

A NEW GEMSTONE PROVINCE OF EASTERN GHATS MOBILE BELT, INDIA: RESULTS OF GEOLOGICAL AND MINERALOGICAL INVESTIGATIONS

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ABSTRACT

A new province of invaluable precious and semi-precious gemstone resources has been explored from parts of Eastern Ghats Mobile Belt (EGMB) in the states of Andhra Pradesh and Orissa, India for the first time. The chief precious minerals are alexandrite, chrysoberyl, chrysoberyl cat's eye, aquamarine, ruby and the semi-precious stones are moonstone, zircon, sillimanite, garnet, tourmaline, and a variety of silica minerals viz. rock crystal, amethyst, rose quartz, smoky quartz, citrine and green quartz. These gem variety stones have their hostage in pegmatites, and potential when criss-crossed by the basic and ultrabasic rock types. The pegmatites are the immediate hostages and intruded through the gneissose bands of khondalite and leptynite; thus made the EGMB, India as a special precious province of gemstones. The exploration carried out in the pegmatitic bodies of the EGMB region, the potentiality of the gemstones in various pegmatitic colluvium bodies, their nature of characterization, their reserve positions, the activities of the government, the outcome of the mining activities, the illegal practices of mining, the beneficiaries of the precious stone scenario and the mineral dressing activities carried out by the mining organizations are briefly presented in this paper.

Keywords: India, eastern ghats, precious stones, geology and reserves.

INTRODUCTION

Eastern Ghats Mobile Belt (EGMB) rock formations of India are well known for a variety of mineral deposits viz. apatite, bauxite, beach placers, feldspars, building stones, chromite, decorative stones, graphite, manganese ores, mica, quartz / quartzite, radioactive minerals, and sulphide minerals. The principal lithological members of the Eastern Ghats Mobile Belt comprise khondalite, charnockite, leptynite, granite, calc-granulite and quartzite. Pegmatite is one of the important rock types in the present context, which is a treasure-house of many rare, resistive and durable gemstones (Kasipathi, 1993). Pegmatite is an intrusive vein rock body that is intruded in the EGMB members, through khondalite and leptynite gneissose bands. The pegmatite when found criss-crossed even by thin veins of basic and ultrabasic rocks types, potential gemstone bodies were traced out. The details are presented in the following lines.

DISCUSSION

Geology of Eastern Ghats Mobile Belt

Khondalite, charnockite, granite, quartzite, leptynite and calc-granulite are the important members of EGMB (Fig.1), in which a number of thin intrusive bodies of acidic to basic pegmatitic types are delineated. Pegmatite has formed to be an important association of the entire EGMB, which can be considered as a target for mineral exploration of gemstones. It is well known that micas, apatite, feldspars, tourmaline, magnetite and vermiculite

occur in abundance in the major part of the EGMB. These minerals are the products of liquid immiscible injections (Kasipathi, 1995). Weathered colluvial bodies after pegmatite, at the midst of the hill ranges in the valley portions show concentrated bodies of gemstones. Pegmatite shows variable lengths and widths, but continues for long distances. The thickness of the pegmatite veins is variable from about 3 cm to 120 cms in a zigzag pattern. It is very difficult to trace the extensions of the pegmatite vein bands in the field due to their variable thinning and bulging habit, but they follow the strike direction of the host rocks, i.e. khondalite and leptynite along their gneissose bands. Three parallel gemstone zones were recognized in Visakhapatnam and East Godavari Districts (Kasipathi, 1996^{a,b}) (Fig. 2), viz.

- Zone-I - Shallow in-situ gemstone zone in the plains and low-lying EGMB ridges parallel to the east coast with moderate concentrations of precious gemstones to a depth below 50 m. without any weathering zones and formation of colluvium.
- Zone-II - Moderate hill ranges parallel to the Zone -I in the same strike direction of EGMB comprising moderate to high concentrations of precious gemstones with rich secondary colluvium bodies even to a depth beyond 100 m.; and,
- Zone-III - Highly elevated hill ranges parallel to the strike direction of the other two zones, with rich concentrations of the precious stones and semi-precious stones in the hard unweathered in-situ EGMB rock-types and intensely in the

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deep colluvial bodies to an estimated depth beyond 300 m.

