

by Dr J R Kayal (GSI) on the Bhuj earthquake. They discussed the earthquake process, velocity structure, fractals etc. Dr S K Biswas (IIT, Mumbai) and Prof R V Karanth (Univ of Baroda) discussed the geological structure and tectonics of the Bhuj area. Dr Susan E Hough (USGS) delivered a lecture on preparing site response map from macroseismic data. Dr E S Schweig (USGS) and Dr C P Rajendran (CESS) presented papers on probabilistic approach and palaeoseismicity in hazard assessment. Dr Roger Bilham (Univ Colorado) explained the mid plate earthquakes by flexure and fragmentation of the Indian plate. Prof Pradeep Talwani (Univ South Carolina) explained seismogenesis of the global intraplate earthquakes. Dr D N Avasthy (ONGC, Retd.) discussed on the Geodynamics and Dr N K Agarwal (SOI) on the Geodetic infrastructure needed in India. Dr H K Gupta (DOD) delivered a lecture on the artificial reservoir triggered earthquakes. All the invited lectures stimulated discussion and many ideas evolved for future research programmes.

The short presentations/posters also drew much attention and interaction, a few are worth mentioning, like the posters on Surface Wave Tomography and Receiver Function analysis using BB and short period data by Dr Anne E Sheehan (Univ Colorado) and Dr Francis Wu (New York), on the ground deformation study before and after the Bhuj earthquake using the SAR Interferometry technique by

Dr S P Satyabala (NGRI), on shear wave splitting by Mr Simachal Padhy (NGRI), on crustal deformation study using GPS by Dr C D Reddy (NGRI), on the upper mantle path anomaly by Dr ER Engdahl, on proelastic relaxation by Dr Kalpana (NGRI) and on the fault interaction and earthquake triggering in Koyna-Warna region by Dr VK Gahalaut (NGRI).

The invited lectures and the poster presentations were well organized during the first four days. On the last day four research groups were formed based on similar research interests for formulating Indo-US collaborative research programmes. Many ideas were put forward and finalisation of the collaborative research projects is in the process. These projects would be submitted by the four group leaders to the Indo-US Forum, DST, New Delhi for approval and financial support. The workshop was a great success and we all look forward to early submission and implementation of the projects. The results of these projects would be beneficial for both India and US in understanding and enhancing knowledge on earthquakes in general and large mid-plate earthquakes in particular.

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FACTORS OF GOLD CONCENTRATION IN CHAMPION LODGE, KOLAR GOLD FIELDS

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EXTENDED ABSTRACT

Among the greenstone belts of South India, the Kolar gold schist belt is most important one in which the Champion lode (CL) occurs in the central part of the schist belt. The CL occurs in komatiites and is 8 km long on surface but it tapers to 0.5 km at 3.2 km depth. The lode dips at 40 to 45 degrees towards west in the upper levels and is almost vertical in deeper levels. The gold distribution is highly erratic. The CL is cut by dykes, pegmatites, Champion gneiss and faults. Along with gold some scheelite, silver and copper are associated. Gold concentration has taken place at

structurally controlled sites often giving rise to nugget formation.

A careful analysis of mine geological data of considerable time-span has led to the identification of the following factors for gold concentration in CL.

- 1 *Funnel shaped ore body* The CL is 26250 feet long on surface, at 5000 feet depth it is 18000 feet and at 10500 feet depth it is 1500 feet. Thus in the upper levels (from surface to 5000 feet depth), it has an average length of 23,000 feet and in the lower levels (5000 to

^Lecture delivered at the monthly meeting of the Society at Bangalore on 30 July 2003

