# Sunaparanta/Goa dourado/Golden Goa revisited

**Pioneer Discovery of secondary gold deposits-unique bacterioforms and placers in north Goa from deep core metabiosphere**

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# Objectives of press briefing

- To announce pioneer effort of discovery
  To keep the media, government, industry and society informed about the research
- To attract attention of peers –nationally and internationally
- To establish the potential of geomicrobiological research in prospecting minerals and metals

# GOLD facts

- Gold is one of the ten rarest elements in the Earth's crust with an average  oncentration of 5 ng g1 (solid material), and a concentration range from 0.0197 to 0.197 mg l1 in natural waters
- However, gold is not uniformly distributed and is often highly enriched in mineralized zones, where it may form economic primary deposits (for example, skarn type-, vein type- and disseminated deposits

The deposition of gold in primary deposits usually occurs via metal rich hydrothermal fluids, which circulate in open spaces within rocks and deposit gold as consequence of cooling or boiling

- Native primary gold is commonly present as alloys with Ag, Cu, Al, Fe, Bi, Pb, Zn, Pd or Pt, with gold concentration ranging from 50 to 80 wt%

**Table 1.** Occurrence of gold in nature.

| Rocks, soils, waters | Au content ($mg \cdot 10^3\ kg^{-1}$) | Reference |
|---|---|---|
| Igneous rocks (acidic, basic, intermediate, ultrabasic) | < 50 | Zvyagintzev (1941)<br>Vinogradov (1962)<br>De Gracia & Haskin (1964)<br>Phan (1965)<br>Shcherbakov (1967) |
| Sedimentary rocks (sandstone, lime, shale, silt etc) | < 200 | References as above<br>Razin & Rozhkov (1966)<br>Chebotarev (1969) |
| Coal | < 1,000 | Zvyagintzev (1941) |
| Soils | < 2,000 | Vinogradov (1957)<br>Razin & Rozhkov (1966)<br>Lezhneva (1978) |
| Earth's crust | ~ 4.3 | Vinogradov (1962) |
| Waters of rivers | $0–1 \cdot 10^{-3}$ mg $l^{-1}$ | Kropachev (1935) |
| Waters of auriferous deposits | $0–3 \cdot 10^{-2}$ mg $l^{-1}$ | Razin & Rozhkov (1966) |
| | < 1.0 mg $l^{-1}$ | Pogrebnyak *et al.* (1980) |
| Marine water | $< 5 \cdot 0.10^{-2}$ | Kropachev (1935) |

**Table 2.** Occurrence of gold in living organisms.

| Organisms | Au content ($mg \cdot 10^3 kg^{-1}$) | Reference |
|---|---|---|
| *Seas* | | |
| Water including organic component | $0.4–15.3 \cdot 10^{-10}$ ($g\ l^{-1}$) | Pogrebnyak *et al.* (1980) |
| Algae (average) | 150 | Vaganov *et al.* (1978) |
| | | Vaganov & Shtangeeva (1978) |
| Sea urchins | 100 | |
| Sea stars | 150 | |
| Crabs | 250 | |
| Bryozoa | 750 | |

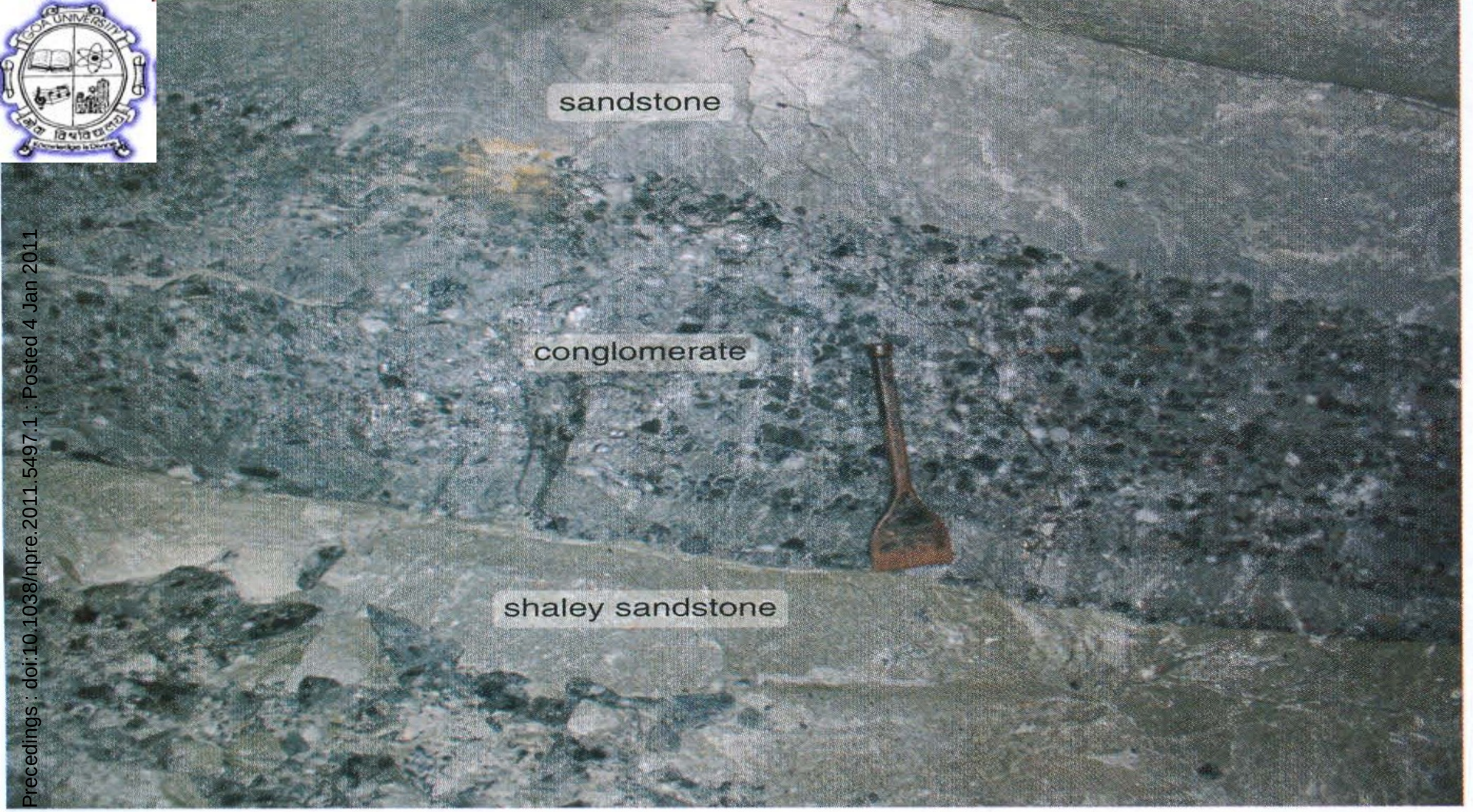
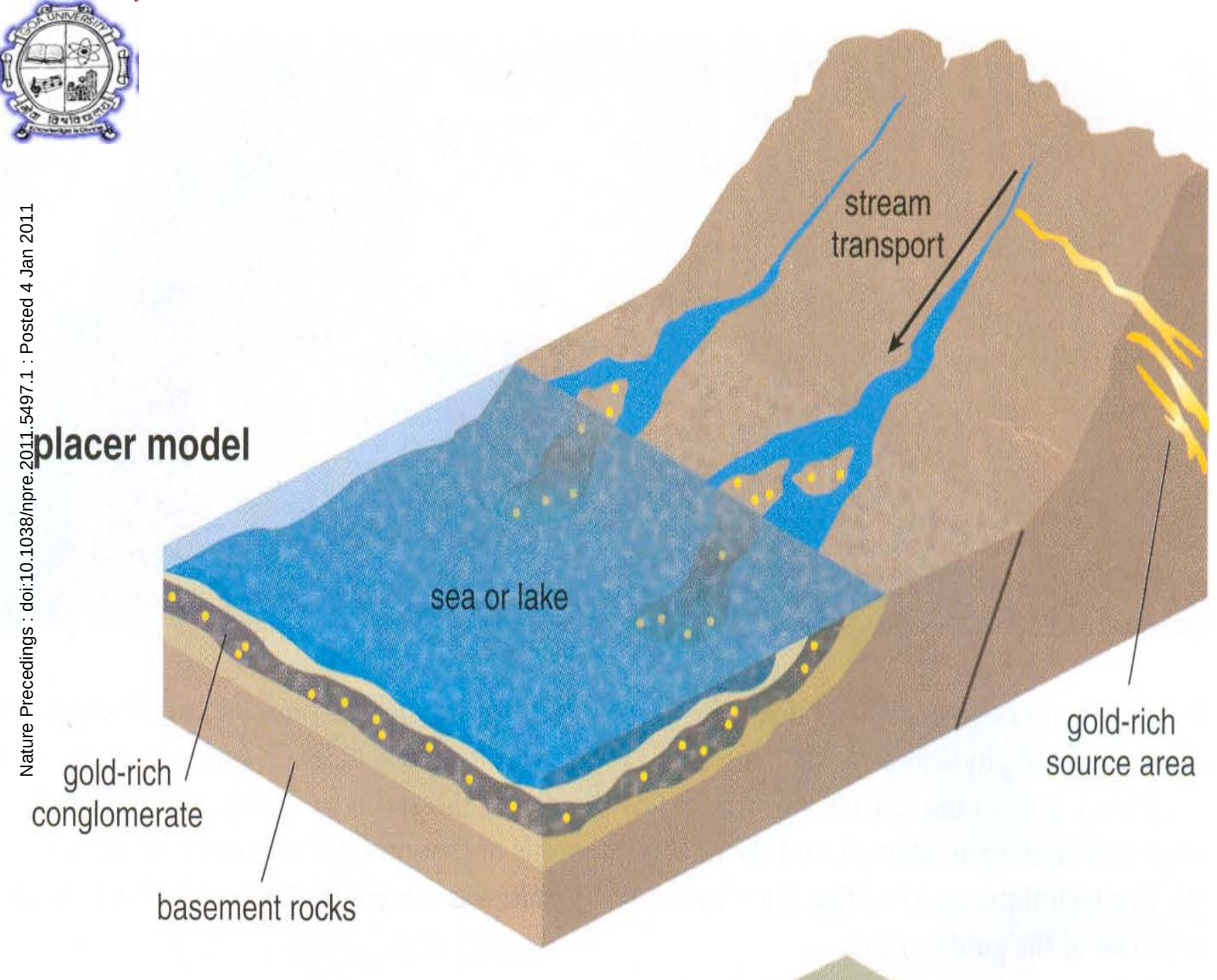