Precious and Semi-Precious Stones of the region

The identified precious and semi-precious stone resources of the region are alexandrite, chrysoberyl, chrysoberyl cat's eye, aquamarine, ruby (**Plate-I**), moonstone, garnet, tourmaline, sillimanite, zircon, epidote and a variety of silica minerals viz. rock crystal, citrine, rose-quartz, smoky quartz, and green quartz (**Plate-II**). Minor amounts of precious minerals viz. emerald and sapphire are also identified at places in tiny sizes. These gemstone minerals have shown close association of silicate minerals in the form of plates and books of phlogopite, vermiculite and chlorite, within the pegmatite bodies. The first four are the abundant precious minerals and the next two are rare precious minerals and the remaining minerals are semi-precious stones. The chemistry of the precious minerals is presented in Table 1 for a general understanding of the minerals (Lakshminarayana *et al.*, 2006). The following are the characteristic features of these minerals (Kasipathi, 2007).

Alexandrite is a variety of chrysoberyl with the chemical composition $\text{BeO} \cdot \text{Al}_2\text{O}_3 \cdot n \cdot \text{Cr}_2\text{O}_3$. It is light green to deep green colored, silky, chatoyant to opalescent, indistinct in cleavage, uneven to conchoidal in fracture, vitreous, about 8.5 hardness and about 3.6 to 3.8 specific gravity. The crystals are medium to coarse in size, dominantly less than one carat and often show pseudo-hexagonal forms. Crystals are tabular, vertically striated and twinned. Colour transformation to violet and red with artificial / incandescent light is its valuable character (Kasipathi, 1997). It is a valuable gemstone. It is distributed in parts of Visakhapatnam and East Godavari districts of Andhra Pradesh and in parts of Sambalpur district of Orissa.

Chrysoberyl and Chrysoberyl Cat's Eye: Their chemical composition is $\text{BeO} \cdot \text{Al}_2\text{O}_3$. Chrysoberyl is crystalline, mostly tabular, columnar, short prismatic with distinct prismatic striation. It varies in length from 5 mm to 30 mm and width from 2 mm to 35 mm. It is light yellow to yellowish-green coloured, green and deep yellow, transparent to translucent, hardness 8.2 to 8.5 and specific gravity is 3.7 to 3.8. It produces beautiful cut stones after processing. Chrysoberyl Cat's Eye is a chatoyant chrysoberyl, massive, variable in dimension, translucent, yellowish, yellowish-green, lemon yellow and golden yellow in colour. Different fine layers of transparent and translucent chrysoberyl bands result a cat's eye effect. Chrysoberyl cat's eye is suitable for processing to yield cabachons. These stones are distributed in the north coastal districts of Andhra Pradesh and southern coastal districts of Orissa (Bhaskara Rao *et al.*, 2002).

Aquamarine: It is $\text{Be}_3(\text{Al,Fe,Cr})_2 \text{Si}_6 \text{O}_{18}$. It belongs to hexagonal system and is a member of beryl group with sky blue colour, light blue-green or even light green. It is pleochroic. They are free from inclusions. Lustre is vitreous. It is found so far only in parts of Orissa (Badmal-Mursundi area of Subarnapur district) as per Das (1993), but not in Andhra Pradesh.

Ruby: It is a gem variety of corundum with chemical composition $\text{Al}_2 \text{O}_3$ and belongs to hexagonal system. It occurs as barrel-shaped / pyramidal crystals / hexagonal bipyramids and also as massive and granular bodies. There is no cleavage. Its luster is vitreous and fracture is uneven or conchoidal. It is reddish colored, sometimes violet-red and pleochroic. It shows fluorescence under ultraviolet light. They are mostly crystalline cylindrical prisms with a width of 3 mm to 12 mm and height of 25 mm to 40 mm. It has hardness of 9 and specific gravity of

Table 1. Chemistry of precious stones (Neutron Activation studies).

Wt.%	1	2	3	4	5	6	7	8
Be O	18.70	19.10	17.82	17.66	19.16	19.15	---	---
Al_2O_3	75.32	76.88	78.50	78.54	76.32	76.34	99.68	98.68
Fe_2O_3	0.28	0.34	2.45	1.76	2.41	---	0.08	Tr.
Cr_2O_3	0.38	0.35	0.08	0.06	Tr.	---	0.01	0.82
FeO	0.42	0.86	Tr.	Tr.	0.42	3.60	Nil	Tr.
MnO	---	---	---	---	---	---	0.01	Tr.
MgO	0.46	0.38	0.27	0.40	0.30	---	0.01	0.06
CaO	1.24	1.05	0.22	0.31	0.22	---	Nil	0.02
TiO_2	0.47	0.21	0.18	0.26	0.24	0.55	0.02	0.01
SiO_2	2.65	0.92	0.31	0.81	0.52	---	0.05	0.12

Tr. : Traces; --- = Not determined / Under detection limits; Nil = Absent.

