GOVERNMENT OF INDIA

GEOLOGICAL SURVEY OF INDIA

MISCELLANEOUS PUBLICATION NO. 30

GEOLOGY AND MINERAL RESOURCES OF THE STATES OF INDIA

PART VII – Karnataka & Goa

Compiled By

OPERATION : Karnataka & Goa
Bangalore
2006

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SECTION-1

GEOLOGY AND MINERAL RESOURCES OF KARNATAKA

Chapter 1 : Introduction

The State of Karnataka constituted in 1956 includes the erstwhile princely states of Mysore, Coorg, Hyderabad and many tiny kingdoms situated within the geographic boundaries outlined by the major dominions, besides parts of Madras and Bombay presidencies. The state forms the west central part of Peninsular India between North Latitudes 11°35'30" and 18°25'30" and East Longitudes 74°06'00" and 78°35'30". It occupies an area of 1,91,792 sq.km of which 1,86,792 sq.km are covered by hard rocks consisting of crystallines and older sedimentaries and a narrow coastal strip of about 5,000 sq.km of Tertiary and Quaternary sediments.

The earliest account of the geology of parts now included within Karnataka were given by Christie and Capt.Newbold of the British East India Company. Robert Bruce Foote of the Geological Survey of India was the first to make a regional study. Geological mapping in most of the area of Mysore and Hyderabad states was carried out prior to 1950. Systematic geological surveys and studies in the erstwhile Princely State of Mysore, now forming the southern part of Karnataka were initiated as early as 1898, under the aegis of the Mysore Geological Department by V.S.Sambasiva Iyer, B.Jayaram, P.Sampath Iyengar, W.F.Smeeth, J.M.Maclaren, E.W.Wetherall and was continued by B.Rama Rao, C.S.Pitchamuthu, B.P.Radhakrishna and others. Investigations by these workers dealt with various aspects of classification of the schistose rocks and the granitoids, their mutual relationship vis-à-vis the gneisses. The northern part of the state which constituted a part of erstwhile Hyderabad State was mapped by Capt.L.Munn, S.K.Mukherjee, C.Mahadevan, L.S.Krishnamurthy, H.S.Krishnamurthy, Syed Kazim among others. These works are readily available in the Journal of the Hyderabad Geological Survey.

Besides these pioneer workers, doyens in Karnataka geology who contributed significantly to reach the present level of its understanding are C.S.Pitchamuthu, K.Naha, B.P.Radhakrishna, M.Ramakrishnan, S.M.Naqvi, to name a few.

A pool of eminent geoscientists of the Geological Survey of India have carried out systematic geological mapping on 1:1,26,720, 1:63,360 and 1:50,000 scales and also specialised thematic mapping on 1:25,000 scale. Exploration and assessment for a variety of mineral deposits was too taken up. Results of these studies are broadly classified and summarised in this volume.

Chapter 2 : Physiography

Karnataka can be divided into three well defined geomorphic regions viz., (1) the coastal plains on the west bordering the Arabian Sea, (2) the Malnad or mountainous region

comprising the Western Ghat and (3) the plateau region on the east. The coast line is straight and is about 400 km long. The coastal plains rarely exceed 30 km in width. To the east of the coastal plain, the Western Ghats forming the sub-continental water divide rise precipitously in a series of scarps and terraces towering more than 1000 m above m.s.l. within a short distance from the coastal plain. The Western Ghats trend NNW-SSE parallel to the west coast and have an average width of about 40 km. They are dotted with high peaks, viz., Kudremukh (1884 m) and Mulaingiri (1912 m) in the Bababudan hills.

The Western Ghats grade into the plateau region towards east. This plateau is the southern extension of the Deccan Plateau with an average elevation of about 650 m with a series of narrow, linear ridges and hill ranges of schistose rocks and bouldery granitoid hills.

The state is drained by three major easterly flowing river systems. These are : (1) Manjira River of the Godavari basin in the north, (2) Krishna with its tributaries, Tungabhadra, Ghataprabha, Malaprabha, Bhima and Vedavati draining the northern and central part and (3) Cauvery with its tributaries, Kabini, Hemavathi, Simsha and Arkavati draining the southern part.

Besides the easterly flowing river systems, there are several westerly flowing streams with short, straight and steep courses. The most prominent of them are : Kalinadi, Sharavati and Netravati.

Most of the river courses are principally aligned in two directions: (1) ENE-WSW to WNW-ESE, (ii) north-south to NNW-SSE and correspond to the major lineaments, faults, shear zones and joints. Many of the major rivers, particularly the west flowing rivers and some sections of all the east flowing rivers have straight courses and sharp turns suggestive of strong structural control on the drainage pattern.

There are a number of rapids, cascades and waterfalls along the major rivers. The well known among them, are the Jog Falls on the Sharavati River and the Sivasamudram Falls on the Cauvery River.

The state experiences humid Tropical to Semi – Arid climate for most part of the year. The annual rainfall is about 300 to 500 cm in the coastal plains and the Western Ghats and about 80 cm on the eastern plateau. The Western Ghats are thickly forested. The plateau is generally devoid of dense forest.

Chapter 3 : Geology

Karnataka forming a part of the Indian Shield is constituted of rock formations ranging in age from 3300 m.y. to 5 m.y. Barring a narrow coastal strip of about 5000 sq.km of Tertiary and Quaternary sediments and another 31,250 sq.km of Deccan basalts, the remaining area is dominated by Archaean-Proterozoic rocks. Mysore Plateau,

geologically constituted of Dharwar Craton comprises of greenstone-granite belts, gneisses and granulites. Greenstone belts essentially consist of meta-volcano-sedimentary sequences, surrounded and dissected by Peninsular Gneiss. At the southern end of the craton these give way to granulite suite of rocks. The craton preserves a billion year orogenic history from 3400 m.a. to 2400 m.a. Epicratonic or intracratonic sedimentary basins called Purana Basins occupy the northern segment of the craton whose northern part in turn is concealed by Deccan basalts. Thus younging of lithosequence from south to north is evident.

Generalised regional lithostratigraphy worked out for Karnataka, is presented below, followed by a brief description of major groups.

Table-I

GENERALISED REGIONAL STRATIGRAPHY OF KARNATAKA

Eon/Era/Epoch	Suite/Assem-blage Supergroup	Group/Formation and other lower ranks	Lithology
WESTERN BLOCK			
Recent			Alluvium/soil
Quaternary			Undifferentiated fluvial/coastal sediments; transported red soil/ alluvium
Neogene			Laterite
Mio-Pliocene		Warkhali Beds	Sandstone, clay, marl and limestone.
Late Cretaceous To Paleogene 67-65 ma		Deccan Trap	Continental flood basalt of tholeiitic chemistry; inter-trappean beds of chert & marl
Neo Proterozoic 900-540 ma		Bhima Group	Predominantly Mg poor carbonate sequence with shale; sandstone and conglomerate at the base
Neo Proterozoic ≈ 800 ma		Chamundi granite	K-rich porphyritic to homophanous granite
Meso-Neo Proterozoic 1600-1000 ma	Kaladgi Supergroup	Badami Group Bagalkot Group	Horizontally bedded multistorey sequence of arenite; shale and limestone in lesser amounts Two mega cycles of repeated sequence of argillite followed by chemogenic precipitates predominantly of sandstone and dolomite; quartzites and conglomerates forming the base

Eon/Era/Epoch	Suite/Assem-blage Supergroup	Group/Formation and other lower ranks		Lithology
Palaeo-Proterozoic 2530-2450 ma	Closepet Granite			Alkali granite, monzogranite/adamellite to granodiorite
			Ranebennur Subgroup	Greywacke/BIF/ polymict conglomerate/ volcanics (Mardihalli, Bellara, Medur)

Late Archaean to Palaeo-proterozoic To Late Archaean 2900-2600 ma	Dharwar Supergroup	Chitradurga Group 2700-2600 ma	Vanivilas Subgroup	Polymict conglomerate, cross bedded quartzite, pelite, stromatolitic carbonates, biogenic chert, BIF & manganese formations (Ingaldhal volcanics-thoeliitic basalt-rhyolite suite (Tekkalvatti, Jagar))
		Bababudan Group 2900-2800 ma		BIF & carbonaceous phyllite, basalt-dacite suite (locally pillowed) with minor ultramafics/ alternations of amygdular basalts/cross bedded quartzites, pelite/minor BIF/basal quartz pebble conglomerate
Late Archaean <3000 ma	Peninsular Gneiss-I			Tonalite-trondhjemite-granodiorite
Middle Archaean 3000 ma		Charnockite Group		Metamorphic equivalents of earlier formed rocks
Middle Archaean >3000 ma		Sargur Group		Ultramafic-mafic intrusive complex (Holenarsipur-Nuggihalli)/ serpentinised komatiites, komatiitic and thoeliitic amphibolites, chert, BIF/garnet-biotite schist (with kyanite, sillimanite and staurolite)/local marble and calc sillicates/fuchsite quartzite with chromite and baryte layers
Lower to middle Archaean ≈ 3400 ma	Older Gneiss	Gorur Gneiss/ Hunsur Gneiss		Trondjhemite, granodiorite, grey banded biotite ortho gneiss

EASTERN BLOCK

Eon/Era/Epoch	Suite/ Assemblage Supergroup	Group/Formation and other lower ranks	Lithology
Late Archaean ≈2600 ma	Peninsular Gneiss-II		Juvenile granodioritic to granitic material-all enclosing the true greenstone belts within the younger phase.
Late Archaean ≈2700 ma		Greenstone belts, viz. Kolar Sandur Raichur Hutti Mangalur Hungund-Kushtagi-Hagari	Grit/arenite, pelite/ BIF Bimodal mafic-felsic volcanics Pyroclasts, volcanic conglomerate, BIF local komatiites (main unit in all belts) Quartzite (locally cross bedded), mangan marble, stromatolitic carbonate, calc silicate, cordierite bearing pelite, amphibolite, BIF (Sakarsanahalli, Lepakshi)

Further elaboration on the individual litho-assemblage in the following pages is given suite wise and not strictly in their chrono-stratigraphic order.