**Figure 3. Conglomerate rock, consisting of quartz pebbles cemented together, contains most of the gold in the sedimentary rocks of the Witwatersrand basin. The sediments in the basin were originally carried in by a system of braided rivers that eroded material from surrounding highlands and deposited them at the edge of a large inland body of water. The source of the gold within the sediments is hotly disputed *(see Figure 4)*. This conglomerate layer, the Kimberly Reef, is about 1.5 kilometers beneath the surface within the Evander goldfields. At this particular location the ore contains about one kilogram of gold for every metric ton of rock, which is extremely high, even for the Witwatersrand basin.**



# Tectonic changes

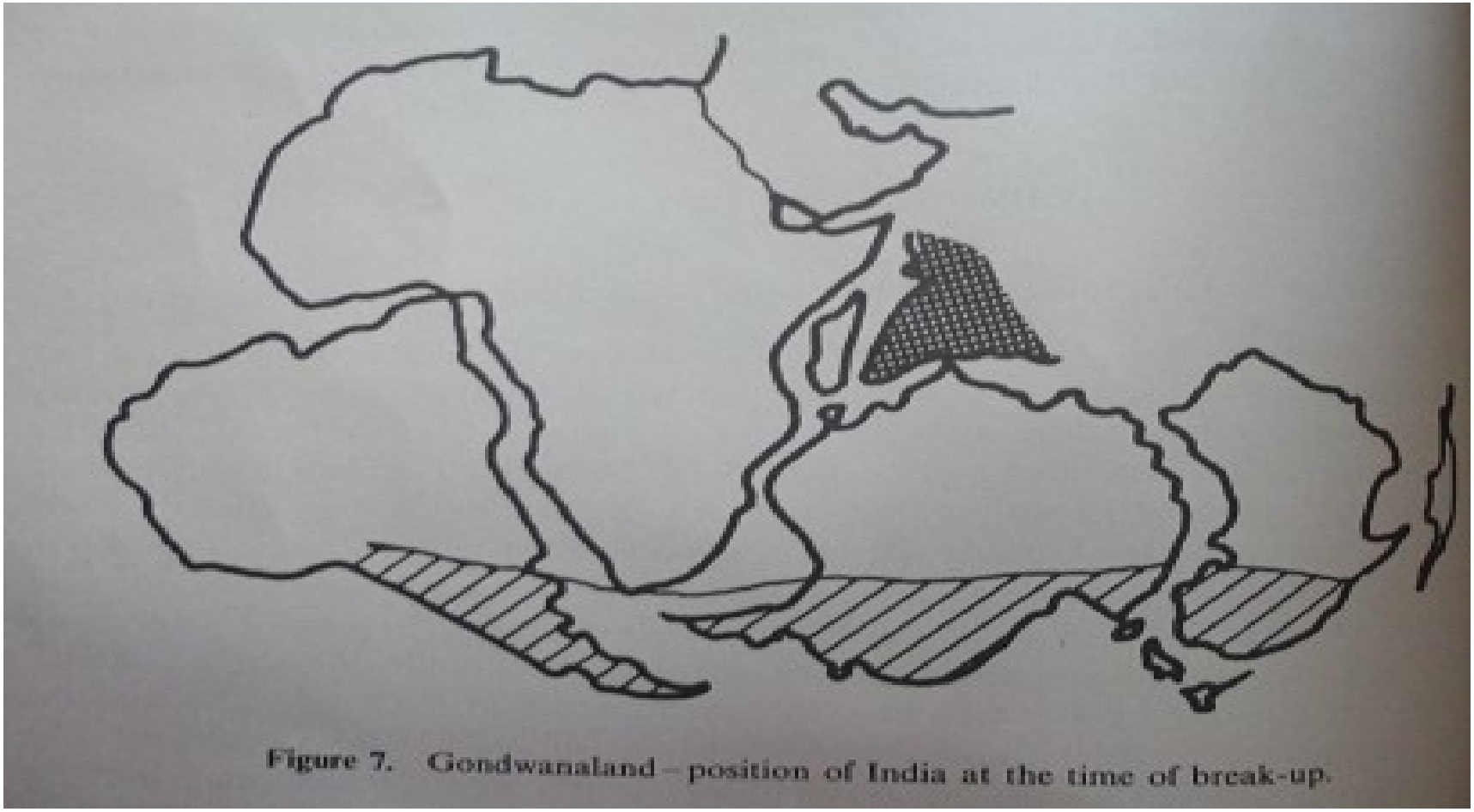


Figure 7. Gondwanaland – position of India at the time of break-up.