Sample details : (1) and (2) Alexandrite from Chintapaka, (3) Chrysoberyl from Chintapaka, (4) Chrysoberyl from Pappusettipalem, (5) Chrysoberyl Cat's Eye from Pappusettipalem, (6) Dana (1992), (7) Grey corundum from Pallalabhavi area, and (8) Red transparent ruby from Mekalakunta area. [Samples numbers 1 to 5 are collections from Visakhapatnam district and 7 to 8 are from Khammam district, Andhra Pradesh].

Table 2. Reserve Estimations of gemstone deposits in different locations of Andhra Pradesh, India.

District	Name of the location of the gem tract	Reserve Estimations in tonnes				
		Chrysoberyl*	Alexandrite	Ruby	Moonstone	Garnet
Visakhapatnam	1. Asakapalli	2.95	---	---	8.69	4.53
	2. Pappusettipalem	815	---	---	27	46
	3. Chintapaka	8.58	51.26	---	---	72.10
	4. Paderu	0.16	---	---	0.23	---
	5. Pedabayalu	0.05	---	---	1.18	---
	6. Araku Valley	0.01	---	---	0.01	---
Khammam	1. Mekalakunta	---	---	7.22	---	10.18
	2. Lakshmiapuram	---	---	18.30	---	53.34
	3. Singaraipalem	---	---	3.10	---	9.97
	4. Pallipadu	---	---	7.69	---	23.66
	5. Kodavatimetta	---	---	2.10	---	2.88

(* Including Chrysoberyl Cat's Eye Reserves)

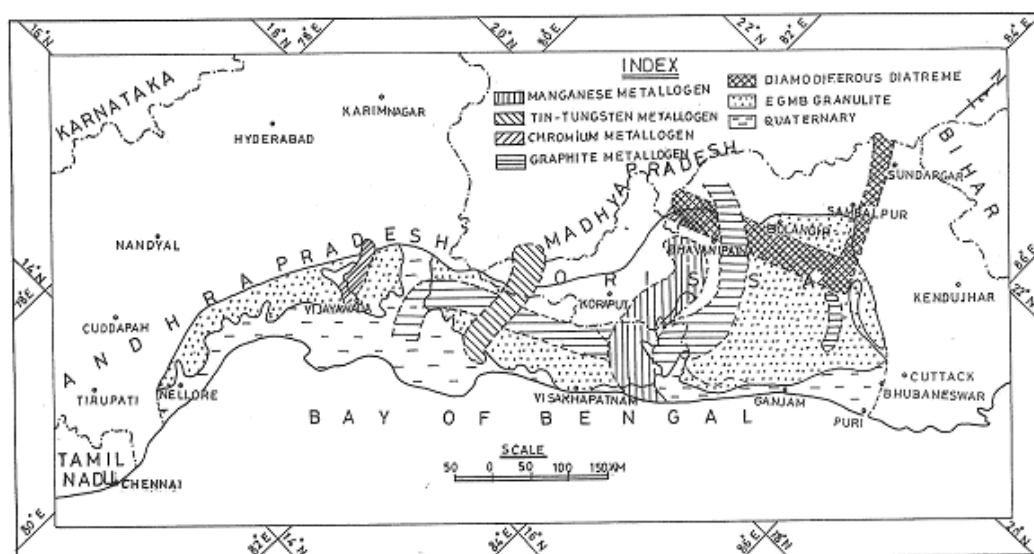


Fig 1. Geological map of the Eastern Ghats mobile belt (after Mishra, 1998).

4. It is available only in parts of Southern parts of Khammam district of Andhra Pradesh adjoining the supracrustal rocks and near Bhawanipatna (Orissa).