Sargur Group

Large scale, mega enclaves of high grade schistose rocks, south of Mysore around Sargur and in its adjacent areas were considered to be a distinct stratigraphic entity and older. These litho-assemblages are considered to be equivalent to the Dharwarian event by another school of workers. The important belts of western greenstone include Sargur (type area), Holenarsipur, Nuggihalli, Aladahalli, Kalyadi, Krishnarajpet, Ghattihosahalli (see Table-II). The main litho-components in the Sargur belt are meta ultramafites and are altered variants such as serpentinised komatiite, talc-tremolite schist, amphibolite and high grade metapelites such as fuchsite quartzite, kyanite-sillimanite schist, carbonates and banded iron formation. Other belts too have similar litho constituents.

Peninsular Gneissic Complex and Charnockite

Peninsular Gneissic Complex (PGC): Foote (1886) considered the granitic-granodioritic-tonalitic gneisses forming a part of the Dharwar Craton to be the basement and called them 'Fundamental Gneiss', that occupy the cores of anticlines, with the supracrustal rocks of Dharwar Supergroup exposed in synclinal keels. Later workers differed with this view and considered it younger to Dharwar. According to Rama Rao

(1940) and Pitchamuthu (1982), Peninsular Gneiss has a protracted evolutionary history extending over a period of time and therefore has no stratigraphic significance.

The mineralogical characters of the gneiss vary greatly and dependent on the adjacent greenstones it has migmatised. Therefore this rock suite is said to be composite gneiss, formed by migmatisation of supracrustals in different phases at different stratigraphic levels (Naha et.al 1993). Most common variety of Peninsular Gneiss-I consist of quartz, microcline and oligoclase with traces of muscovite, apatite and zircon in the leucocratic part; biotite, hornblende and epidote by and large form the melanocratic component. Peninsular Gneiss-I is characterised by low K_2O. The Na_2O/K_2O ratio, more than 1 and initial $^{87}Sr/^{86}Sr$ ratio less than 0.7014 suggest that they are mantle derived orthogneiss.

Components of Peninsular Gneiss always show isoclinal folds with thinned limbs and stretched hinges defined by compositional banding. Viscosity contrast between the quartzo-feldspathic layers and amphibolite mass under the compressive forces have caused a variety of structures. Ptygmatic folds in quartzo-feldspathic materials, agmatitic structures are the few common forms. Though extensively remobilised and repeatedly migmatised showing the presence of remnants of original basement components such as Gorur Gneiss of 3400 m.y. (Radhakrishna, 1983), Peninsular Gneiss is considered as the basement for the entire greenstones.

Peninsular Gneiss thus consists of a complex of different types of granitic rocks – true plutonic acid intrusions, granitised older crystalline rocks, migmatites or mixed composite gneisses and possibly unrecognised portions of the primitive crust and granitic rocks on which the rocks of Dharwar Super Group were deposited. However, based on the radiometric ages, at least three major accretionary events viz., older gneiss, forming the sialic basement for Sargur as recorded at Gorur and Hunsur, PGC-I, the major constituent of the basement rock in the Western Craton on which Dharwar Supergroup have been formed and the youngest event PGC-II on the Eastern Craton, to the east of Closepet Granite were broadly identified and depicted in the enclosed Plate-I accordingly.

Charnockite:

These are essentially blue quartz-hypersthene bearing granular suite of rocks now broadly referred to as pyroxene granulite. These are confined to a 30 km wide transition zone between the low grade gneissic terrain in the north and high grade granulite terrain to its south. They occupy Biligiri Rangan hills, Male Mahadeswara hills in Mysore District, southern segment of Coorg District, set in a regional trend of northwest to southeast. These isolated massifs of charnockite are said to be the product of later regional thermal metamorphism with fluids driven from deeper part of the crust playing a vital role in its transformation. Charnockite with protoliths of younger age of 2600 Ma is recorded from the greenstone-granulite transitional zone of Kabbal-Kushalnagar areas.

Greenstone Belts

Greenstone belts of Karnataka attracted the attention of geological community, both for its complex geological history and rich mineral resources. The era of 2900 million years to 2600 million years witnessed this great event of the evolution of Greenstone belts in Karnataka. Stratigraphic level vis-à-vis geochronological positioning of different schist belts had always been a point of endless yet useful debate.

Large scale, mega enclaves of high grade schistose rocks, south of Mysore around Sargur and in its adjacent areas were considered to be a distinct stratigraphic entity and older in age. These litho-assemblages are also considered to be equivalent to that of Dharwarian event by another school of workers. The entire schistose rocks of Karnataka are broadly grouped into Eastern block true greenstone belts, Western block schistose belts. These two blocks are separated by the Chitradurga boundary fault near the western margin of Closepet Granite. The later is further divisible into belts of green schist facies and of higher grade amphibolite facies as shown under:

While describing the greenstone belts of Karnataka (1) Western block (Dharwar), (2) Western block (Sargur), (3) Eastern block (Dharwar), (4) Transitional belts are dealt as per the recent classification given by Ramakrishnan (1994).

Litho-assemblage of western greenstone block of Dharwar Supergroup is divided into lower Bababudan Group, largely consisting of volcanic suites with shelf/platformal meta-sediments rich in iron and manganese precipitates; and the upper Chitradurga Group, that is largely made up of sedimentary sequence of argillite-greywacke assemblage with meta-sediments in lesser quantities. Presence of ortho-conglomerate units at the base of Bababudan at many places demonstrates a major hiatus. A number of oval or rounded gneissic/granite bodies occur within the Dharwar Supergroup, such as at Sirankatte. These bodies are considered to be mantle gneiss domes.

Table-II

IMPORTANT GREENSTONE BELTS OF KARNATAKA CRATON

Western Greenstone Belts-Western block (Sargur)	Low grade greenschist facies belt-Western block (Dharwar)	Eastern greenstone belts- Eastern block (Dharwar)
1	**2**	**3**
i. Sargur	i. Western Ghat	i. Kolar
ii. Holenarsipur	ii. Kudremukh	ii. Hutti
iii. Nuggihalli-Aladahalli-Kalyadi	iii. Shimoga-Goa	iii. Raichur
iv. Krishnarajapet (K.R.Pet)-Hadanur	iv. Bababudan-Chikmagalur	iv. Gurgunta
v. Ghattihosahalli	v. Chitradurga-Gadag including Javanahalli	v. Mangalur
vi. Nagamangala-Mayasandra	vi. Holenarsipur	vi. Hagari-Hungund-Kushtagi
vii. Jayachamarajapura (J.C.Pura)	vii. Sigegudda	**Transitional belts in Eastern block**
		i.Sandur belt
		ii. Javanahalli belt
		iii. Huliyurdurga-Kunigal belt
		iv. Small belts of Ghataparthi, Parasurampur, Saggere, Bidalotti and Hesseraghatta enclaves at the margins of Closepet granite.

(Geographic names adopted from where the belts are well formed)

These belts do not show any stratigraphic position but denote only their geographical disposition.

TABLE-III

GENERALISED LITHOSTRATIGRAPHY OF DHARWAR SUPERGROUP
(Swami Nath and Ramakrishnan, 1981)

Group	Formation (as in the type area)	Litho-assemblage
	Hiriyur	Predominantly greywacke with Fe-Mn chert; polymict conglomerate
Chitradurga Group of Chitradurga belt	Ingaldhal	Quartz-chlorite schist, argillite with Fe-Mn chert and metabasalt
	Vanivilas	Fe-Mn formations, carbonates, phyllite and quartzite with conglomerate at the base
Dharwar Supergroup	------- Unconfirmity -------	
	Mulaingeri	Fine clastics, predominantly with chemical sedimentation
Bababudan Group of Bababudan belt	Santaveri	Bimodal volcanics, quartzite in subordinate amounts
	Allampur	Quartzite with basic igneous rocks
	Kalasapura	Basic volcanics with quartzite and conglomerate at the base

Litho assemblage of the eastern belts can be categorised in association with greenstone suite an immature platformal sedimentary sequence with the later consisting of quartzite, meta-pelites, marbles and banded iron formation and occur at the migmatised margin of Kolar belt. The greenstone suite consists of bimodal mafic-felsic volcanics, and pyroclastics are mainly seen in Hutti and Mangalur belts. Immature sediments are mainly exposed in Hungund and Hagari belts. Eastern greenstone belts are predominantly

composed of meta-volcanics, and meta-sediments in subordinate amounts. The peripheral zones are exclusively migmatised by the younger phase of Peninsular Gneiss, hence the basement-cover relationship remains ambiguous. Characteristically these belts are endowed with gold mineralisation.