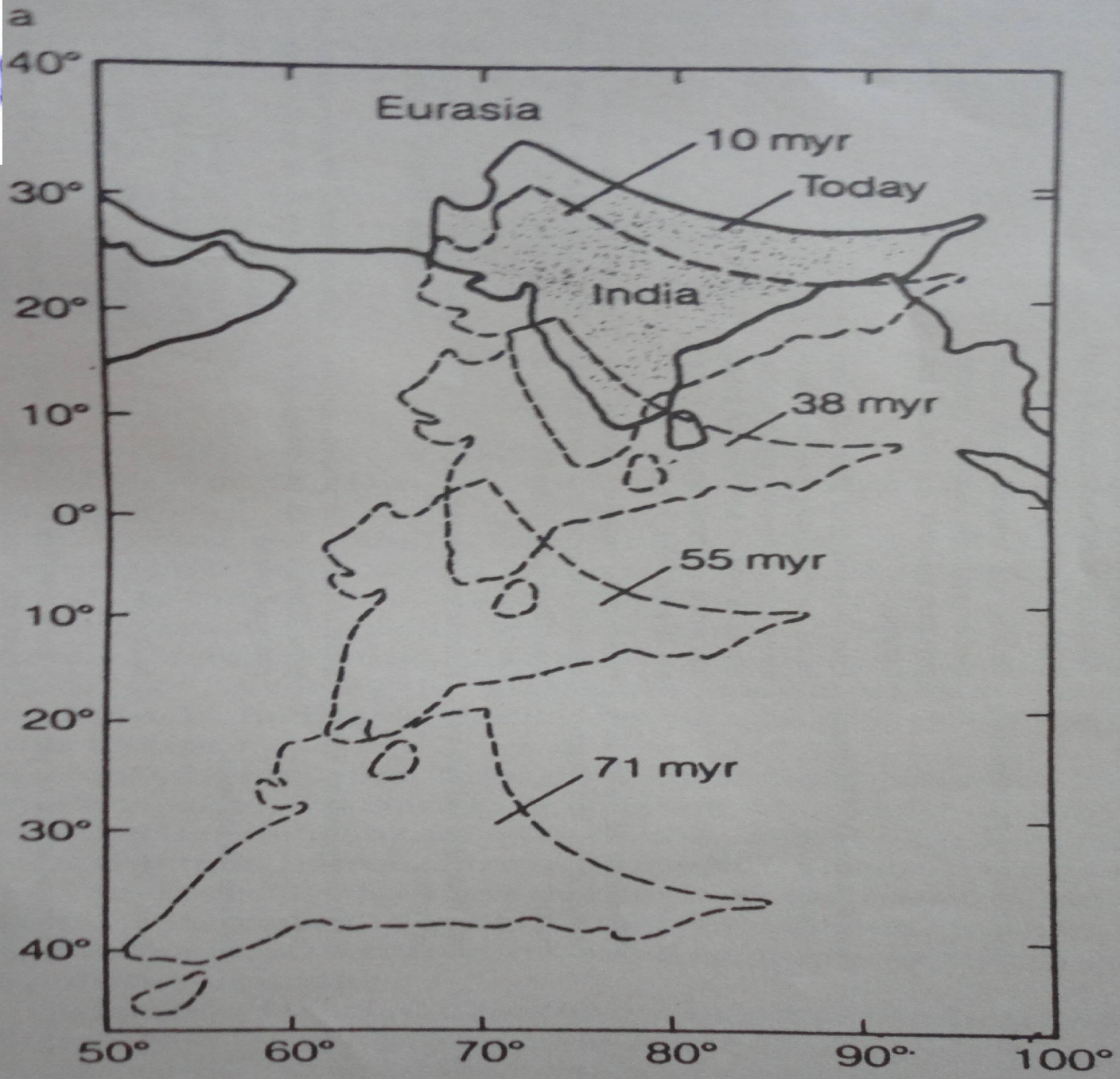



**Figure 8.** Northward flight of India. (after Molnar *et al.* 1981).

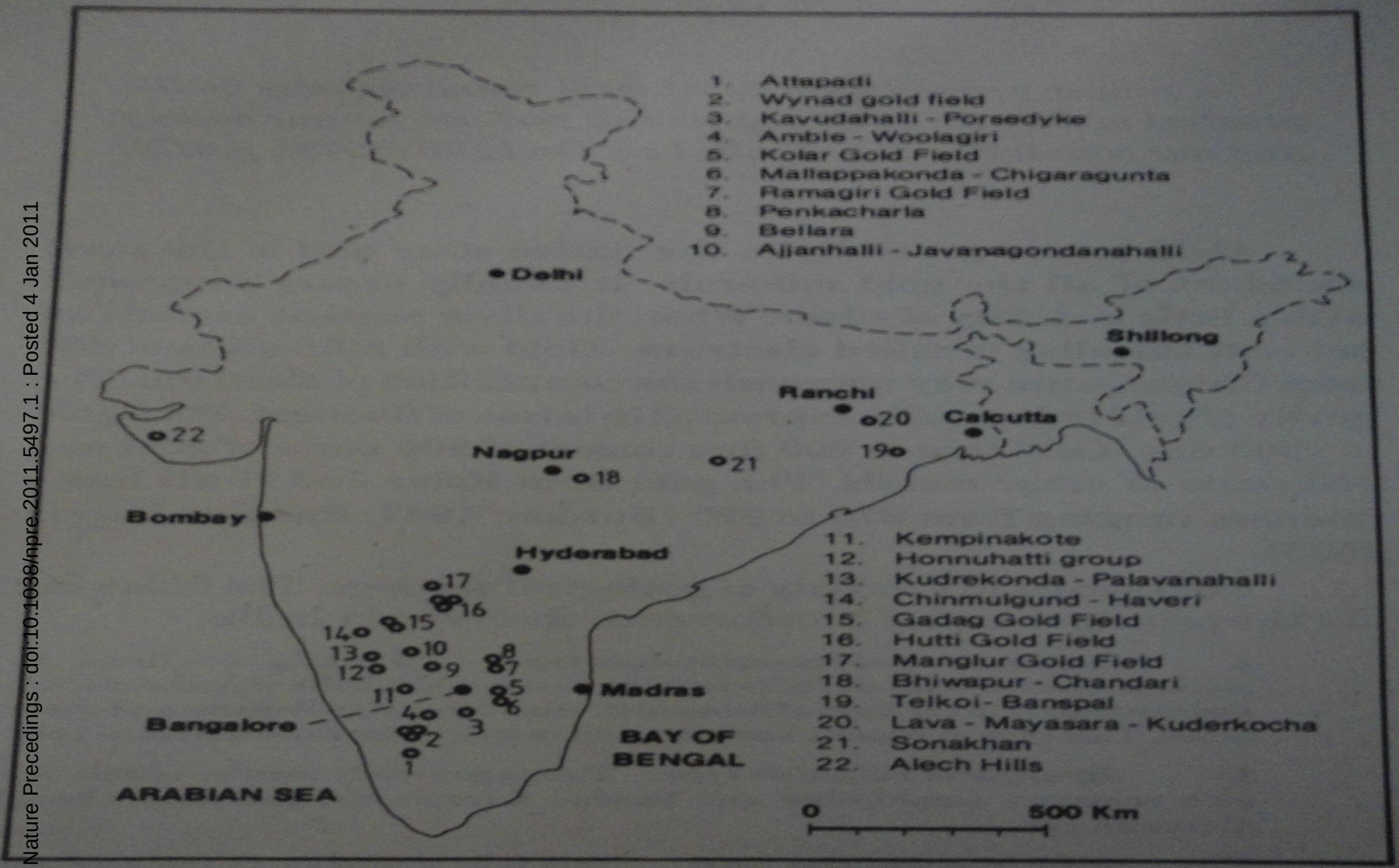



Fig. 2. Primary gold deposits.

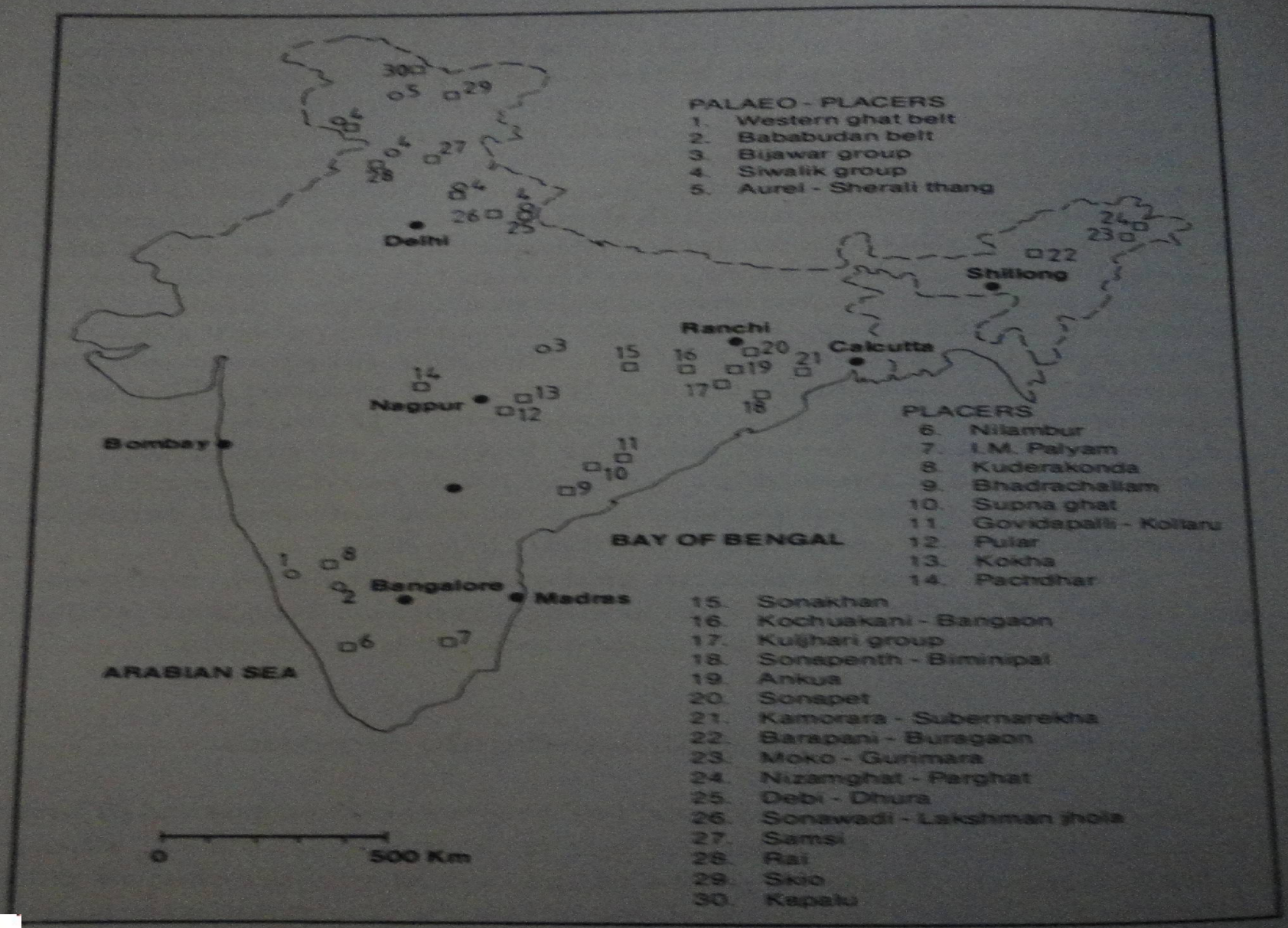
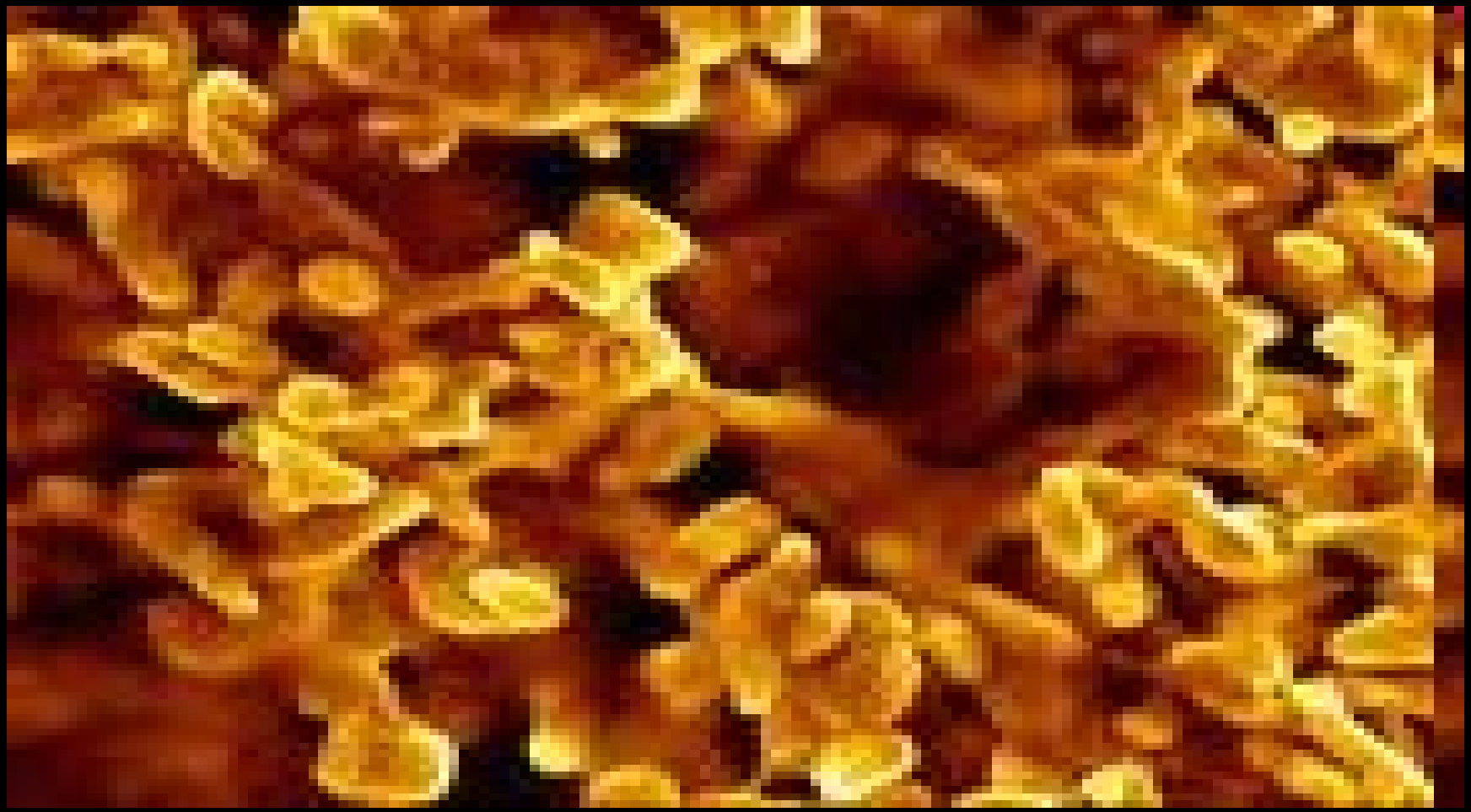



Fig. 4. Secondary gold deposits.