- 10500 feet depth), it is 8000 feet long. Thus the additional length of 15000 feet in the upper levels is a major geological factor for the gold concentration.
2. *Vent of the ore body*: The CL in the central part of the mine extends deep and forms a neck-like body below 6000 feet depth. This neck acted as the vent of the CL through which auriferous fluids migrated upwards. During the waning periods of mineralisation, because of reduced pressure, the ascending fluids could not rise high, with the result that the auriferous fluids collapsed into the vent itself giving rise to high concentration of gold in the vent region.
 3. *Host rock and source rock*: The CL is hosted in a basaltic komatiite, which is a mantle derived high Mg-volcanic rock. In the Kolar Gold Mines the komatiite is itself auriferous. Hence the komatiite is both a host rock and a source rock for gold.
 4. *Fracturing*: Various types of fractures formed the channel ways for the auriferous solutions and acted as receptacles for gold deposition.
 - a) *Earth's gravity*: As the ore bearing solutions were carried upwards from deep seated ore chambers, they entered the fractures and moved upwards and finally settled down on the footwall due to gravity. The sample records maintained in the mines show that nearly two thirds of the samples show higher gold values along the footwall because of gravity concentration.
 - b) *High gold concentration both along footwall and hanging wall contacts*: With continuous pumping of auriferous solutions, the fractures get saturated with gold. With further pumping the solutions tried to move out of the quartz veins along the contacts with the host rocks. Since these contacts acted as barriers, gold tended to get concentrated both along footwall and hanging wall.
 - c) *Fracturing due to collapse of hanging wall block*: A small blind ore body called Mundy's lode occurs in the Champion reef mines about 500 feet west of the CL. Mundy's lode is 500 feet long and occur from 300 feet to 2000 feet. It is believed that this lode was formed as a result of new fracturing due to collapse of hanging wall blocks.
 - d) *Better concentration of gold at sharp changes in strike and dip*: Where ever there are sharp changes in the dip and strike of the ore body there is a better concentration of gold along the concave loops and kinks. This is best seen in the upper levels in all the four mines.
 - e) *"Horse tail" type of fracturing giving rise to multiple veins*: With diminishing pressure, the tension fractures as they travel towards surface become weak and gave rise to horse tail pattern of fracturing. All these fractures get mineralized leading to the formation of multiple lodes resulting in enhanced gold concentration.
 - f) *Converging and intersecting fractures*: The CL is not a single fracture "but consists of several converging and diverging fractures which give rise to V, N & Z shaped pseudofolds which are common in the upper levels. At places where the fractures converge the width of the quartz vein gets enlarged giving rise to more gold concentration.
 - g) *Low angle dip of the CL in the upper level*: Up to 3500 feet depth the dip of the CL varies from 35 to 60 degrees towards west. This low angle provides better receptacles for gold retention. Such low angle gold deposits with high gold values are reported from Japan, USA, Canada, Australia, Brazil and Ghana.
 5. *Caught up ore shoots*: Normally the post mineralization faults are not mineralized. However there are two significant and small ore shoots caught up in the Mysore North Fault within the Mysore mines area. These ore shoots are present in the fault zone because of the drag suffered by the ore body during faulting and this has considerably enhanced the gold concentration in the upper levels.
 6. *Microfracturing leading to nugget formation*: Gold nuggets are lumps of placer gold which weigh more than 30 grams. However, in Kolar Gold Mines the term nugget value is used for mine samples which analyse more than 50 grams of gold per tonne of ore. Nugget values have resulted due to repeated fracturing of quartz vein on a microscopic scale under hydrothermal condition. Nearly 70% of nugget values are concentrated in the upper levels of the Kolar Gold Mines.
 7. *Reduced pressure and temperature*: The auriferous solutions during ascent found favourable fractures for gold deposition under conducive conditions like reduced temperature and pressure in the upper part of the gold mines. Actual temperature and pressure gradient studies in Kolar Gold Mines up to 3000 m depth confirm the reduced P & T values but it does not conform to the theoretical assumptions.
 8. *Damage due to pegmatites*: In the Kolar Gold Mines area there are no outcrops of pegmatites but below 5000 feet depth pegmatites occur as "roots" of the CL and have assimilated very rich and large patches of CL. The near absence of pegmatites from surface

to 5000 feet depth is of great significance which has prevented the Champion lode from being assimilated.