Sandur belt sandwiched within the Closepet Granite is unique in the sense, it is a transitional belt between the Eastern and Western blocks, having the litho-assemblage affinity of Bababudan type, but geographically located towards the eastern segment.

Peninsular Gneiss of younger phase having granodiorite to granite composition dating around 2600 million years enclose all these narrow greenstone belts in the Eastern block. These gneissic rocks are essentially remobilised/reworked ancient gneissic crust with plenty of subsequently accreted crust.

Three phases of deformational episode were found to be common in all these rock suites described so far (Naha, et.al. 1996).

i. Isoclinal folds of first generation (F_1) are co-axially folded into open folds (F_{1a}) imparting the regional schistosity.

ii. The earlier folds have been involved in upright folding of varying tightness (F_2) with the axial planes trending nearly N-S/NNW-SSE/NNE-SSW, imparting the present trends to the greenstone belts.

iii Later warps (F_3) with axial planes striking nearly E-W, which accentuated the variation in the plunges of F_2.

Closepet Granite

A 500 km long north-south trending linear belt of granite body rich in potash feldspar is named 'Closepet Granite'. This belt with an average width of 20 km extends from Bilgi in the north, forming the basement to Kaladgi Supergroup upto Sivasamudram in the south. Closepet is the old name for Ramnagaram in Mysore district, which is the type area. Closepet Granite is constituted of a cluster of individual plutons or plugs of different sizes, emplaced along the suture zone welding the eastern and western blocks of Dharwar Craton (Swami Nath and Ramakrishnan, 1981).

By and large, Closepet Granite is composed of pink and grey coarse grained porphyritic granite, it is determined to be around 2500 million years old.

In contrast to the earlier view of its magmatic and intrusive nature, potash metasomatism of the deeper crustal rocks is said to be responsible for its formation. Its other equivalents such as Chitradurga Granite, J.N.Kote Granite, Hosadurga Granite, Karwar Granite and Banawara Granite are considered to be co-eval and are found to have similar composition, texture and geological history.

Another minor yet important event in the geological history of Karnataka is the emplacement of anorogenic stock-like bodies of pink granite called Chamundi Granite 800 million years old. They are said to be the youngest plutons reported so far in Karnataka.

A few classical orbicular granite/diorite bodies are also recorded from Raichur and Koratagere areas (Srikantia et al, 1994; Prakash, 1996).

Mafic-Ultramafic Complexes

The mafic-ultramafic rocks occur as a group of lenses, enclaves and narrow elongate bands, at different stratigraphic positions. They are:

i. **Ultramafics of Sargur type:** These occur as enclaves with a few tens of kilometers length and 2 km width in association with the high grade metapelites, in the southern parts of Karnataka. They typically comprise serpentinite, usually altered to actinolite-tremolite-talc-chlorite schist. Such bands reported around Banasandra, K.R.Pet, Nagamangala and Nuggihalli are rich in MgO with komatiitic chemistry exhibiting pillow structure and spinifex texture showing their extrusive origin. The other layered mafic-ultramafic complex with early phase chromite and late phase Ti-V magnetite with tholeiitic affinity indicated their intrusive origin. Thus in the Sargur belt, both extrusive and intrusive, mafic-ultramafic complexes are recorded.

ii. **Younger basic pluton-intrusive into the PGC:** A basic pluton of gabbro-norite-anorthosite traversed by basic dykes is recorded from Konkanhundi area from south of Mysore (Ramakrishnan and Mallikarjuna, 1976). PGE mineralisation has been recorded from this basic plutonic variants and dyke rocks.

ii. **Ultramafic of Dharwar type:** These include layered gabbro (with titaniferous-vanadium bearing magnetite, peridotite, pyroxenite and dunite with chromite lenses. They show intrusive relationship with the lower sequences of Chitradurga Group. These bodies are seen around Masanikere-Tavarakere-Magyathahalli in Shimoga district.

All these ultramafic bodies seem to have been emplaced during different orogenic episodes along a mantle controlled arcuate zone (Ramakrishnan, et.al. 1978). This arcuate zone extends from south of Mysore upto Goa and even beyond for hundreds of kilometres and consists of a series of lenses and belts of chromiferous serpentinite, meta-pyroxenite, gabbro, anorthosite containing prominent bodies of titanomagnetite.

Dyke Rocks

Dyke of both mafic and felsic composition and of various dimension and age criss-cross all the major litho types of Karnataka, while the mafic dykes are ubiquitous, felsic varieties are confined to southern parts of the State. These are the manifestations of the crustal extension and fractures along which these materials were emplaced. In chronological terms, these dykes could be grouped as:

i. Older metamorphosed varieties of >2600 million years old, mainly confined to the transitional zone between low grade greenschist terrain to the high grade granulite in southern Karnataka. These dolerites are rich with clouded feldspars which could be due to effects of regional thermal metamorphism.

ii. Younger unmetamorphosed dolerite to gabbroic dykes formed later to Dharwar event. Their general trend is ENE-WSW. Dyke swarms of this group are seen near Hunsur, Arsikere, Banavara, north of Chitradurga and around Kunigal.

iii. Felsite, alkaline and porphyry dykes are seen around Srirangapatna and Bidadi. These varieties are considered to be the youngest and related to plutonic activity of Chamundi Granite dating 800 million years.

Subsequent to the accretion of many microplates and the collision of western block with the eastern block of Dharwar Craton along a N-S trending suture, roughly demarcated by the eastern thrust margin of the Chitradurga belt, southern part of Karnataka is said to have been cratonised; no further major activities were witnessed but for the last mentioned dyke intrusions and emplacement of anorogenic granites. However, the northern part of Karnataka, after a long repose of more than 1000 million years, witnessed a few more important geological events.

Proterozoic (Purana) Basins

The north and northeastern segments of Peninsular India witnessed orogenic event of MesoProterozoic Mobile Belts, involving the subduction of the margins of plate boundaries, these compressive forces were complemented by intraplate extensional tectonics resulting in the formation of a series of intracratonic basins, viz. Kaladgi (Bagalkot and Badami) and Bhima. These sedimentary basins are popularly known as Purana Basins and the hiatus involved is called Eparchaean Unconfirmity in the Indian Geological Literature. On the basis of the imprints of diastrophism, these basins can be broadly classified into an older group that underwent buckling deformation by compressive forces, i.e. Bagalkot Basin and the younger group that were subjected mainly to faulting deformation i.e. Badami and Bhima basins.

Kaladgi Supergroup (earlier known as Kaladgi Series) is divisible into two groups, the Lower Bagalkot Group and the Upper Badami Group separated by a disconformity. These sedimentary sequences occupy an area of 8300 sq.km spreading in parts of Bijapur and Belgaum districts. Their total aggregate thickness measure around 4500 m

(Jayaprakash et al, 1987). Bagalkot Group has been further sub-divided into two Subgroups, viz. the Lower Lokapur and the Upper Simikere. They consist predominantly of carbonates and argillites with siliciclasts in lesser quantity. Badami Group of sediments are found as a vast expanse of horizontally bedded ferruginous arenites from the northwestern tip of Raichur district, spreading over Bijapur and Belgaum districts and beyond into Maharashtra State; argillites and carbonate precipitates too occur, but as small and isolated outcrops in the central part of the basin. To its east lies the Bhima Group of sediments which are essentially rich in limestone sequence interbedded with argillites with less developed arenites and rudites marking the base of the basin. This group of sediments are confined in the southern parts of Bijapur and Gulbarga districts and further east extends into Mehaboobnagar district of Andhra Pradesh. Bagalkot Group of sediments have undergone two sets of folding deformation, accompanied by low grade metamorphic effects leading to recrystallisation of limestone, development of quartzitic texture in arenaceous units and schistosity in certain argillites. Based on their morphological characters, the age of Bagalkot sedimentation could be roughly put to be of Meso-Proterozoic (1600-1000 million years).

Deccan Trap

Flows of Deccan basalts occupy an area of 31,500 sq.km. covering the entire Bidar district, parts of Belgaum, Bijapur and Gulbarga districts. Their maximum thicknesses are estimated to be of the order of 600 m, spreading to a total number of 31 flows. By and large these continental flood basalts are tholeiitic in composition and exhibit flow characters of both "Aa" and "Pahaehoe" types. Integrated geomagnetic, geochemical tectonic and radiometric studies indicate the age of their outpouring was in the range of 65 to 67 million years (Courtilott, et al 1986).

Warkhali Beds

Beds of shelly limestone, clay and grit, intercalated with lignite layers are recognised in the southern coastal tracts of South Kanara district, these quasi-indurated sequence of sediments are considered to be the extension of Warkhali Beds occupying further south of Kerala. These Miocene beds are about 20 m thick and unconformably overlie the weathered gneisses and charnockites and are capped by laterites. Warkhali Beds are not depicted in the accompanying map due to cartographic constraints.

Laterites

The majority of the rock sequences of Karnataka are lateritised due to their exposure to suitable climatic conditions for a prolonged period. These laterites occur as extensive cappings in the Western Ghats and in coastal plains. Their thickness ranges from a few cm to as much as 60 m. Based on their elevation level, two types are identified, one at +600 m elevation confined to Western Ghats and the other fringing the coastal lines along the west. The later type is gravelly to sandy in texture and appears to be transported, whereas those confined to Ghats are homogenous and less sandy.