# Gold in Laterite :
## A surprising challenge in metallogeny

One of the most surprising challenges in metallogeny in recent years is the reported occurrence of gold at currently economic levels in laterite at Boddington and Telfer, Western Australia. The discovery was made during the course of mining of bauxite. Multilayered concentration is shown to have taken place in clay-laterite horizon developed over an Archaean greenstone belt. The factors controlling the concentration of gold in near-surface geological environments, and the condition under which it gets remobilized and reprecipitated are under study. Significant concentration of gold is stated to occur within the lower part of the underlying nodular 'B zone'. Mineable ore reserves are estimated to be 44 million tonnes at an average grade of 1.8 gms to a tonne. A mine has been planned to process 3 million tonnes of ore per annum. Gold is stated to be fine-grained and less than 5 microns in size. It occurs as free gold mostly of secondary origin and is considered as a chloride

# Australian bacterioform Gold

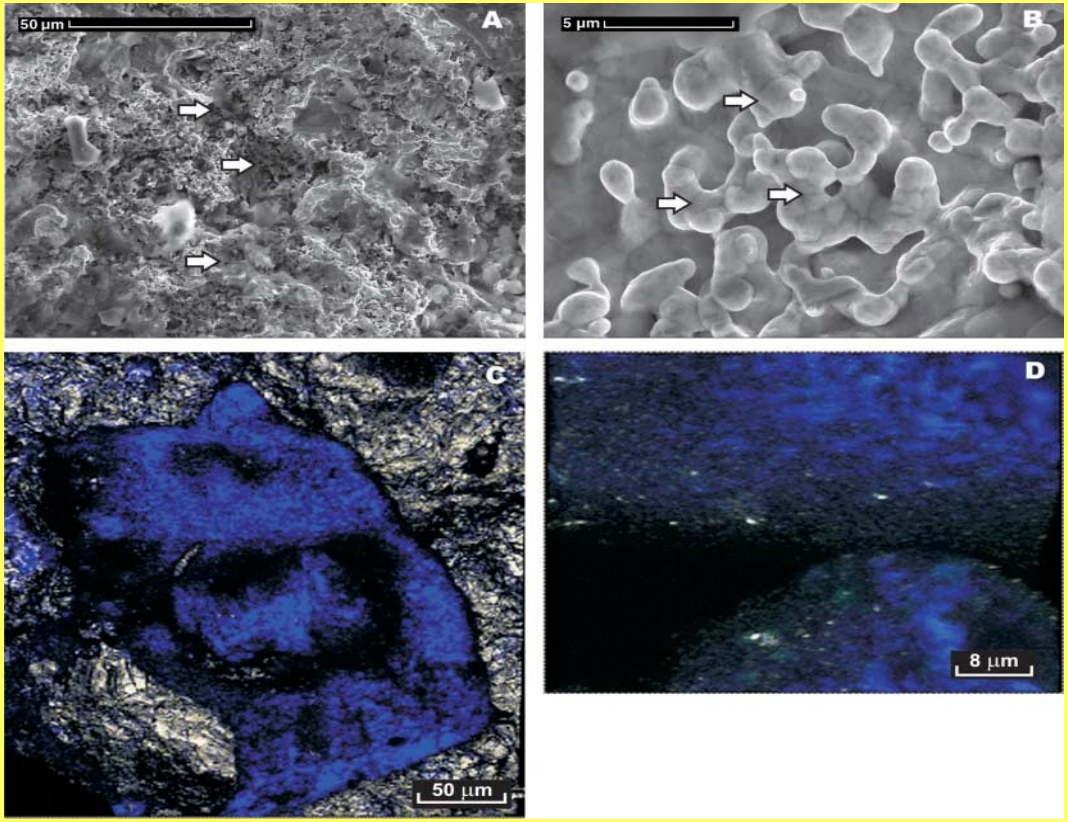


# Biomineralization of Gold:

Biofilms on Bacterioform Gold

Frank Reith,1,2* Stephen L. Rogers,1,4 D. C. McPhail,1,2 Daryl Webb3

This study provides evidence that bacterially mediated processes contribute to the formation of secondary gold grains.

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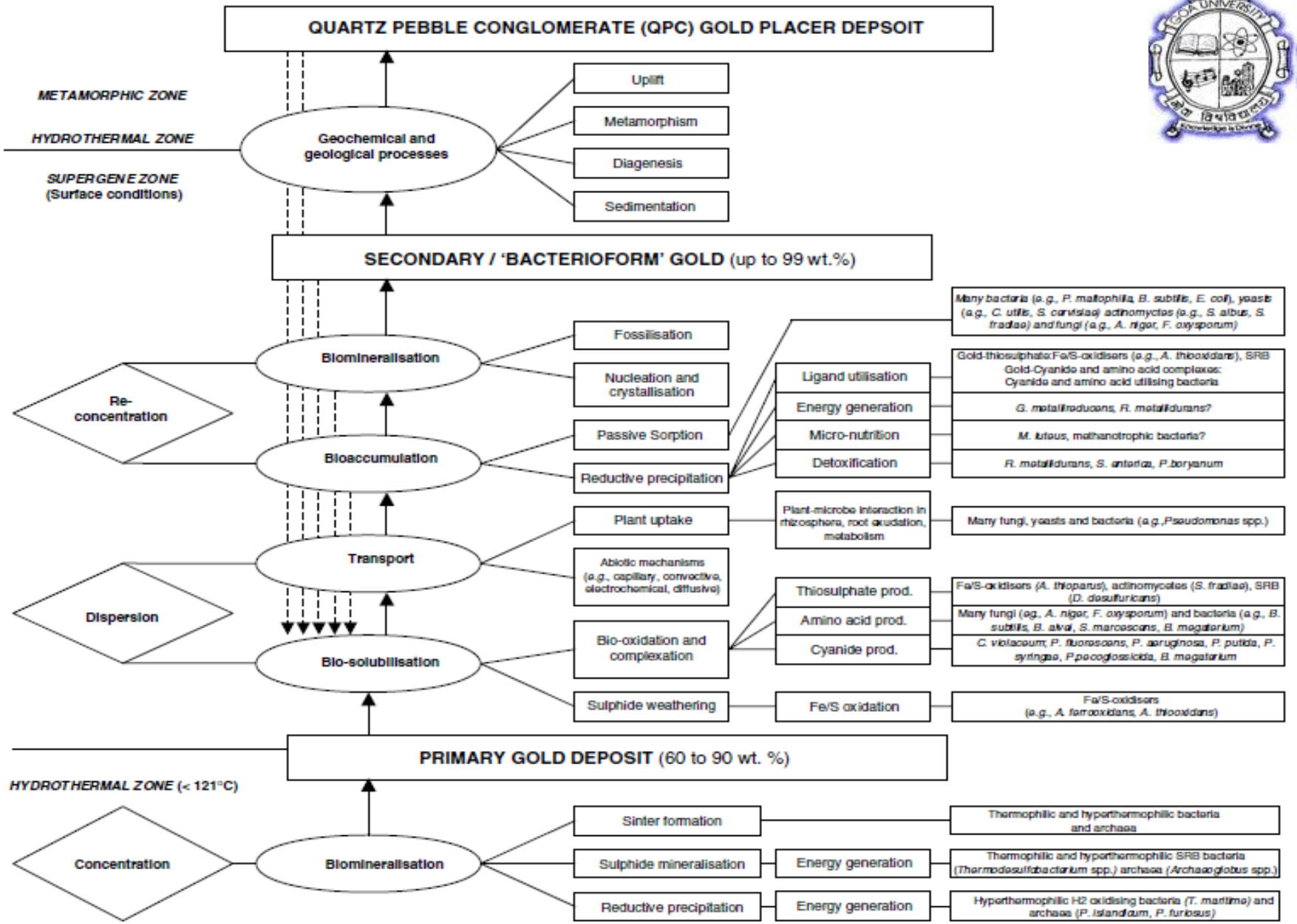



**Figure 1** Schematic model for the biogeochemical cycling of gold linking gold dispersion and concentration in the environment to biological processes, microbial populations and selected abiotic mechanisms.

# Bacterial Gold

- The origin of secondary gold grains is controversial and widely debated in the scientific community; the two main theories are that they are detrital or are formed by chemical accretion. However, there is growing evidence pointing to the importance of microbial processes in the cycling of gold.
- Common soil bacteria (Bacillus megaterium, Pseudomonas fluorescens, Bacterium nitrificans) are able to solubilize several milligrams of gold per liter of medium under in vitro conditions

# Bacterioform gold

- In field studies, structures resembling golden crusted microfossils observed on numerous gold grains from the Americas and Australia have suggested that microbial processes contribute to the formation of secondary gold grains.
- It can therefore be concluded that the structures described as bacterioform gold by previous authors may indeed be of bacterial origin.