Zircon: It is $Zr.SiO_4$, colourless, pale-yellow, grey, brownish-yellow and reddish-brown, transparent to opaque, conchoidal in fracture, brittle and adamantine in luster. It's hardness is 7.5 and specific gravity is variable between 4.35 and 4.82. It is found in the association of Chrysoberyl and Chrysoberyl Cat's Eye in parts of EGMB.

Garnets: Due to isomorphism, they show variable chemical composition as $3(Ca,Mg,Fe^{ii})_3O.(Al,Fe^{iii},Cr,Ti^{iii})_2 Si_3O_{12}$. These are light to deep pink, red, rose, yellow and brown coloured, crystalline, transparent to translucent, and relatively coarse grained among the gemstones family. They show mostly dodecahedral and

trapezohedral crystalline forms and massive also. They are sub-conchoidal to uneven in fracture. Hardness is 6.5 to 7.5 and specific gravity is 3.15 to 4.30. It is brittle and parting is distinct. It is vitreous and resinous. The transparent and coloured garnets are used as gemstones. Huge concentration of variety of garnets are found independently without any sympathetic and antipathetic relation with the other gemstone members; but associated with the rubies of Khammam district (Andhra Pradesh) and near Bhawanipatna (Orissa).

Moonstone: It is $Na Al Si_3O_8$. It is a variety of orthoclase feldspar. It is vitreous and often pearly. It is colorless, white, pale yellow, red, grey and green. It is transparent to translucent and usually crystalline and shows opalescent play of colors, when polished. It is distributed rarely in the association of chrysoberyl and chrysoberyl cat's eye, but not much with alexandrite.

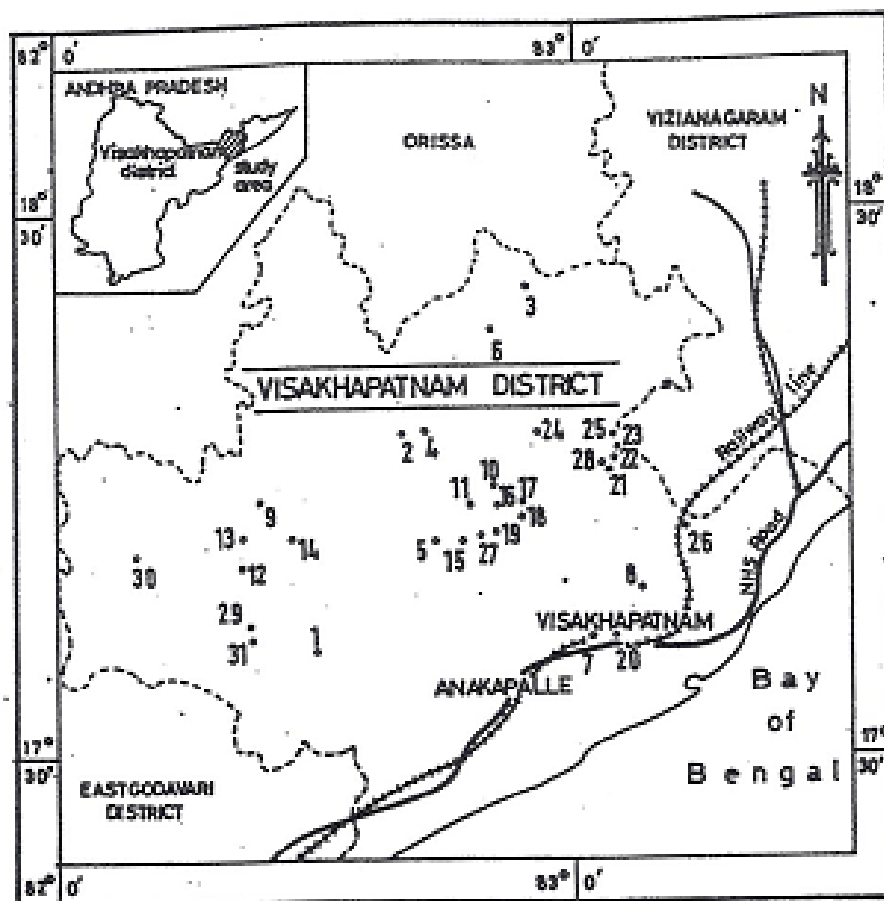


Fig 2. Location of gemstone occurrences in parts of Visakhapatnam district, Andhra Pradesh, India.