In the hinter land of southern Karnataka also vast tracts of laterite are reported in the north and northeastern part of Bangalore district and in parts of Kolar district. In the Deccan Plateau region, thick carpet of laterite capping the Deccan basalts and sandstones of Badami sequence are a common feature.

Lateritisation is considered to have taken place during Pliocene-Pliestocene period since the Warkhali Beds of Miocene too were lateritised.

Quaternary Formations

Quaternary formations occur as a narrow long strip all along the West Coast from Mangalore to Karwar, covering an area of about 5000 sq.km. Sand blankets, loamy soil, transported lateritic red soil are some of the major constituents of the Quaternary units. They are of Pleistocene to Holocene in age.

Recent Alluvial Soil and River Alluvium

Vast blanket of river alluvium, in the rivers Ghataprabha, Mallaprabha, Krishna, Tungabhadra, Cauvery and their tributaries constitute the economically important youngest geological units in Karnataka. Transported black clayey soil or black cotton soil spreading over the sedimentary units in parts of Gulbarga and over the basement rocks in parts of Raichur, Bellary and Belgaum districts occupy a pre-eminent position in their agrarian utility, thus underscoring its socio-economic significance.

Chapter-4 : Structure

The most striking feature of the greenstone-granite terrain is the disposition of the schistose formations as sub-parallel curvilinear belts whose regional trend swings from N-S in the southern part to NW-SE in the northern part. The other most readily recognisable feature is the pervasive, penetrative planar fabric (schistosity/foliation) defined by the preferred parallel orientation of platy and prismatic minerals, such as chlorite, mica and amphiboles, developed in varying degrees in the metamorphosed volcano-sedimentary rocks and in the migmatitic gneisses. The regional trend of the foliation is parallel to the regional trend of the greenstone belt. Thus, the parallel alignment of greenstone belts and concordant fabric elements in the schistose formations and migmatitic gneisses point to similar structural evolution of these rocks.

Folds

The regional fold closure at the south and fanning out of supracrustal rocks to the north, suggest that the regional structure is a northerly plunging synclinorium. There is increase in metamorphic grade to the south in conformity with this structure. The regional synclinorium causes older stratigraphic units to be exposed progressively southwards.

Three phases of folding events are clearly recognisable. The earliest folds (F_1) are tight, isoclinal with thickened hinges and thin drawn out limbs; these are generally rootless and of mesoscale. The first folding event was accompanied by the development of penetrative cleavage/foliation/schistosity (S_1) and greenschist to lower granulite facies metamorphism at different crustal levels.

The second folding deformation (F_2) is denoted upright folding which have rotated the earlier folds and S_1 foliation and has resulted in the development of crenulation /close spaced fracture cleavage (S_2). Most of the major fold hinges with N-S to NW-SE trending axial planes are due to F_2. F_1 and F_2 are nearly co-axial.

The third phase of folding (F_3) was of lower intensity, producing broad open folds and warps on transverse axial planes, i.e. ENE-WSW to WNW-ESE directions. The E-W to NE-SW swing in the alignment of the greenstone belts as seen in the Gadag belt can be attributed to this folding episode.

The Bhimas and the Deccan volcanics are mostly horizontal with occasional gentle undulations, the Kaladgis have been folded into open, upright anticlines and synclines on E-W trending axial planes and weakly refolded on N-S axial planes.

Shear Zones, Faults and Lineaments

Joints and brittle to ductile shear zones mostly parallel to the axial planes of F_2 and F_3 folds are noticed in the greenstones. Shear zones parallel to axial planes of F_2 host gold mineralisation in Kolar Gold Fields, Hutti, Gadag and Javanahalli belts. Shear zones and faults trending ENE-WSW to WNW-ESE have affected not only the greenstone belts, but also the gneisses and younger granites. The near E-W trending faults have affected Purana Basins and Deccan flows. The precipitous scarps of the Western Ghats and the straight coastline have been generated by a series of step faults in NNW-SSE direction.

Some of the major lineaments, which could be deep seated faults/shear zones, have been deciphered from the study of aerial photographs and imagery. These are:

i. WNW-ESE – Cauvery lineament
ii. ENE-WSW – Krishna lineament
iii. ENE-WSW – Vedavathi lineament
iv. NNW-SSE – Tunga-Hemavathi lineament

v. N-S – Arkavathi lineament
vi. ENE-WSW – Dharwar-Tungabhadra lineament
vii. NE-SW – Lakshmanthirtha lineament
viii. ENE-WSW – Kabini Lineament
ix. ENE-WSW – Kumadvati-Narihalla lineament
x. NNW-SSE – Kaiga-Mothimakki lineament

Chapter 5 : Mineral Resources

Karnataka State occupies the premier position with regard to the known resources of gold, manganese ore, magnetite and limestone in the country. The percentage of the total resources contributed by the state being 64% for gold, 36.5% for manganese ore, 80% for magnetite and 22.5% for limestone. Karnataka has substantial resources of haematite, bauxite, chromite, dolomite, quartz and silica sand alongwith various types of clay, fuller's earth, titaniferous/vanadiferous magnetite and talc, steatite (soapstone). Resource evaluations done by GSI for important commodities are given in the respective subheads.

TABLE-IV

Mineral production in Karnataka for the year 2002-03
(excluding Atomic Minerals)

Data from IBM Year Book-2003

Commodity	Production 2002-03	
	Quantity	Value in '000 Rs.
All Minerals		10642762
Bauxite	29529	3425
Chromite	19139	30825
Gold ore	544378	-
Gold	2705	1232303
Iron ore	24044	7641457
Manganese ore	222899	164462
Silver	270	2145
Clay (others)	-	-
Dolomite	166967	22593
Dunite	11515	691
Feldspar	6288	1967
Fire Clay	11296	2427
Felsite	1094	723
Kaolin	14978	10655
Kyanite	297	163
Laterite	-	-
Limestone	12181	868858
Limeshell	87712	37824

Magnesite	17179	17747
Ochre	34349	4793
Quartz	2973	465
Silica Sand	91213	6595
Shale	488810	9163
Steatite	1892	123
Minor minerals	-	583358

Exploration for mineral deposits is being carried out in Karnataka by the Geological Survey of India, Directorate of Mining & Geology, Government of Karnataka, the Atomic Minerals Directorate for Exploration and Mineral Exploration Corporation Limited and many new private firms have initiated exploration in these areas. Based on the data available from the work carried out by these organisations, a brief account of the mineral resources/occurrences of Karnataka is presented below:

Antimony

Stibnite and its altered product cervantite occur as disseminations in the quartz veins traversing metabasalt and greywackes at Chikkonahalli and G.R.Halli in the Chitradurga district. Recently stibnite bearing quartz veins have been reported near Dinnisamudra in the Hutti-Maski schist belt, Raichur district.

Asbestos

Asbestos, mainly the anthophyllite and tremolite variety with some chrysotile and amosite occurs in a large number of localities in Bellary, Bijapur, Chikmagalur, Hassan, Mandya, Mysore, Shimoga and Tumkur districts. The anthophyllite-tremolite and chrysotile varieties are associated with serpentinites and the amosite variety occurs as layers in Banded Iron Formation.

Hassan district: Anthophyllite-tremolite variety occurs in the Holenarsipur schist belt in a zone about 30 km long and 1 km wide. The asbestos veins range in width from 2 to 30 cm and occur along (i) the contact of serpentinite and actinolite-tremolite schist (ii) axial planes of minor folds and (iii) irregular fractures.

The other noteworthy deposits are situated near Yedegondanahalli, Tirumalapur, Mangalapur and Kabur.

Amphibole asbestos has also been recorded from Yerabalu in Bellary district, Yelagatti in Bijapur district.

No major chrysotile asbestos occurrences are known. Minor occurrences have been reported from Amrutapura and Dodda Kundur in Chikmagalur district; Yedegondanahalli, Tirumalapur and Tagadur in Hassan district; Gopalapura, Mavinahalli area of Mysore district, Banasandra in Tumkur and Bhadra Reservoir area in Shimoga district.

Chikmagalur district: Amosite bands from serpentinite alternating with magnetite bands of Bababudan Group ranging in width up to one centimeter are seen as discontinuous lenses and pockets of varying concentrations (average 3.5%) over a length of about five kilometers between Kavikalagandi and Manikyadhara Falls in Chikmagalur district. This deposit is being mined by M/s.Hyderabad Asbestos Cement Products Ltd.

Amosite occurrences have also been recorded from the Kodachadri hills, Shimoga district and Yerabalu, Bellary district.

Barytes

Chitradurga District : Thin bands and lenses of barytes upto 1 m wide and 200 m long occur in association with the fuchsite quartzite bands of Sargur Group in the Ghattihosahalli and adjacent areas.

Mysore District : Thin layers and interbeds of barytes within sillimanite quartzite have been reported near Kundur.

Bijapur District : Barytes is reported to occur near Mudhol in association with chert bands of the Kaladgi Group.

Gulbarga District : Impersistent and thinly bedded and nodular barytes of sedimentary origin have been reported in the middle shale beds of Bhima Group of rocks in the area around Katamdevarahalli.

Basemetals (Copper, Lead and Zinc):

Only a few small low grade deposits of copper are known from Karnataka. But a number of occurrences of basemetal mineralisation, particularly copper mineralisation have been recorded. The deposits / occurrences are seen in various geological setting viz.,

i) in association with the greenstone belts of the Dharwar Supergroup.

ii) in association with sheared quartz veins and metabasic rocks traversing the granitoids,

iii) in association with ultramafic complexes and

iv) in the schist belts occurring as enclaves within the Peninsular Gneissic Complex.

