pp.625-632.

CAMERON, E.N. (1961) Ore Microscopy. John Wiley and Sons, New York, 293p.

COX, D.P. and SINGER, D.A.(1986) Mineral Deposit Models. U.S.G.S. Bull., no.1693, 379p.

KOROBEINIKOV, A.F. (1988) Gold in volcanic rocks of different composition and age. Geokhimiya, no.11, pp.1618-1626.

LINDSLEY, D.H. and SPENSOR, K.J. (1982) Fe-Ti oxide geothermometry: Reducing analyses of coexisting Ti-Magnetite (Mt) and Ilmenite (Ilm). Trans. Am. Geophy. Union, v.63, no.18, p.471.

OLINIKOV, B.V., KOROBEINIKOV, A.F., KOROLEVA, O.V., KRISHNAMURTHY, P., GOPALAN, K. and KUMAR, A. (1991) Gold in Deccan plateau basalts. Dokalady USSR Acad. Sci. (in Russian), v.319, pp.228-230.

OLINIKOV, B.V., KOROBEINIKOV, A.F., KOROLEVA, O.V., KRISHNAMURTHY, P., KUMAR, A. and GOPALAN, K. (1993) The gold content of Deccan basalts, Western Ghats, India. Jour. Geol. Soc. India, v.42, pp.243-246.

PATTANAYAK, S.K. (1999) Geochemical Flow Stratigraphy of Basalts from Eastern Deccan Volcanic Province, India. Unpublished Ph. D. thesis, University of Delhi, India. 98p.

PATTANAYAK, S.K. and SHRIVASTAVA, J.P. (1999) Petrography and major-oxide geochemistry of basalts from the Eastern Deccan Volcanic Province, India. *In:* K.V. Subbarao (Ed.), Deccan Volcanic Province. Mem. Geol. Soc. India., West Volume, no.43, pp.233-270.

PENG, Z.X., MAHONEY, J.J., HOOPER, P.R., MACDOUGALL, J.D. and KRISHNAMURTHY, P. (1998) Basalts of the northeastern Deccan Traps, India: Isotopic and elemental geochemistry and relation to southwestern Deccan stratigraphy. Jour. Geophys. Res., v.103, no. B12, pp. 29,843-29,866.

POWELL, M. and POWELL, R. (1977) Geothermometry and oxygen barometry using coexisting iron-titanium oxides: a reappraisal. Min. Mag., v.41, no.318, pp.257-263.

VANDAMME, D., COURTILLOT, V., BESSE, J. and MONTIGHNY, R. (1991) Palaeomagnetism and age determinations of the Deccan Traps (India): Results of Nagpur-Bombay traverse and review of earlier work. Rev. Geophy., v. 29, pp. 159-190.