1. Pappusetipalem, 2. Paderu, 3. Arakuy, 4. Turaiguda, 5. Pittagedda, 6. Matsyapuram, 7. Venkataramannapeta, 8. Eruwada hill, 9. Lothugedda, 10. Goppulapalem, 11. Khutikonda, 12. Pinapadu, 13. Geelugumetta, 14. Pedakonda, 15. Pedapittagedda, 16. Ravipalem, 17. Korramamidipalem, 18. Goppuru, 19. Siripuram, 20. Yeduvokala, 21. Chintapaka, 22. Pedda Madina, 23. Chinna Madina, 24. K. Vallapuram, 25. Turakalapudi, 26. Asakagalli, 27. Rolugunta, 28. Gunnempudi, 29. Karaka, 30. Gurralagondi, 31. Salika Mallavaram.

Sillimanite: It is Al_2SiO_5 . It shows a columnar structure and also a cat's eye (Rao and Basu, 1994). Colour is deep brown, hair-brown, greyish-brown, pale-yellow, green and black. It is transparent to translucent and pleochroic. It is distributed rarely only in the association of chrysoberyl and chrysoberyl cat's eye only in the EGMB.

Tourmaline: It is $(H_9Al_3(B.OH)_2Si_4O)_{19}$. Crystals are usually prismatic, acicular and flattened. Prismatic faces strongly striated vertically and barrel in shape. Cleavage is indistinct and fracture is uneven. Hardness varies from 7.0 to 7.5 and specific gravity from 2.98 to 3.20. Lustre is vitreous. Color is variable viz. black, brownish-black, bluish-black, marine blue, green, red, colorless, deep blue and intermixed colors. It is mostly opaque (Schorl). The transparent varieties are the semi-precious stones. This is

a common associate in almost of all the pegmatite bodies of this region. It is commonly distributed with all the pegmatitic bodies of EGMB in association with the precious minerals, except the ruby-bearing pegmatitic bodies of Andhra Pradesh and Orissa.

Varieties of Silica: It is SiO_2 . It is colorless (Rock crystal), yellow (citrine), rose (rose quartz), violet (amethyst), smoky (smoky quartz), green and red. Its hardness is 7 and specific gravity is 2.65. It is vitreous and transparent. These are used as common semi-precious stones and in sculpturing. These minerals are omnipresent with chrysoberyl, chrysoberyl cat's eye and alexandrite and distributed in the gemstone province of EGMB, both in Andhra Pradesh and Orissa.