Chitradurga District :

A belt of polymetallic sulphide mineralisation with a copper, lead, zinc, antimony, arsenic, gold and silver, has been traced over a strike length of about 40 km, along the

eastern part of the schist belt. This mineralised belt designated as the Chitradurga sulphide belt, extends from Chikkahonnanahalli in the north to Yarahalli in the south.

Copper mineralisation is prominent in the Belligudda-Ingaldhalu-Kunchiganahalu sector over a strike length of about 5 km. The Ingaldhalu mines is located in this sector. At Ingaldhalu, chalcopyrite with minor pyrite, pyrrhotite, galena and sphalerite occur as disseminations, stringers and fracture fillings in quartz veins occupying narrow shear zones in the meta-basalts.

The Belligudda-Ingaldhalu-Kunchiganahallu section has been explored by drilling, jointly by GSI and the Dept. of Mines and Geology, Govt. of Karnataka. On the basis of drilling data and the mine development data, reserves of 2.14 million tonnes with an average copper content of 1.22% are estimated in the mine blocks, northwest and northeast block.

The copper ores also carry considerable silver and gold content.

Gulbarga and Raichur Districts :

There are a number of prospects located in granitoid terrain near Kallur, Machanur and Antraganga of Raichur district. In these prospects chalcopyrite and pyrite occur in brecciated and sheared quartz veins and/or metabasic rocks emplaced along nearly E-W or N-W trending shear zones.

In Raichur district a total of 2.47 million tonnes of copper ore with 0.83% of Cu and 1.91 million tonnes with 0.95% of Cu were estimated in Kallur and Machanur areas respectively. Reserves in Tinthini is estimated to 1.85 million tonnes with 0.60% of Cu.

Hassan District :

In the Nuggihalli schist belt, sulphide mineralisation of pyrite with subordinate pyrrhotite and chalcopyrite associated with titaniferous magnetite bands is seen near Nuggihalli, Belagumba and Tagadur. The copper mineralisation in these areas is generally poor with less than 0.5% Cu but is observed over considerable widths of upto 18.5 m.

Kalyadi Copper Deposit : Mineralisation is associated with folded and sheared quartzites of Sargur Group which occur as enclaves in the migmatitic gneisses. The ore zone has been explored by drilling jointly by GSI and Dept. of Mines and Geology, Govt. of Karnataka. The drilling has established the ore body over a strike length of 500 m down to a depth of 250 m. Mine development indicates that the ore body ranges in width from 5.60 to 26.31 m (average 14.34 m). The average copper content in the various 6 levels ranges from 0.59 to 1.03%. Indicated reserves are placed at 3.8 million tonnes.

In Aladahalli a 12 km long, NW-SE trending high grade pelitic schist enclave within the Peninsular Gneissic Complex has been traced from Ugranahalli to Bhaktarahalli chalcopyrite-pyrite-pyrrhotite mineralisations occur in micaceous chlorite. On the basis

of drilling, reserves of 1.94 million tonnes with 1.15% Cu have been estimated. Some zinc values are associated with the ore in the Bhaktarahalli and Mangalapura blocks.

Shimoga District :

In the Masanikere-Tavarekere-Magyathahalli areas, copper mineralisation (pyrite and chalcopyrite) is seen in the magnetite gabbro occurring in the basal part of gabbro-anorthosite complex intruding the Chitradurga Group of rocks. Copper is concentrated in the magnetite gabbro and vanadiferous titaniferous magnetite bands. Copper content ranges from 0.3 to 1.56%.

North Kanara District :

In the Kaiga-Mothimakki area, sulphide mineralisation is found in the pyroxenite, peridotite and gabbro which constitute the ultramafic complex. Pyrrhotite is the dominant sulphide with pyrite (cobalt-bearing) while chalcopyrite is present in subordinate amounts. Marcasite, pentlandite, bismuthinite and rarely native gold are also recorded. Exploration by drilling in the Kaiga area has delineated a zone of copper mineralisation over a strike length of 300 m, with 1.23% Cu and about 0.2% Ni, to a total reserve of 0.32 million tonnes of ore.

Chikmagalur District :

Near Kalasapura, pyrite and chalcopyrite occur in a quartzite bands along with quartz-sericite schist form the basal part of the Bababudan Group.

A few mineralised zones delineated by GSI range in width from 1.10 to 8 m with copper contents of 0.13 to 0.43%. The mineralisation is conspicuously restricted to the uppermost contact of the quartzite with amygdular amphibolite. Reserves of 0.16 million tonnes have been estimated over a strike length of 240 m. Uranium mineralisation is also associated with the quartzite and conglomerate.

Other reported occurrences of copper ore :

i) Near Harapanahalli, Davanagere district, in basic dykes and quartz veins traversing granitoids.

ii) Near Yeswantnagar, Bellary district in silicified metabasalt.

iii) Near Hadabanatta, Mysore district, in pyroxene granulites and fenitised gneisses.

iv) Near Khajjidoni and Gaddenkere, Bijapur district, in Kaladgi limestones.

v) At Handigund, Belgaum district, as native copper along joint places in Deccan basalts.

vi) Musturu, Chitradurga district, in chert band within the Peninsular Gneissic Complex.

vii) Nagavand, Dharwar district, in meta-volcano-sedimentary rocks.

Bauxite

Bauxite deposits occur as cappings over the Deccan basalts and granitoids/gneisses in the Belgaum, Chikmagalur, South and North Kannara districts. A total reserve of 27.332 million tonnes of good quality bauxite are estimated in the State.

Belgaum District : High level aluminous laterite and bauxite occur as cappings over Deccan Trap, in a number of flat topped plateau at elevations of 930 m to about 1020 m, above m.s.l. Most of the deposits fall in the Khanapur taluk forming a part of the Malaprabha Valley. They are the southern extension of the deposits identified in Kolhapur district of Maharashtra. The important deposits are: (i) Boknur -Navgge, (ii) Kiravale, (iii) Betne, (iv) Karle Hills (Kiniya), (v) Mendil, (vi) Bailur and (vii) Rajhansagad. The thickness of bauxite ranges from less than 3 m to a maximum of 8 m. The composition of the bauxite ranges from 47 to 60% Al_2O_3; 1.5-2.8% $Si0_2$; 4-11% TiO_2; 2-18% Fe_2O_3.

Chikmagalur District: In Bababudan ranges occurrence of bauxite deposits in laterite cappings have been recorded on the hillocks in the vicinity of Doopadagiri, Kemmanagundi and Kalhattigiri.

South and North Kanara Districts: Bauxite occurs in the laterite capping over granitoids/gneisses in the low level plateaus (at elevations of about 50-220 m above m.s.l.) which dot the coastal plains.

In South Kanara district, two clusters of deposits occur - one near Baindoor and the other around Coondapur.

In North Kanara district, there are three clusters of deposits located on the plateaus near Kumta, Honnavara and Bhatkal. The more important deposits are located near Swarnagadda, Kumta, Haldipur, Nittadgi, Bhatkal and Mandali. The generalised laterite profile in North Kanara displays reddish brown lateritic soil on top underlain by hard, concretionary and pisolitic laterite, underlain by 0-3 m thick aluminous laterite and 0-4 m thick bauxite zone.

Chromite

Chromite occurs in altered ultrabasic rocks (serpentinised dunites and peridotites) in the form of veins, lenses and segregated pockets in the Chikmagalur, Chitradurga, Hassan, Mysore and Shimoga districts.

Chikmagalur District:

Small deposits of low grade chromite have been reported to occur near Bandre, Banur and Gijikatte.

Chitradurga District:

Chromite occurrences have been recorded from Heddani and Kallangavi.

Hassan District:

A number of occurrences and deposits are known from Nuggihalli schist belt. The deposits at Byrapur, Jambur, Tagadur, Bhaktarahalli and Chikkonahalli, are being mined by M/s.Mysore Minerals Limited.

In the Byrapur deposit, there are three thick lenticular bodies and a few thin lenses and veins cutting across the schistosity of the ultrabasic rocks. The Cr_2O_3 content ranges from 48-52%. Drill hole data indicate their persistence at depths over 300 m. The deposit is being mined by underground methods and the other minor deposits being worked by open cast methods.

Clay:

Clay occurrences in the state can be classified mainly into three categories: a) Kaolin, produced by the weathering and decomposition of granitic rocks, (b) alluvial clay found in the stream courses and terraces and in tank beds, and (c) lithomergic clay occurring below the extensive laterite cappings noticed in several parts of the state, particularly on the Western Ghats.

Important clay deposits, district-wise are as follows:-

Bangalore District:

Lithomergic clay occurs below the laterite cover in the NE part of the district and also in the adjoining Kolar district, particularly in Hoskote and Chintamani taluks. Kaolin also occurs in the highly weathered and dissected terrane (bad lands).

Kaolin is mined at Gollahalli, NE of Nelamangala, Soldevanahalli and near Chickbanavara.

Bidar District:

Large deposits of kaolin occur under a 10 m thick mantle of laterite, about 6 km west of Bidar.

Chitradurga District:

0.4 million tones of clay with Al_2O_3 content of about 37% has been estimated in Bedarabommanahalli, Bhimasamudra area.