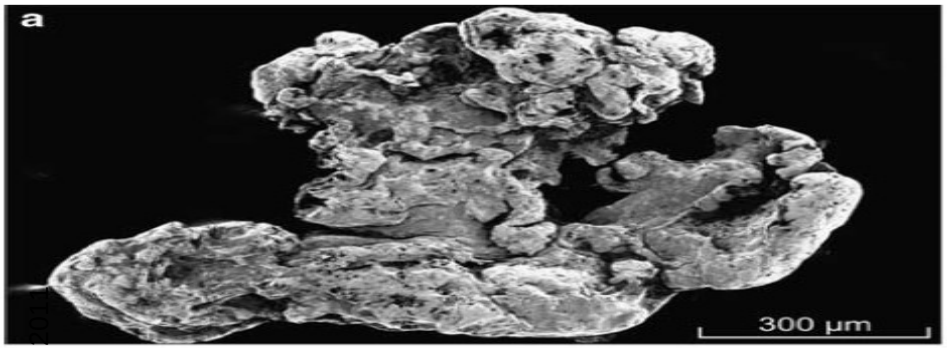
Biochemistry of Gold, Author(s): E. D. Korobushkina, G. I. Karavaiko, I. M. KorobushkinSource: Ecological Bulletins, No. 35, Environmental Biogeochemistry (1983), pp. 325-333

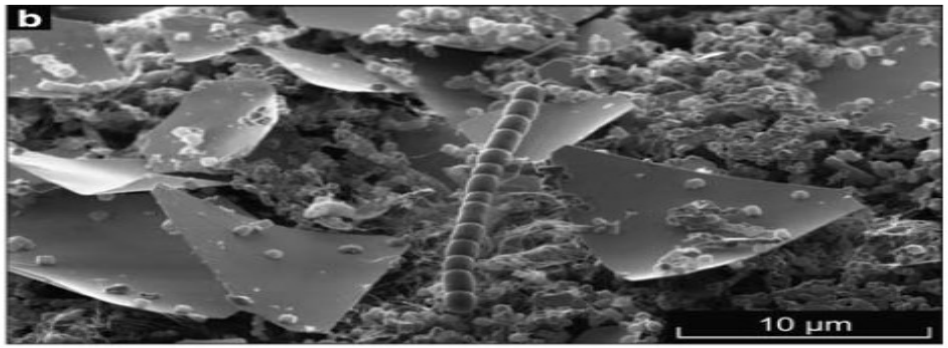
The enormous scope of formation, circulation and migration of organic matter in the biosphere proves that its role in the redistribution and creation of local concentrations of gold in the crust of weathering is great.

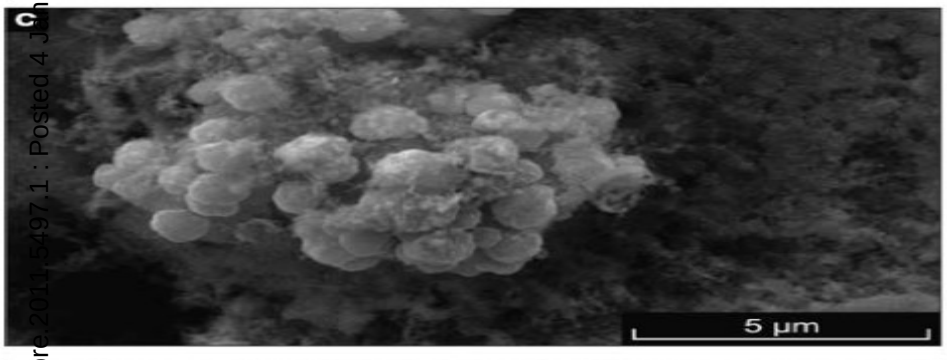
It is estimated that 3800000 MT of gold is bound in organic matter of sedimentary rocks.

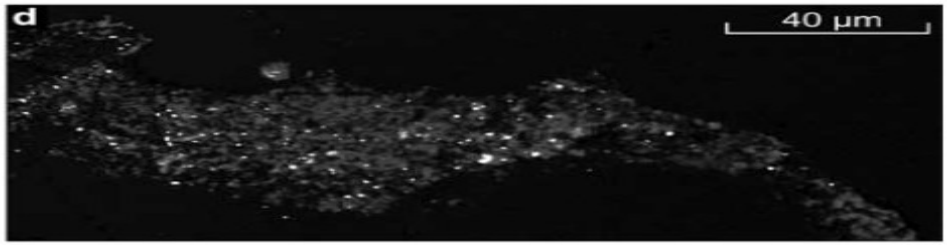
The geomicrobiology of gold
Frank Reith, Maggy F Lengke, Donna Falconer, David Craw and Gordon Southam, The ISME Journal (2007) 1, 567–584

Recent research suggests that bacteria and archaea are involved in every step of the biogeochemical cycle of gold, from the formation of primary mineralization in hydrothermal and deep subsurface systems to its solubilization, dispersion and re-concentration as secondary gold

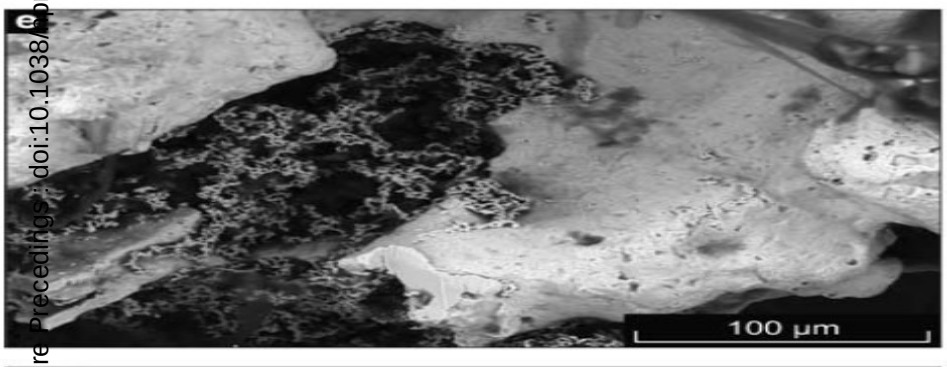


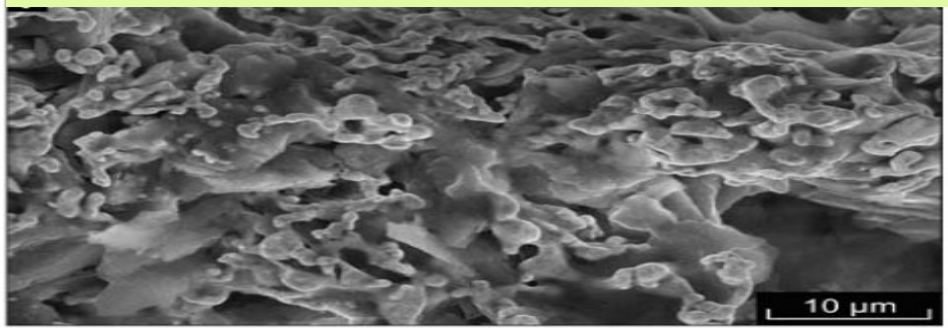



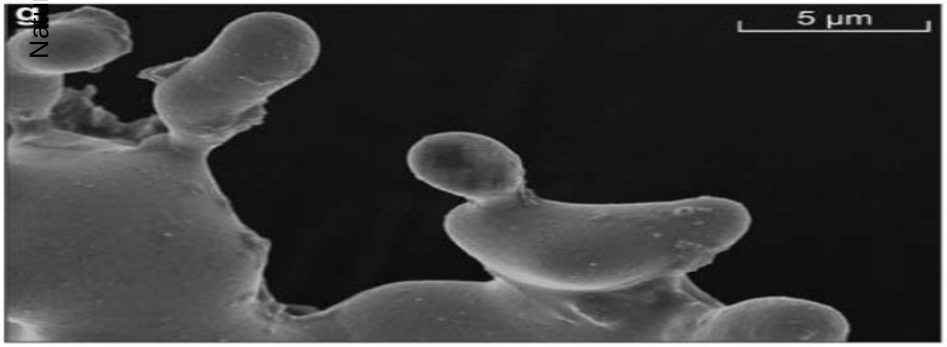



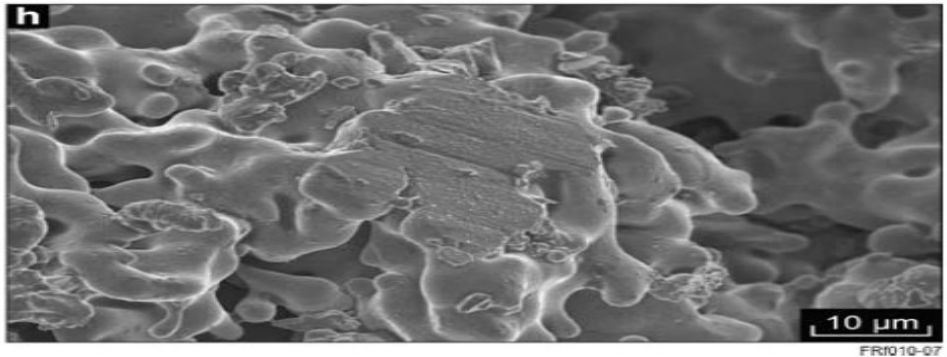



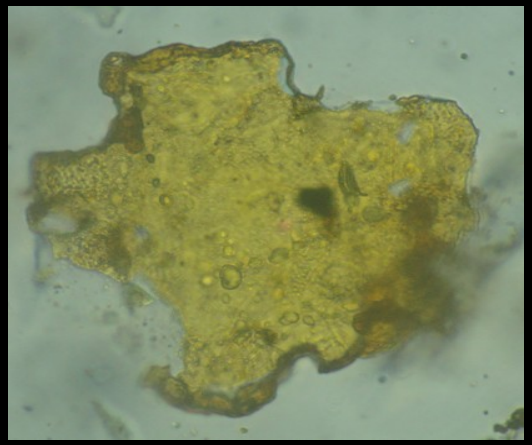
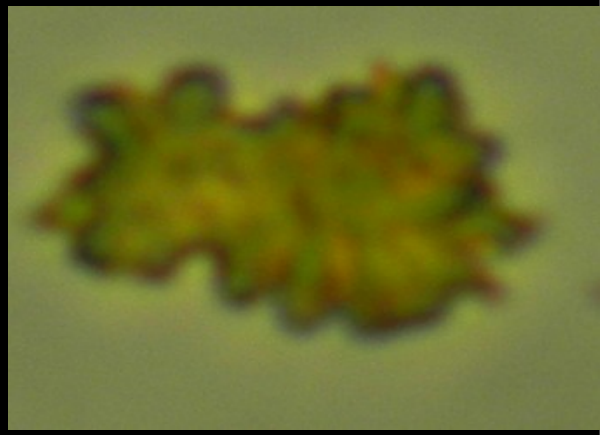