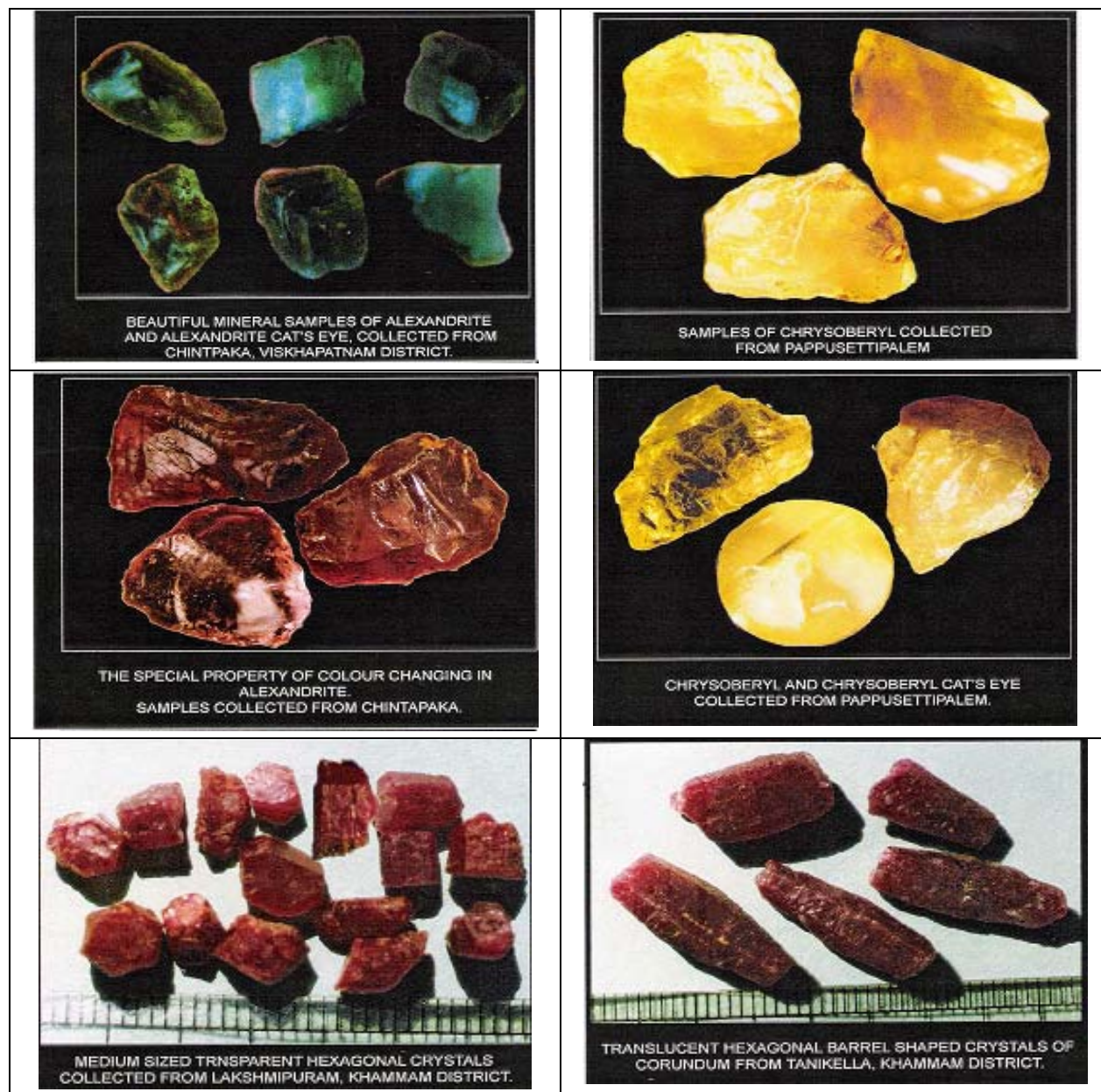


Plate I

The following significant mineral affinities and departures are noted in the gemtracts of EGMB (Mishra *et al.*, 1993; Kasipathi *et al.*, 1999):

- Rock crystal and beryl are often found together,
- Topaz and beryl seems antipathic with each other,
- Tourmaline and aquamarine are generally sympathetic, and
- Corundum (Ruby) and muscovite usually occur in each other's company, but the pair show antipathic relation with biotites.
- Chrysoberyl / Chrysoberyl Cat's Eye / Alexandrite / Aquamarine sympathetic with (i) zircon and (ii) hydroxyl micaceous minerals viz. biotite, lepidolite,

phlogopite and (iii) hydrous micaceous silicates of chlorite family, including vermiculite.

Gem mineral localization in EGMB

The described gemstones are found present in the EGMB along the gneissose bands of khondalite and leptynite. The miraculous rock, 'pegmatite' is found to be the important rock type that holds the gemstones in close affinity with the micaceous minerals viz. phlogopite, biotite, vermiculite and muscovite in the lower order of abundance. If the pegmatite is found in close interference with the mafic and ultramafic rock types, the pegmatite shows potential pockets of the gemstones. Primary pegmatite shows variable dimensions, thinning and