Hassan District:

Kaolin of relative purity suitable for use in ceramic industry occurs over the gneisses at Bageshpura, Appenahalli and Nandihalli. The inferred reserves are 2.5 lakh tonnes.

Tumkur District:

Lithomergic clay of varying thickness developed between laterite cover and phyllites are recorded at Sondenahalli with their reserves estimated to be 3.43 million tonnes with Al_2O_3 ranging from 33 to 40%.

North and South Kanara Districts:

Lithomergic clay is being mined at several localities in both these districts. In fact, both these districts are known for their quality tiles and stoneware pipes.

Important deposits in South Kanara district are along the slopes of Chidigudda and Halgeriguchinogudda hills, as well as near Suratkal.

In North Kanara district, clay occurs at Castle Rock, Supa, Kumta and Bhatkal.

The total reserves of china clay and fire clay in the state are estimated to be 12.85 million tonnes and 8.77 million tonnes, respectively.

Corundum

Corundum occurs in a large number of localities in the state. Corundum bearing cordierite-sillimanite schist/gneiss occur on either side of Closepet Granite as enclaves in Peninsular Gneisses. Corundum is also developed at the contact of ultramafics and pegmatite/aplite veins intruding them, and also as disseminated grains in anorthosite. However, corundum is generally recovered from the gravel beds and stream sediments derived from the above mentioned corundum-bearing rocks. The bulk of the corundum, thus collected is of abrasive (industrial) quality and a very small proportion of them form gem quality popularly known as ruby and sapphire.

There are five principal zones ranging in length from 30 to 60 km and in width from 3 to 5 km wherein a number of corundum occurrences have been recorded. These zones are:

a) The eastern zone lying on the eastern border of Closepet Granite in which corundum is sporadically distributed in a stretch of 60 km extending from Koratagere to Pavagada in Tumkur district.

b) The east-central zone lying on the west and southwest of the Closepet Granite which runs for 60 km from Malavalli to Huliyurdurga in Mandya district.

c) The central zone which runs from Kupya in Mysore district to Mandya for 30 km.

d) The west-central zone extending from Sargur to Arsikere in parts of Mysore and Hassan districts.

e) The western zone which runs from near Sringeri, for a distance of 18 km northwards, in Chikmagalur district.

The main localities of corundum quarrying are as follows:

Chikmagalur District :

Red corundum has been periodically won from Sringeri and Koppa.

Hassan District :

Bageshpura and Kalyadi, as well as northeast of Idegondanahalli and Makavalli are some of the localities known for sporadic occurrences of corundum in gravels.

Kolar District :

Corundum occurs in pelitic schists at Dodderi and Kamasamudram.

Mysore District :

Corundum occurs in pelitic schists and gravel derived from at Kupya, Varuna, Bannur, H.D.Kote and Sargur. At Budipadaga, corundum occurs in anorthosite. Ruby and star-ruby have been found at Kupya, Bannur and Budipadaga.

Tumkur District :

Corundum of both industrial and gem varieties have been reported from Koratagere, Akampalli and Pavagada, in the cordierite-sillimanite schists, as well as in ultramafic rocks which have been intruded by pegmatite.

Diamond

Except for some possible old workings for diamond in a Dharwarian conglomerate bed near Huvinahadagalli in Bellary district and Jagarkal in Raichur district, no previous occurrence of diamond has been reported from the state. However, recent surveys by Geological Survey of India have lead in locating pipe rocks of kimberlite affinity from Undraldoddi near Raichur.

Dolomite

Dolomite/high magnesia limestone occurrences have been recorded at a number of places.

A possible reserve of 1112 million tonnes and a probable category reserve of 16 million tonnes of dolomite deposit have been estimated in Belgaum and Bijapur districts respectively. The dolomite deposits are categorised as complex deposits forming part of folded sequence of Bagalkot Group of rocks and interbedded with shale and limestone sequence.

Mysore District:

To the east of Bettadabidu as well as near Hosur in H.D.Kote taluk, 800 to 1200 m long and 120 to 150 m wide bands of dolomitic limestone, associated with bands of high-calcium limestone and pockets of calcite are reported.

North Kanara District:

In Nagjhari valley, 1.5 km long and 100 m wide band of dolomitic limestone is exposed. In the vicinity of Chilmi, Hebal, Godemane and Natarge villages discontinuous dolomitic limestone beds of an average width of 80 cm is exposed over a strike length of 4.5 km. To the NW of Vadepkli in Yellapur taluk a 1.5 km long and 200 m wide band of high-magnesia limestone is located.

Feldspar :

Feldspar is mined from coarse pegmatites. It is being produced on a small scale from a number of localities mainly from Bangalore, Mysore, Hassan, Tumkur and Raichur districts. The bulk of the production, however is from Bangalore district.

Bangalore District :

Feldspar is recovered from coarse pegmatite reef traversing granite gneiss at Neralemaradi Doddi and at Chickbanavara.

Fuller's Earth :

Fuller's Earth is known to occur mainly in Gulbarga and Belgaum districts, in association with Deccan lava flows. Fuller's Earth occurs as 1 to 1.5 m thick bands below a soil cover ranging in thickness upto 1.5 m. It is usually exposed in a nala section and tank beds.

Belgaum District :

A deposit of Fuller's Earth has been located at Dodikuppe in Chikkodi taluk. Here Fuller's Earth occurs as 1.4 to 5.5 m thick horizontal layer sandwiched between Deccan Trap flows. The inferred reserve is 4 lakh tonnes.

Gulbarga District :

Deposits of Fuller's Earth occur in Korvi, Sulaphet, Dastapur, Chimaidalai and Chincholi. There are several other minor occurrences also. The total reserves of Fuller's Earth in Gulbarga district are estimated to be 11 lakh tonnes.

Garnet

Garnet is widely distributed in the state as a constituent of some high-grade psammo-pelitic schists and of some pegmatites.

Garnet is won on a small scale from the gravels on the slopes of Yenneholerangabetta in Hassan district, for use as abrasive.

Gem quality garnet, i.e. pink and red coloured transparent variety as well as star-garnet, is recovered occasionally from the stream bed after or during monsoon near Mavinahalli, Varuna and Sargur in Mysore district and from the bed of the Kemphole River in Sakleshpura taluk of Hassan district.

Gemstones

Gem quality corundum (ruby, star-ruby, sapphire and star-sapphire), pink, red and green coloured garnet (almandine uvarovite and star-garnet), fuchsite quartzite (aventurine), blue, white or yellow kyanite, opal, beryl (aquamarine), iridescent gedrite, enstatite, diopside and bronzite, microcline (moonstone) and labrodorite showing play of colours, staurolite, amosite/crocidolite, quartz (rock crystal) and cordierite occur sporadically in a number of localities, principally in Mysore, Hassan, Mandya, Bangalore, Kolar, Tumkur, Chikmagalur and South Kanara districts.

Corundum, cordierite, garnet, kyanite, staurolite, gedrite etc., are constituents of high grade psammo-pelitic schists belonging to the Sargur Group. Corundum bearing cordierite, sillimanite schist/gneiss occurs on either side of the Closepet Granite as enclaves within Peninsular Gneissic Complex. Corundum is also developed at the contact of ultramafic rocks and pegmatite veins intrusive into PGC. Corundum also occurs as disseminated grains in anorthosite.

Green diopside and green garnet are found in a tarurite, a calc-silicate rock. Beryl and moonstone are localised in pegmatites traversing the Sargur Group and the granulites. Amosite/crocidolite commonly known as 'tiger's eye' is found as layers within banded magnetite quartzite. Rock crystal, amethyst and opal occur as amygdules in the Deccan

basalts. Due to weathering these minerals are sparsely distributed in the colluvium (mainly gravel) and alluvial sand derived therefrom.

Well known occurrences of gem quality corundum, garnet and fuchsite quartzite are as follows :

1) Corundum :

Corundum gems occurring at the contact of ultramafic rocks and pegmatite:

a) Kollur, Maddur tract and Malavalli-Doddi tract in Mandya district.

b) Honmachanahalli, Bandihalli, Tumkur-Pavagada, Baichapur-Madhugiri in Tumkur district.

Corundum gems occurring in pelitic schists :

a) Gundlupet, Bhimanahidu nugu, Manchahalli, Sargur / Thoravalli, H.D.Kote–Jayapura, Chikunda and Budipadaga in Mysore district.

b) Maralvadi, Kodamballi, D.Mara–T.G.Halli and Jalamangala in Bangalore district.

2) Fuchsite quartzite (Aventurine):

Aventurine is reported from Belvadi, Sindigere, Mallenahalli, Mundre in Chikmagalur district.

3) Garnet (Gem variety)

Pink coloured almandine garnet occurs in (a) Elwal–Madahalli, Mavinahalli, Sargur–Thoravalli, Kundapatna–Motha in Mysore district, (b) Sakleshpura–Kemphole, Kadamane, Holenarsipura–Dodkadanur in Hassan district.

Green garnet (uvarovite) occurs in (a) Bandihalli in Tumkur district, (b) Bidadi–Tavarekere–Chickbanavara in Bangalore district and (c) Chikkalavanchi, Kamasandra in Kolar district.

Star-garnet is reported from (a) Kuppe–Chunchankatte sector of Adhur Betta in Mysore district. (b) Sakleshpura–Kemphole in Hassan district.
In addition to gem quality corundum and garnet occurrences detailed above, blue and green coloured, transparent, facet-grade kyanite have been located at Sringeri, Koppa, Agalagandi, Hirekodage in Chikmagalur district, Tirumalapura, Doddakadanur, Yedegondanahalli and Malvanghatta in Hassan district, Kudineerkatte in Chitradurga district and also in Sargur area in Mysore district.