9. *Weathering*: As the Champion lode and its enclosing rocks were exposed to weathering for the last several million years, the lode and the host rock underwent mechanical and chemical changes resulting in wide fractures which were later filled by weathered products.

The gold particles because of their higher specific gravity moved slowly downwards into the weathered zone leading to secondary enrichment. During the first two decades of mining in the Kolar Gold Mines, when ore was recovered from the weathered zone, the average grade of the ore was more than 40 g/t although the average grade of the CL from surface to 3.2 km depth is only 10 g/t.

GOLD PROSPECTING AND SMALL-SCALE MINING

In many countries, gold prospecting/mining are operations that are carried out with more seriousness either by private companies or by government controlled/supported organizations, in the case of third world countries. In USA, gold mining and prospecting are treated as a game or hobby rather than a profession. Recreational gold prospecting is an exclusive activity of some prospecting clubs and the field trips are fun events, to experience adventure and thrill, as a whole range of equipment are available for prospecting and gold recovery, and any profit derived would certainly not hurt anyone!

I have come across a book entitled *Gold Mining in the 21st Century: The Complete Book of Modern Gold Mining Procedures*, by Dave McCracken, (2000) Keene Engineering Company, 20201 Bahama Street, Chatworth, CA 91311, USA which epitomizes this spirit. The author, Dave McCracken states that some people become so serious about the gold mining operation and lose track of the fact that it is simply a game with the goal, of course, to find lots of gold!

The book is a manual outlining modern gold mining procedures and techniques in a simple, direct language, more in a conversational style; not sounding too technical except where machines and instruments are dealt with. The book is well illustrated with figures and photos to make the theme topics of each chapter visual and easy to understand. The book is mainly intended for those who pursue it as a small-scale commercial activity. According to the author, a small-scale gold mining operation is "a one- or two-men operation."

The main focus is on a search for placer deposits, Tertiary channels (ancient streambeds) and nugget hunting. The required methodology including innovations on older methods and use of modern equipment for achieving quick success in a gold venture are described in detail.

The basics of lode mining is briefly described. It is mentioned that this field is a highly specialized one requiring

a substantial financial investment and application of highly sophisticated technology. It is mentioned that the rate per fire assay is about \$10 for gold and \$12.50 for gold and silver. Some prospectors learn to do the assay themselves at a cost of 20c per assay! Besides, "Do it yourself kits" are available. The author also mentions that serious hard rock prospectors do not generally rely on a single assay report but send their most important/promising samples to three different assayers and take the average for the final analysis. However, there is no mention of other sophisticated instrumentation available e.g., portable XRF devices to know the gold content and check the grade.

As per the 1872 Mining Law, any citizen of USA can claim portions of the public lands in his own name for the purpose of developing the mineral resources on that land, except some specific areas - like national parks, permanent lake beds and other areas, which are closed to mineral entry (and development). One may prospect in such areas but cannot claim the mineral rights. It is stated that gold deposits have been reported in all the 50 states of USA.

In our country we are more familiar with the prospecting and mining techniques of lode deposits and therefore, it is interesting to know details about placer gold deposits, their geology and various methods and tools applied to mine them. The description of placer deposits is graphic and informative - the various types and tracing the path of gold along a streambed to locate pay-streak areas. It is stressed that the bed rock irregularities at the bottom of the streambed are important in determining where gold would be trapped - in a crack or crevice in the bed rock.

Various methods viz; panning, sluicing, dredging and dry washing deployed in prospecting and small-scale mining for gold are described in detail.

Panning is regarded all over the world as one of the oldest and most valuable tool for a gold prospect. The gold panning procedure and the practice to be adopted is explained elaborately so as to teach and aid a novice. A