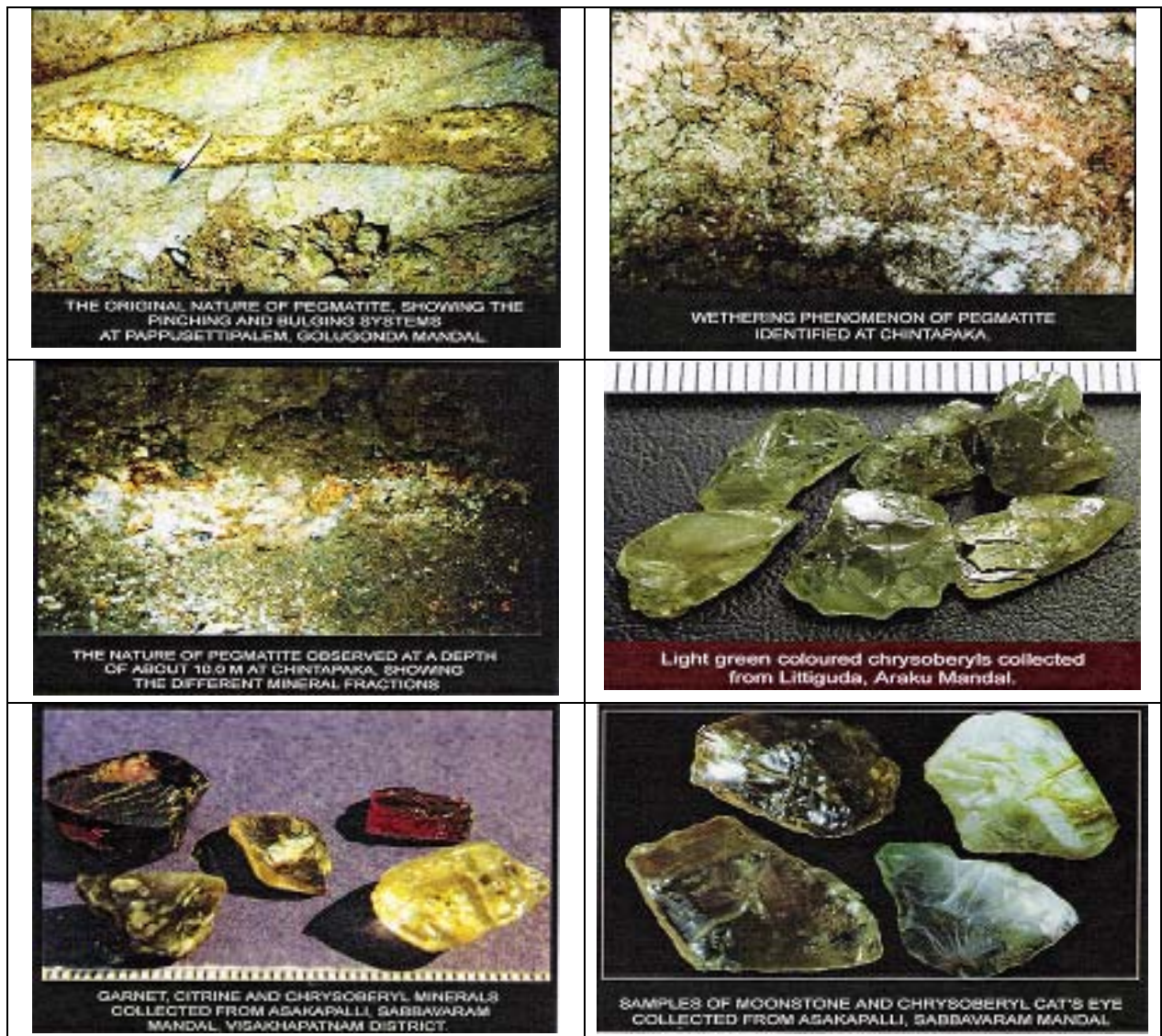


Plate II

thickening and bulging structures in the unaltered rocks. The secondary plastic clayey mass, after pegmatite is described as colluvium (Kasipathi, 1997). The secondaries after pegmatite are the rich exploration targets for gemstones in EGMB. The deposits so far observed indicates mono-mineral potentials of any one of the precious minerals viz. Chrysoberyl / Chrysoberyl cat's eye / alexandrite / aquamarine with the remaining semi-precious stones. It implies that the pegmatitic body favours only one precious mineral, as per the geochemical affinities and the intensity of pneumatolysis. The remote plain areas within the vicinity of pegmatite dominated EGMB hilly terrains were thoroughly checked for the potential gem pockets in the colluvium. Many secondary bodies were identified in Andhra Pradesh and Orissa in this perspective. Mining for gemstones in the hard pegmatitic terrains is difficult, as separation of the valuable gemstones from the adjoining hard mineral zone

is not really possible, unless we cut the stone. Even to cut the stone, the hilly rocks have to be blasted and the net result is the powdered gemstone material. So, mining in the colluvium is suggested, where every gem mineral can be separated, picked, and washed easily.

The mineral 'alexandrite' must have formed at a very high temperature, when compared to the other precious minerals. The chemical composition of alexandrite is more or less the same as that of chrysoberyl, but constitutes a little amount of chromium impingment in its chemical structure, which results in green colored mineral.