A band of bluish green kyanite and deep red corundum has been located at Itna in Mysore district. Narrow seams of amosite/crocidolite of 'Hawk's eye' variety has been located in BIF in Bababudan Hills. Opal showing dendritic structure occurs within ultramafic rocks at Malvanghatta in Hassan district and Marurganahalli in Mysore district.

Lolite exhibiting deep blue to straw yellow dichroism occurs in porphyroblasts in the cordierite-sillimanite-garnet gneisses/schists near Tippasandra in Tumkur district and Maralvadi and Muddainpalya in Bangalore district.

Moonstones occur in Biligirirangan Hills in Mysore district. Green and yellow coloured beryl occurs in pegmatites are reported around Doddakadanur and Mandur in Mysore district.

Gold

Karnataka State contains the bulk of the known gold resources of the country. The mines in the Kolar Gold Fields (KGF) and the Hutti mines accounted for about 98% of the primary gold production in India during 1992. The well known Kolar Gold Field has a long record of continuous production since 1880 with a peak production of 19,565 Kg in 1905 and has so far produced 815 tonnes of 'Yellow Metal'.

Much of the mineralisation so far identified in the Kolar, Hutti-Maski, Gadag and Chitradurga schist belts appears to be essentially shear controlled, but the gold is also hosted in a variety of rocks. In the KGF the gold lodes are associated with tufted amphibolite (basic/ultrabasic rocks), while in the Kempinkote of Nuggihalli schist belt, the mineralisation occurs in mafic-ultramafic sequences. In the Hutti-Maski schist belt the host rocks are essentially low-potash, iron-enriched tholeiitic meta-basalts, along with acid volcanics and meta-gabbro, in some deposits. In the Gadag schist belt, the mineralisation is associated with tholeiitic meta-andesite, quartz porphyries and argillite-greywacke assemblage. Part of the mineralisation is also in sulphidic BIF as in the Nagavi block.

In parts of the Chitradurga schist belt, gold is localised in quartz veins traversing meta-basalts and greywackes close to the contact with meta-basalts (G.R.Halli, Bellara) as well as in BIF (Ajjanahalli area). Sulphidic facies of BIF and the interbedded tuffs form the principal host rocks in the Chinmulgund and adjacent areas of the Shimoga belt.

Incidence of gold has also been recorded from the basal quartz, pebble (oligomict) conglomerate of the 'Dharwar Supergroup'.

Summary of gold deposits explored by GSI is as follows:

TABLE-V

NAME OF THE BLOCK	SCHIST BELT	HOST ROCK	RESERVE (Million tonnes)	Grade Au (g/t)
Raichur district				
Uti	Hutti-Maski	Meta-gabbro	1.027	2.04 to 18.98
Wandalli	Hutti-Maski	Meta-gabbro	0.796	2.00 to 7.56
Hira-Buddini	Hutti-Maski	Contact of acid-basic volcanic rocks	0.520	11.90
Kadoni	Hutti-Maski	Meta-basalt	0.064*	8.70
Chinchergi	Hutti-Maski	Meta-basalt	0.058	2.10 to 23.20
Dharwar district				
Hosur-Champion	Gadag	Meta-basalt	0.690	2.00 to 4.48
Sangli mine	Gadag	Argillite	1.690	1.87 to 3.77
Mysore mine	Gadag	Meta-basalt-argillite	0.230	1.17 to 4.83
Kabuliyatkatti North	Gadag	Meta-gabbro	0.247	1.14 to 4.64
Nagavi	Gadag	Sulphide BIF	0.065*	2.01
Chitradurga district				
Ajjanahalli Main	Chitradurga	Sulphidic iron formation	1.512	2.86
Ajjanahalli West	Chitradurga	Sulphidic iron formation	0.775	2.76
G.R.Halli	Chitradurga	Contact of meta-basalt and argillites	0.60	4.00
Hassan district				
Kempinkote	Nuggihalli	Ultramafic rocks	0.112	0.89
Haveri district				
Chinmulgund	Shimoga	Sulphidic BIF	2.93	3.39 (2 gm cut-off)
			4.597	*2.59 (1 gm cut-off)

*Chinmulgund - A probable resource of 2.93 million tonnes with 3.39 g/t at 2.00 gm cut-off and 4.597 million tonnes with 2.59 g/t at 1.00 gm cut-off has also been estimated. Subsequently, exploratory deep drilling was also carried out by MECL which also shows encouraging values in depth.

Kolar District :

The Kolar Gold Field comprising the Champion, Nundydoorg, Mysore and Bisanattam mine areas is located in the central part of the 80 km long Kolar schist belt. These are two zones of subparallel lodes which are sub-conformable to the meta-basite host rock viz., the Champion lode on east, and on the west Oriental lode and McTaggert lode.

Two types of lodes are normally distinguished (1) gold-quartz lodes represented mainly by the Champion lode (2) gold-quartz sulphide lodes represented by the Oriental and McTaggert lodes. In type-1 lodes, sulphides, viz., arsenopyrite, pyrite, chalcopyrite, pyrrhotite, pentlandite and galena are subordinate varying from traces to 2% of volume of rock, scheelite is present in appreciable quantity at places. In type-2 lodes, sulphides viz., pyrrhotite, pyrite, arsenopyrite, chalcopyrite, sphalerite and rare galena are in the order of 10-12% of volume of rock.

Gold is hosted in a succession of pillowed meta-basalt (Komatiitic and tholeiitic), meta-gabbro and schistose meta-pyroxenite, localised along steeply dipping (mostly subvertical) N-S trending shear zones. The lodes appear to thicken at the intersections between two successive generations of shear zones, striking respectively N-S and NNW-SSE. Also on a broader scale, an affinity is indicated between the Champion lode and komatiitic basalts (tuffed amphibolites).

The Chigargunta and Mallappakonda mines in Andhra Pradesh lie along the southern continuation of the Kolar Gold Field.

Raichur District

In the Hutti-Maski schist belt, gold mineralisation is localised along the shear zones developed parallel/subparallel to S_1 schistosity in both basic and acid meta-volcanic rocks represented by chlorite schist, chlorite-biotite schist and sericite-chlorite-biotite schist. The Hutti mines of M/s Hutti Gold Mines Limited (HGML), is located in the northern part of the belt. It produced 1048 kg of gold during 1990-91.

Extensive and detailed investigations were carried out by GSI from 1967-68 to 1992-93 in Hutti mines area, Wandalli, Uti, Hira-Buddini and Maski proving sizeable gold reserves.

The Hutti Mines block extends over a strike length of about 1500 m. There are six subparallel reefs from west to east viz., Main reef, Oakley's reef, Zone-I reef, Village reef and Strike reef. The maximum depth of the mine is about 1135 m.

In Uti block, 18 mineralised zones with a cumulative strike length of 3320 m have been delineated. The individual lodes range in strike length from 40 to 670 m and in width from 0.6 to 10.0 m. The mineralisation is hosted in schistose and coarse grained amphibolite and meta-acid volcanic rocks.

Exploratory mine development by Mineral Exploration Corporation Limited (MECL) has indicated that at lower cut-off grades reserves of about 2.5 million tonnes are estimated.

Dharwar District

In the Gadag gold fields of this district, ancient workings and mines are seen over an area of 200 sq.km. All the known gold bearing lodes are confined to the western limb of an overturned syncline over a strike length of 15 km.

The prospects explored by GSI between 1967 to 1993 are:

(a) Western Group comprising Hosur-Champion, Yelishirur and Venkatapur mines hosted dominantly in meta-basalts and meta-andesites.

(b) Middle Group comprising Kabuliyatkatti-Attikatti, Mysore Mine and Sangli Mine, hosted mostly in greywacke.

(c) Eastern Group comprising Sankatodak block and a fewer prospects of east of Nabhapur and Kabuliyatkatti villages which are hosted in greywacke. In addition, gold mineralisation is also known from the area north of Nagavi which are hosted in BIF and its contact with tuffaceous rocks.

In the Hosur-Champion blocks, two ore bodies, Hosur-Champion east (strike length 1100 m) and Hosur-Champion west (strike length 2240 m) have been identified.

In the Mysore mine block, there are three lodes viz., East lode, Middle lode and Hospital lode hosted in meta-andesite.

In the Sangli mines there are three lodes viz., Temple East lode, New East lode and Middle lode localised in sub-parallel shear zones developed at the contact of the meta-volcanics and meta-sediments. Possible reserves estimated are 0.592 million tonnes.

Investigations carried out by GSI in recent years has shown significant gold mineralisation in the sulphidic Banded Iron Formation (BIF) and the interbanded tuff occurring in the argillite-greywacke sequence of the Chitradurga Group.

In the Chinmulgund block, surface work has indicated mineralisation over a considerable length. A probable resource of 2.93 million tonnes with 3.39 g/t at 2 gm cut-off and 4.597 million tonnes with 2.59 g/t at 1.0 gm cut-off has also been estimated in the sulphidic BIF/BMQ zones. Subsequently, exploratory drilling was also carried out by MECL.