Bacterioform Gold under electron Microscope



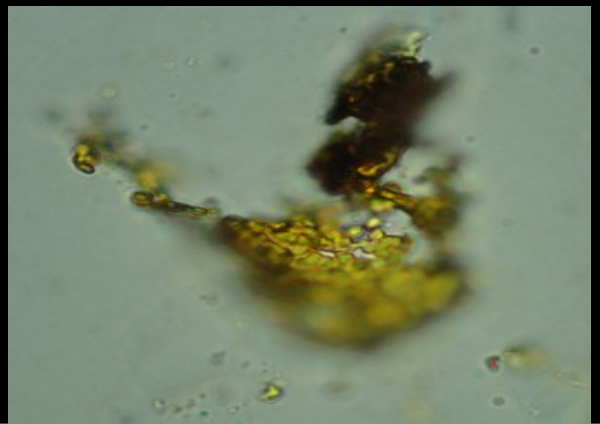



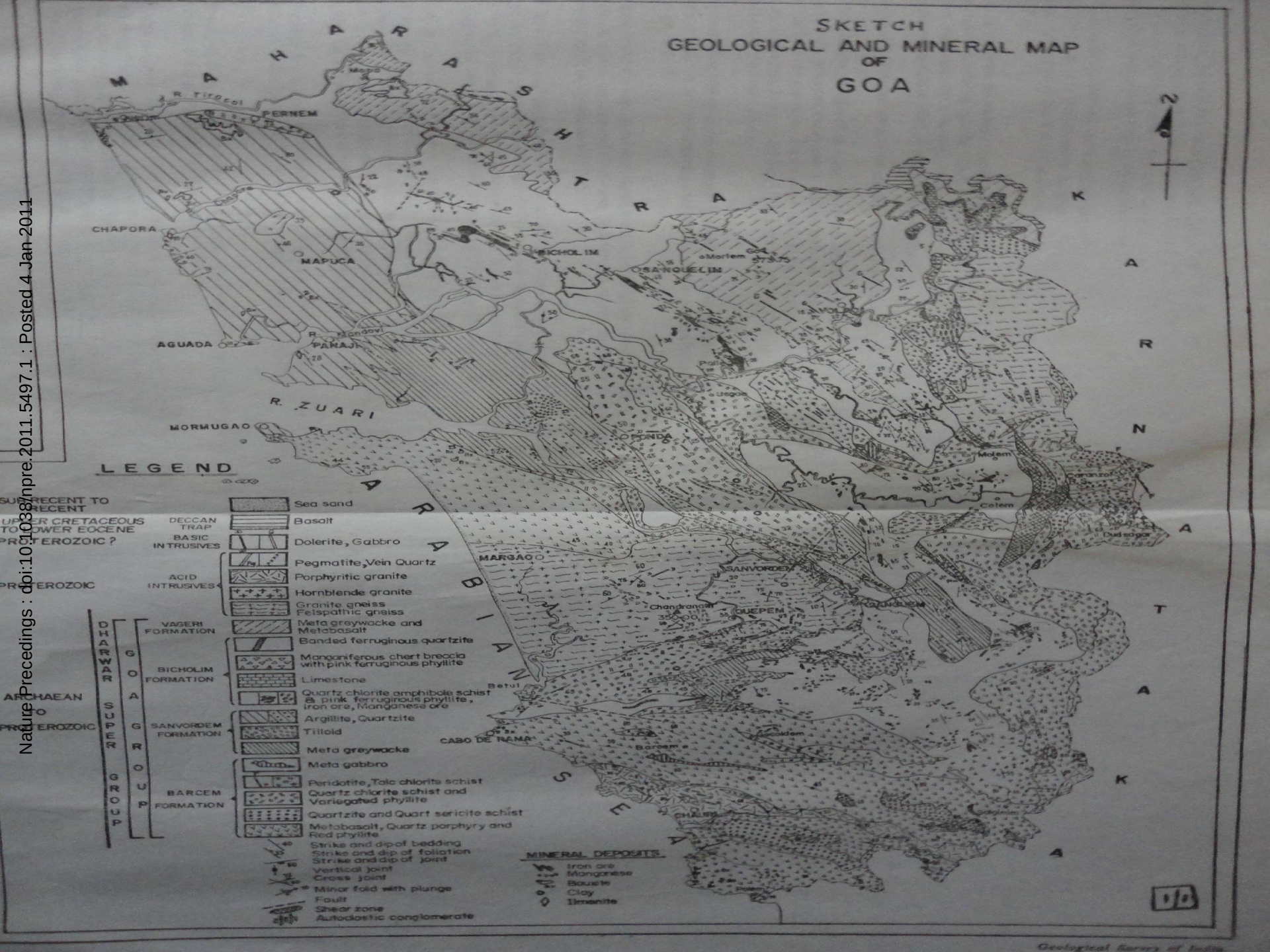




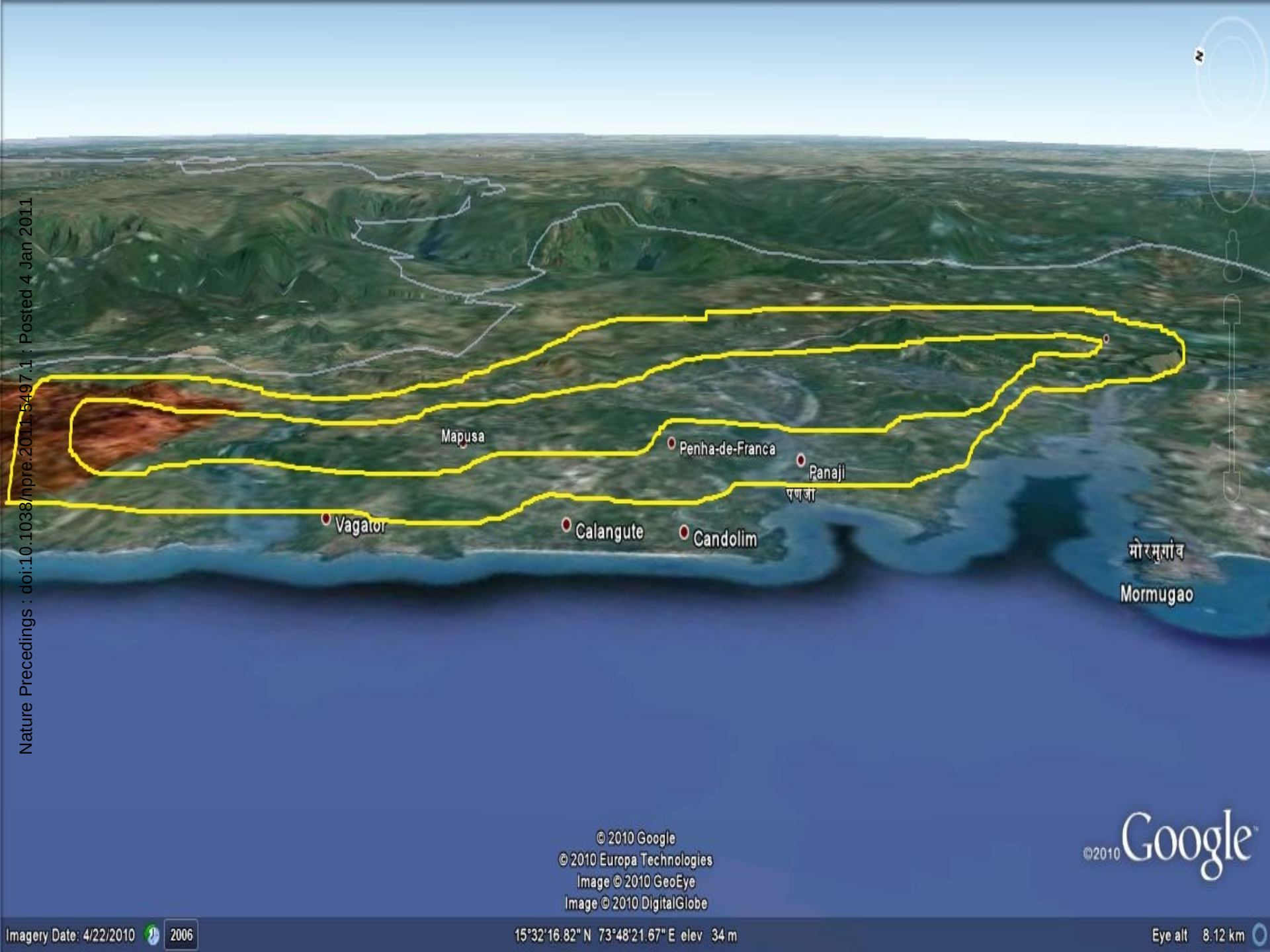
# Details of discovery of bacterioform Gold in Goa, India