Gemstone Resource Estimations

Gemstones are not new to Indians, where India was exclaimed as a 'Ratnagarbha' in the ancestral times and the present 'Golconda' (Hyderabad) was the centre for

gemstone trade in this country. After a few centuries, the same tradition has been continued in the country, where the present annual turnover of the gem and jewellery trade of India crosses about US \$ 20 Billion.

Considering the geology, field relations, structural features and lithological controls, geoscientific exploration was carried out in some of the important gem-bearing locations of Andhra Pradesh. Geological mapping, physiographic contouring, structural parameters, pitting, trenching, drilling and sampling were carried out, in addition to Electrical Resistivity surveys. The collected samples were categorized in the laboratory and characterized with their physical and optical parameters. The samples were also graded and the ratio of gemstone resource and the gangue was also determined. Reserves were estimated using cross-section methods. The gemstone concentration levels with different lithological units were also determined. The results are shown in Table. 2.

Government's Policies – Illegal Mining Activities

It is very well understood that a few precious stone varieties and many a semi-precious stones are available with the EGMB and there piled a history of 'geology and mining of gemstones' of 15 years. The first known gemstone incidence to the government was at Sambalpur (Orissa) during 1992 and Araku (Andhra Pradesh) during 1992-93. Mining of corundum, ruby and garnet was already active by that time at Khammam. It became a major issue to the governments of Andhra Pradesh and Orissa to control the un-lawful mining activities of the rural and tribal sections all along the EGMB and the news reached the headlines of all the leading national and international newspapers and magazines. Many illiterate men and women have been died in these illegal mining activities (Kasipathi and Rao, 2006), even though the government missionary comprising the revenue, police, forest, mines & geology and mineral development corporations have been vigilant day and night to stop the illiterate labour mobs and the government could not really control these activities and it is humanly impossible for any agency to stop it, as these workers have been maintained by some of the top gem businessmen.

Much of the vegetation of the Reserve Forests is vanished with the illegal prospecting operations of the illiterate rural and tribal folks and many of the labour were died in these activities. The green vegetation was completely scraped out by the labour for the sake of the precious gemstones. And the hilly regions lost their beautiful soil cover and made ugly, resulting rat holes everywhere in the EGMB. The iron and steel implements used in the illegal mining activities were made use of killing other workers of the same mining sphere. Many a common men became multi-billionaires and could earn a lot of properties. In nutshell, there is a lot of change in the life

style of many rural and tribal families and villages of EGMB, viz. Paderu, Araku, Dumbriguda, Narsipatnam, Eleswaram, Bhawanipatna, Elamanchili, Payakaraopeta, Addateegela, Karaka and Krishnadevipeta.

After a clear observation of the situation, the Government of Andhra Pradesh has sanctioned prospecting licences in parts of Visakhapatnam district to seven parties through Andhra Pradesh Mineral Development Corporation by public auction. The government could collect about Rs. 3.5 Crores through the auction and the royalties of the mined-out gemstone material in a span of 6-months period of prospecting and mining. In other words, the government has given a chance to the prospective agents and agencies to purchase the adjoining and surrounding gemstone-bearing prospective lands of the declared gemstone prospects and, there by, there is no free land available with the government and the rural locals for furtherance of legalized gemstone mining activities in these areas. Now, the gemstone-bearing areas are being given mining leases for systematic mining, which is very much welcoming for the prosperity of the gemstone mining and the associated small-scale lapidary industries. The government may immediately take up detailed gemstone exploration programmes in the entire EGMB, so that the correct potential locations can be recognized and the mining can be initiated by the government or by the private agencies. If it is done, a good amount of employment can be generated and the minimum infrastructural facilities will be resulted in the tribal areas.

Outcome of the Gemstone Province

1. Authorised systematic mining and ore dressing activities will be opened.
2. The government can collect good amount of revenue.
3. Required infrastructural facilities can be provided by the mining organizations.
4. Employment can be provided to the locals.
5. Major, minor and small-scale lapidary units will be established in the nearby cities.
6. A new gemstone (raw and cut) marketing and trade will be initiated in the nearby towns and cities.

CONCLUSION

To conclude the paper, the gemstone-bearing parts of Eastern Ghats Mobile Belt of Andhra Pradesh and Orissa, India forms a separate 'gemstone province' and their time and space relations have to be worked out in detail. The total gemstone reserves may be estimated, good amount of mining can be taken up, there by can provide a lot of employment, infra-structural development and mineral-based industrialization in the rural and tribal areas of this remote region.

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