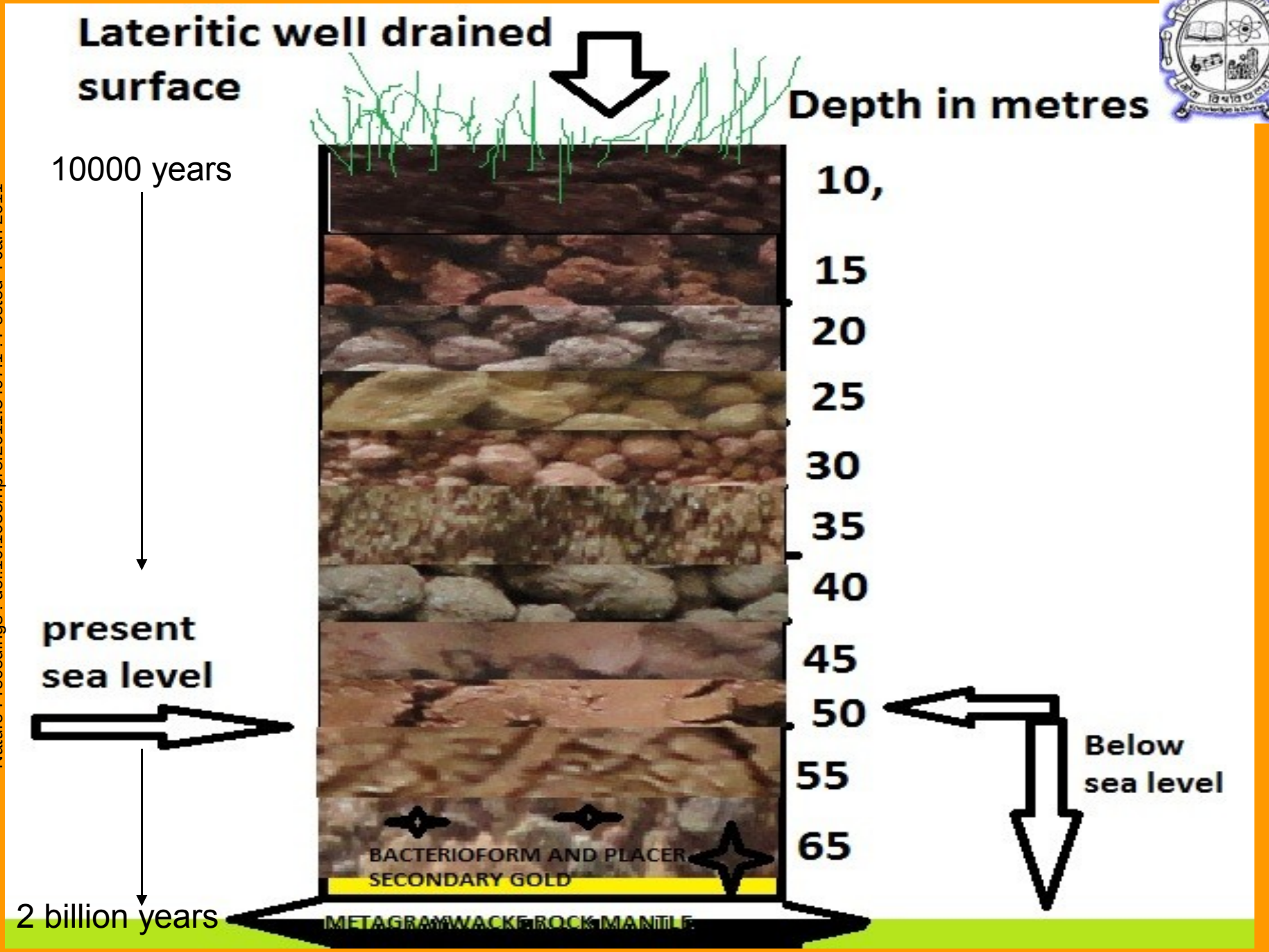


# SKETCH GEOLOGICAL AND MINERAL MAP OF GOA





# Where is the Gold in GOA?
# A peep into hitherto unexplored subsurface metabiosphere



# Gold bearing deposits in New zealand and Goa



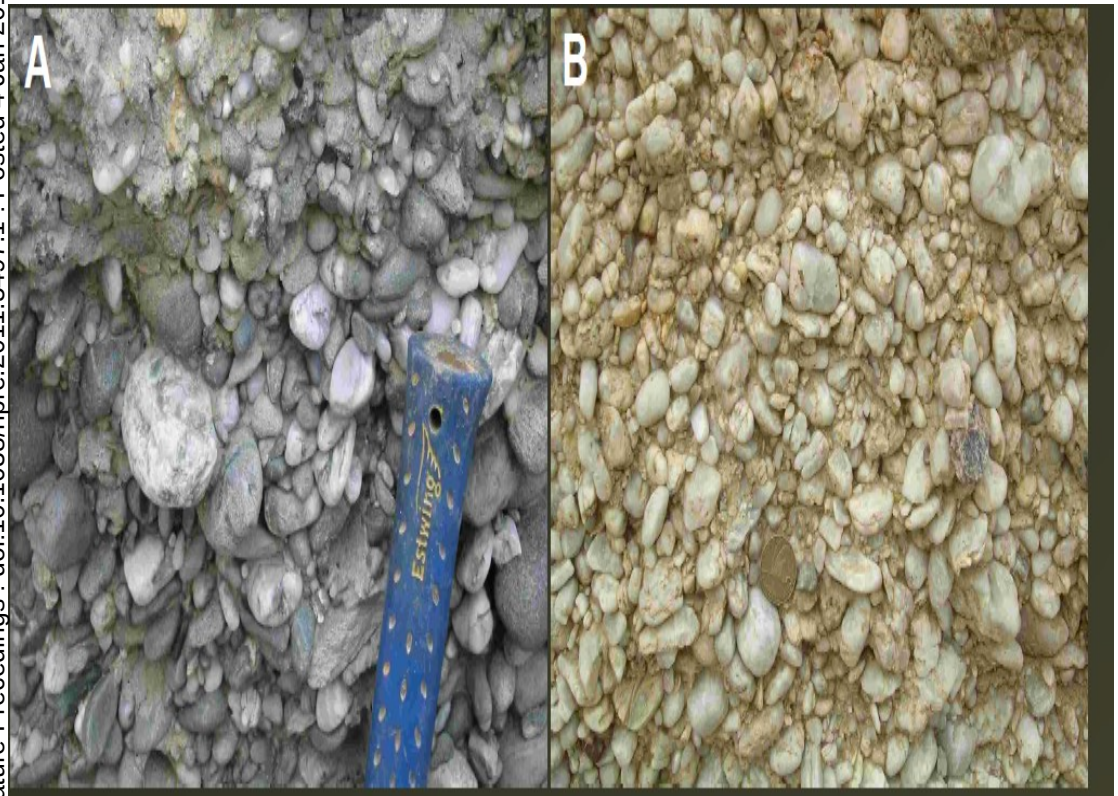



**Figure 2:** QPC conglomerates at Waimumu. **(A)** Unaltered primary conglomerate with up to 70 % lithics (greywacke). **(B)** Supermature QPC with 99 % quartz.

**Lensoidal Tilloid bodies-GOA**

# Authigenic gold

Authigenic gold either occurs as discrete particles (Fig. 4A), or as an overgrowth on detrital gold particles (Fig. 4C,D). Authigenic gold most commonly occurs as overgrowths on detrital gold particles in the form of spheroids, polyspheroidal aggregates, budded masses and more, rarely pseudohexagonal plates. Sheet-like authigenic gold (0.5 to 4 mm) is associated with carbonaceous mudstone overlying the QPC at Parker Road.

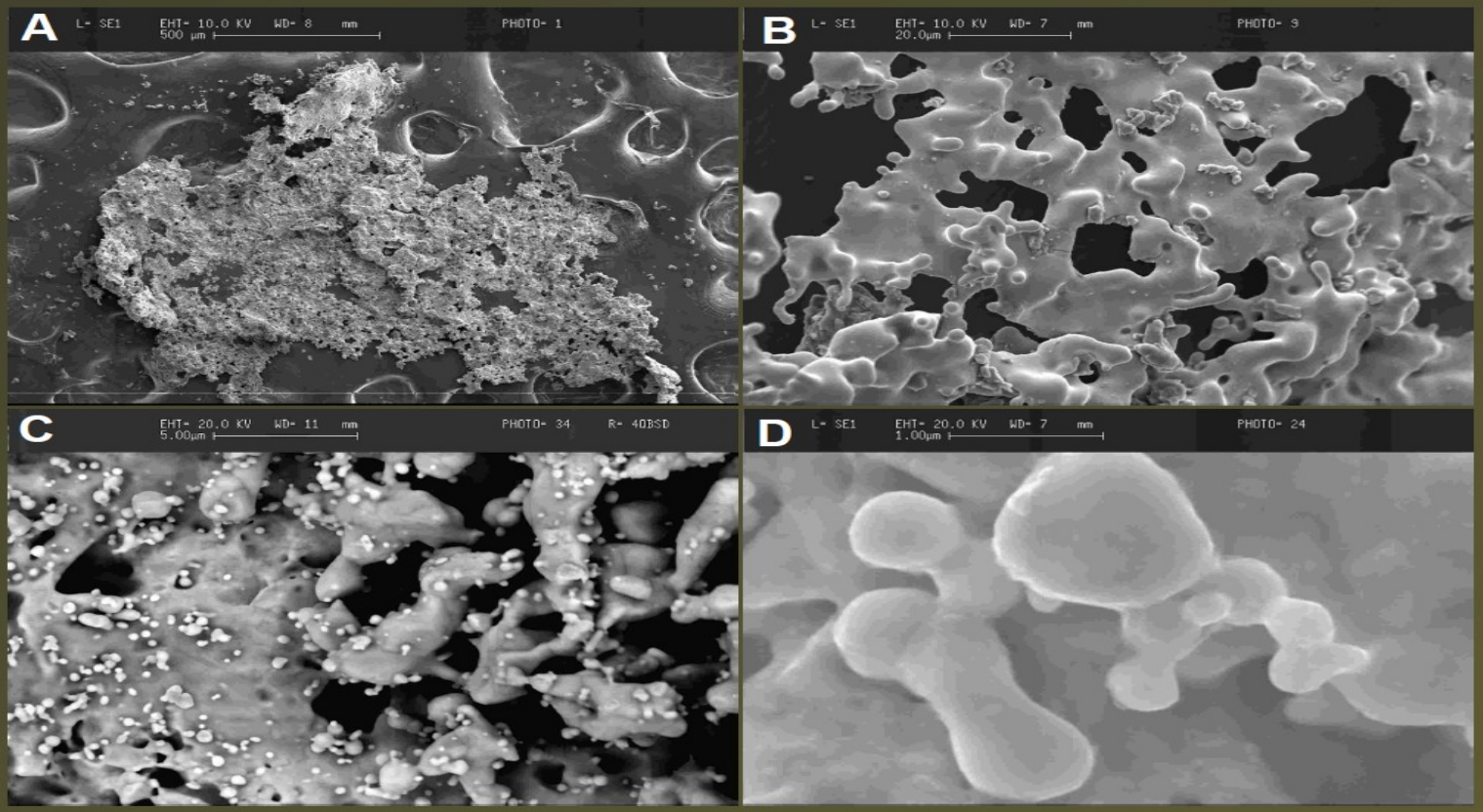



**Figure 4:** SEM photomicrographs of authigenic gold. **(A)** Irregular sheet-like authigenic gold particle. **(B)** Close-up of authigenic gold surface from (A). **(C)** Authigenic gold occurring within a cavity in detrital gold (from Fig 3B) **(D)** Polyspheroidal budded-like aggregates of authigenic gold on the surface of detrital gold.

# Now we shall view the scientific evidence from my laboratory

- There would be a slide show of photomicrographs of various forms of Gold taken at 400-1000 magnification
- This would be followed by short videoclips demonstrating the optical properties of various forms of Gold

# Photomicrographs and Videoclips



- Bacterioform-Gold-Goa\photmicrographs\assorte grains
- Bacterioform-Gold-Goa\photmicrographs\beads
- Bacterioform-Gold-Goa\photmicrographs\control
- Bacterioform-Gold-Goa\photmicrographs\crowns
- Bacterioform-Gold-Goa\photmicrographs\druzes
- Bacterioform-Gold-Goa\photmicrographs\filamer
- Bacterioform-Gold-Goa\photmicrographs\folded lattice
- Bacterioform-Gold-Goa\photmicrographs\geome forms
- Bacterioform-Gold-Goa\photmicrographs\micron
- Bacterioform-Gold-Goa\photmicrographs\plates
- Bacterioform-Gold-Goa\photmicrographs\stars
- Bacterioform-Gold-Goa\photmicrographs\Zircons

- Bacterioform -Gold-Goa\videos

# How bacterioforms of Goan gold are different?

- Forms like folded lattices so far unknown
- Forms like “galactic nurseries” producing Gold starfish assembalges unknown in world
- Forms like layered ‘crowns/Tiaras” unknown
- Gold druzes unknown but such forms common in Calcium Oxalate phyto/mycoliths
- Associations of Zircon in different sizes and forms unusual and can be helpful in dating

# Importance and significance of discovery of Gold

- First report in Goa, India and Asia of bacterioform Gold, an important geomicrobiological and scientific breakthrough
- First report of placer Gold in Tilloid
- First report of microbiogenesis of Gold under a lateritic strata
- Useful for understanding past climate changes, sedimentation processes
- Possibility of finding Zirconium, Hafnium, Uranium and Thorium deposits

# Implications of Discovery

- Moratorium required in North Goa on excavations below 60 m depth, or below sea level
- All subsurface deposits to be property of Government of Goa
- All conglomerates and Tilloids to be subjected to analysis for Gold,Uranium, Thorium, Zirconium, Hafnium

# Impact on Land classification

- Land use classification needs to be changed
- Land use policy to be proactive-to lock in subsurface Gold as strategic mineral reserve
- Property prices in lateritic plateaus may be affected
- No mining to be permitted till full geochemical prospecting is over

# Estimates of bacterioform and placer Gold deposits

- For a 100 ha. Area if the deposit bearing band is 1-10 metres thick (average 5), then the volume of rock is five Million cubic M
- Considering a density of 3 MT/CuM, the weight would be 15 MMT
- With average content of 1g/MT the area would produce 15 MT of Gold
- At present market cost of Rs. 2000/gm this would be worth Rs. 3000 million

# How Much Gold Could be Expected?

- Probable lateritic area:- 100, 000 ha.
- Area with Gold bearing deposits:- 20-40000 ha.
- Estimated Gold concentration:-1-2g/MT
- Estimated Gold deposits:-Max. 6000 MT-Min. 3000 MT
- Estimated market value:-Rs. 600-1200 billions

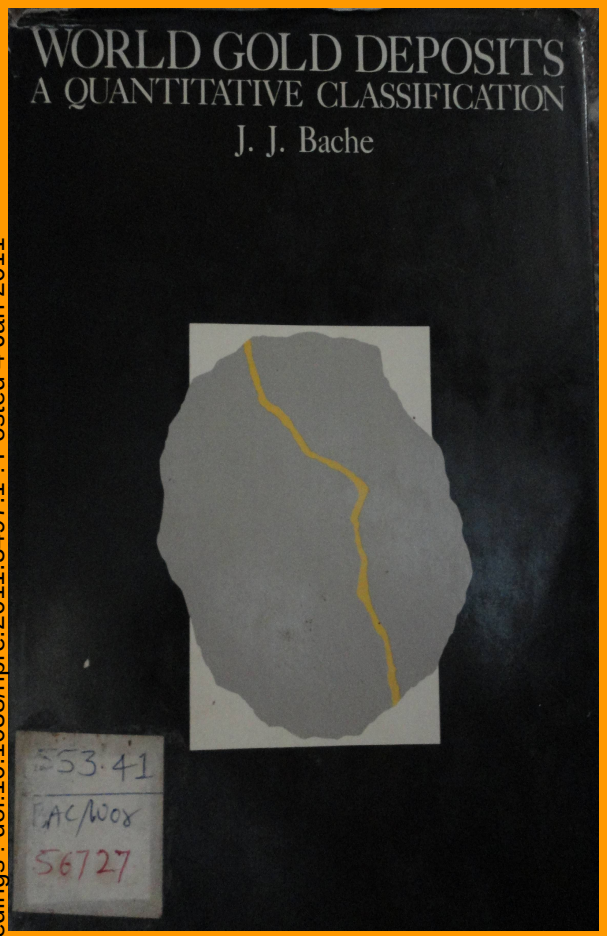
# Systematic geochemical studies

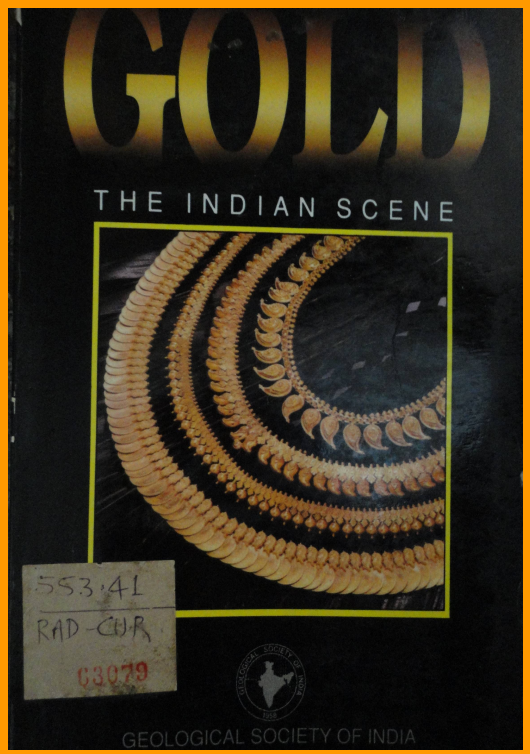
- A note has been sent to Govt. of Goa to form a technical committee for carrying out systematic geoprospecting and geochemical studies by drilling and analyzing deep subsurface core samples and create an Atlas of Gold deposits of Goa

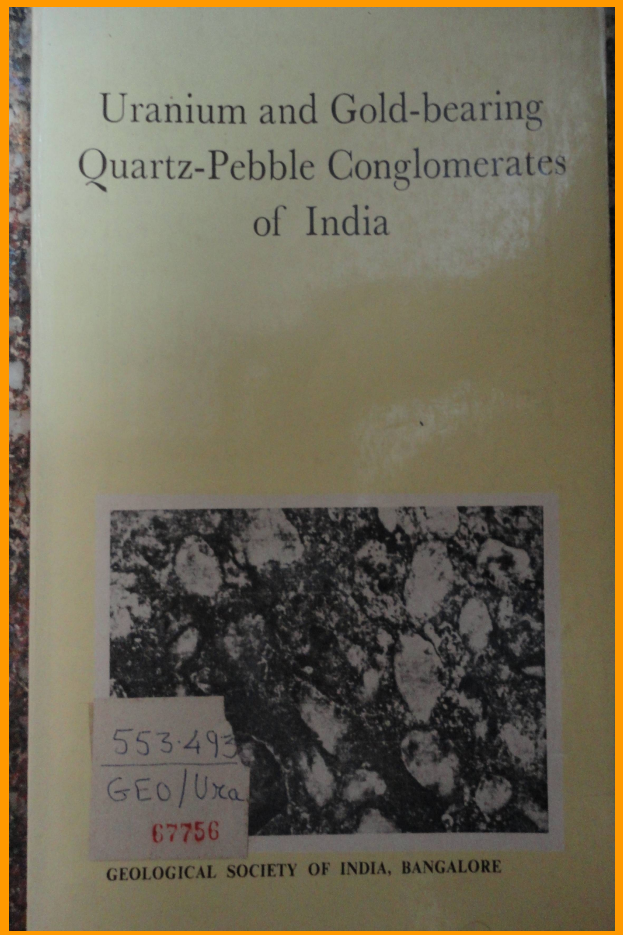
# Work in progress and further investigations

- Geological, geohydrological, geochemical (Prof. Chachadi), Geomicrobiological, biochemical (Dr. N. Kamat), Nanobiotechnological (Dr. Ahmad, NCL, Pune) investigations on more samples and publication of the data
- Collaboration with international expert in this field Prof. Frank Rieth, University of Adelaide, Australia

# Some references on Gold used for study



# Resources for the media

- All the 42 Videos are uploaded on you Tube channel http://www.youtube.com/user/nandkamat?
- All the 254 photographs are uploaded on my Picasaweb channel
- http://picasaweb.google.com/Nandkamat/

# Thank You!

- Discovery of Gold in Goa was a happy coincidence during

  The Golden jubilee year of Goa's liberation
- "Hopefully, Goa may now regain its' reputation as Golden Goa/Sunaparanta"

# Acknowledgements


- Department of Botany, Goa University & Prof. Chachadi, Dept. of Earth Sciences
- My research staff:- Project assistant Ms. Indira Talaulikar, technical assistant- Ms., Neysa Rodrigues, Culture Technician Ms. Priyanka Shirodkar- all from Mycolab
- Prof. Frank Rieth, Australia
- Shri Prakash Kamat, President, GUJ
- GCCI for sponsoring the premises
- Members of the press and electronic media

  My PG and research students and ex students

- The work was partially supported by UGC-SAP and largely by M/s R.N.S. Bandekar & Bros, sponsors of my Mineral biotechnology project