A number of potential blocks, viz., Karjagi, Kattenahalli, Nelogal, Kalledevar-Hosahonnatti, Budapanahalli, northwest of Temmenhalli, Kengod, Devargudda, Salagudda, Lakkikoppa, etc., have also been identified in the adjoining areas.

In the Karjagi area, three parallel bands have been traced over a length of about 400 m on the Karadigudda hill. These bands can be further extended for about 75 m towards NW and about 5.5 km towards SE.

In the Kalledevar-Hosahonnatti area, three to four parallel bands are seen discontinuously over a considerable length, with high gold content.

Shimoga District:

Gold mineralisation hosted in quartz-ankerite veins traversing quartz-chlorite schist is known from the Kadur-Shimoga gold field (Tarikere Valley) and the Honnali gold field.

Numerous ancient workings are seen in the 40 km long Kadur-Shimoga belt extending from Bilikalbetta in the north to Nandi in the south. Recent sampling has indicated values of 0.17 g/t to 1.07 g/t in the Nandi and Hosahalli areas, 0.35 g/t to 9.30 g/t in the Kenchanpura area, upto 1.87 g/t in the Siddarahalli area, mineralisation is recorded in the Nandi and Hosahalli, Kenchapura, Siddarahalli and Singanamane areas.

In the Honnali gold field, a number of old workings have been reported around the Honnali granite gneiss dome. The old workings at Palavanahalli and Kudrikonda located about 10 km apart were developed by the Honnali Gold Mining Company. Extensive gold washing is reported in the Kudrekonda-Palavanahalli areas.

Hassan District:

In the Kempinkote area, gold mineralisation occurs in bands of hornblende-biotite quartzo-feldspathic gneiss occurring at or near the contact of meta-ultramafic flows (talc-tremolite ± actinolite ± chlorite schist) and mafic flows (amphibolite/quartz hornblende-chlorite schist and gabbro). Three mineralised zones , West Zone, Central Zone and East Zone have been delineated.

Gold mineralisation associated with mafic-ultramafic rocks is known from the Gollarahalli and Vittalapura-Yelavare areas in the northern part of the Nuggihalli schist belt.

Chitradurga District

Gold mineralisation occurs parallel to and sometimes closely intermixed with the 40 km long Chitradurga sulphide belt extending from Yerrahalli in the south to Honnemardi in the north.

GSI has carried out extensive exploration in the G.R.Halli, C.K.Halli-Honnemardi areas. Drilling has indicated a 575 m long zone ranging in width upto 4.20 m with gold content of about 3.5 g/t and average silver content of about 80 ppm in the G.R.Halli South block.

Tumkur District

In the Anesidri-Ajjanahalli-Bellara area, gold mineralisation is associated with meta-volcanics as well as sulphidic banded iron formation of the Chitradurga Group. At Anesidri and Bellara the mineralisation localised along shear zones in meta-volcanics was mined by the Indian Mines Development Syndicate between 1902 and 1908. At Bellara the reefs are reported to have been developed upto 120 m depth.

In the Ajjanahalli block, 10 parallel zones of mineralisation localised in shear zones in sulphidic Banded Iron Formation along a fold in the BIF have been delineated by GSI. The strike length of the block is about 1500 m. The estimated reserves at 0.5 g/t cut-off grade are 0.77 million tonnes of ore.

Graphite

Graphite, both crystalline and amorphous varieties, occur as a component of low and high grade pelitic schists. The important graphite deposits in the state are associated with high grade pelitic schist of Sargur Group in Mysore and Kolar districts.

Kolar District

Graphite occurs associated with quartz-mica schist near Ganacharpura. There are three mineralised zones which extend upto 100 m in length and upto 4 m in width. The carbon content ranges from 12 to 25% and estimated reserves are 10,200 tonnes. Vasudev and Mukherjee (1986) documented the details of Garianpura belt.

Gypsum

Gypsum occurs in Gulbarga district, south of Gangurti, a village 25 km east of Gulbarga. Here Gypsum is found sporadically distributed in the black cotton soil and as crystals and nodules in the black clay layer occurring at a depth of 1 m below the soil cover. The gypsiferous clay is 3 to 6 m thick and it is estimated that gypsum forms 10 to 20% of the clay.

Nodules and flakes of gypsum are scattered in black cotton soil, south of Hagari River in Bellary district and the proportion of gypsum ranges upto 15% in the soil.

The possible reserves of gypsum in Karnataka are about 1,069 million tonnes.

Iron Ore

Karnataka is endowed with a number of major iron ore deposits. The iron ore deposits of Karnataka are principally of two types, (i) Lateritoid concentrations, essentially of haematite with minor limonite and goethite. These are products of residual weathering and form thick mantles / caps over areas of ferruginous shales, banded magnetite quartzite / banded haematite quartzites, schists and basic rocks of Dharwar. Most of

these deposits stand out as prominent ridges and generally consist of a hard lateritoid top and 'blue dust' - a friable, high grade, powdery iron ore at the base. The ores are mostly massive and may often show mammillary, concretionary, pisolitic and oolitic textures, (ii) Magnetite mainly occur in the Bababudan Group as lenses or as beds in the banded magnetite quartzite.

In Karnataka, major deposits of haematite occur in Sandur, Chitradurga and Shimoga schist belts in Bellary, North Kanara, Chikmagalur, Shimoga, Chitradurga and Tumkur districts. Magnetite deposits occur in the Bababudan and Western Ghat schist belts in Chikmagalur, Shimoga and North Kanara districts.

Bellary District

Large deposits of lateritoid haematitic iron ore in association with manganese ore from prominent ridges of the Sandur schist belt. There are six ranges carrying iron ore deposits viz., Donimalai, Kumaraswamy, Ramandurg, Kanavehalli, Devagiri and Thimmappanagudi.

The Ramandurg deposit is about 10,400 m long and 150 m wide with 62.3 to 62.6% Fe.

In Donimalai, six ore bodies with sizeable reserves of 65.2% Fe have been estimated.

In Kumaraswamy, Geological Survey of India has estimated iron ore over a strike length of 2.5 km and width of 465 m.

GSI has estimated a reserve of about 1876 million tonnes of iron ore with about 63% of total iron in Sandur belt.

Chikmagalur and Shimoga Districts

Haematite deposits occur in the Mulaingiri Formation of the Bababudan belt. Some of the larger deposits are those at Jansurigudda, Kaldatti, Attigundi, Galikere, Siddaragalli, Rudragiri, Kemmanagundi, Lakkihalli and Marenahalli. The potential resources of the haematite deposits are 488 million tonnes of 52-55% Fe.

The Western Ghats contain about 80% of the known magnetite resources of the country in the form of low grade banded magnetite-quartzite bands. Major deposits are in the Aroli, Kudremukh, Kodachadri and Thirtabare area. The Aroli-Kudremukh deposits have iron content of about 38% and are being exploited to the tune of 22.6 million tonnes/year by the Kudremukh Iron Ore Company Ltd. It consists principally a zone of 80 to 100 m thick banded magnetite-quartzite, weathered to varying degrees. The Aroli-Kudremukh deposits contain about 1000 million tonnes of iron ore and the Kodachadri-Thirtabare deposits about 570 million tonnes.

In the Vanivilas Formation of the Chitradurga schist belt, there are a number of iron ore deposits occurring in detached patches which have been divided into three groups: 1) the

southern group comprising the Karekurchi area. 2) the central group comprising the Chiknayakanhalli area and 3) the northern group comprising the Janehara area. The Chiknayakanhalli occurrences contain 55-60% Fe.

North Kanara District:

Several small haematite deposits in close association with the manganese deposits are reported along a 130 km long N-S belt between Mirjan and Palda. The larger deposits are near Anmod, Badagur, Talginkere, Mavingudi and Kalche with 55-60% Fe.

Kyanite and Sillimanite

Kyanite and sillimanite are constituents of high grade pelitic schists of Sargur Group. Kyanite and sillimanite bearing schists are observed within the western and southern extension of Holenarsipur schist belt in Hassan district, in the Gopalapura-Sargur-Nuguvakankote belt in Mysore district, in Ghattihosahalli and Kudineerkatte belts in Chitradurga district.

Mandya Districts

Kyanite is being mined at Hulahalli in Mandya district.

Chikmagalur District

Kyanite deposits occur in the Sargur enclaves in Koppa, Mudigere and Sringeri taluks. Important localities are Mirikudi, Sringeri, Addagadde and Kalasa.

Chitradurga District

Kyanite has been mined at Kudineerkatte and also at Ghattihosahalli.

Hassan District

Kyanite occurs in association with staurolite in Holenarsipur schist belt. Bladed blue coloured kyanite occurs in quartz reefs traversing the schists. Such deposits occur at east of Holenarsipur and Makavalli.

Limestone

Karnataka State has the largest limestone resources in India. Extensive deposits of high grade limestone form part of the Proterozoic Kaladgi and Bhima basins covering parts of Belgaum, Bijapur and Gulbarga districts. While cement grade, BF (Blast Furnace) grade, SMS (Steel Melting Shop) grade and chemical grade limestone occurs in the lower Bagalkot Group of the Kaladgi Supergroup, the cement grade limestone is reported from Bhima basin.

Large pockets and lenticular bodies of crystalline limestone occur associated with Fe-Mn chert-phyllite constituting the lower part of the Chitradurga Group. Deposits of crystalline limestone, ranging from high calcium type containing less than 3% MgO to dolomitic limestone having 20% MgO, occur in Chitradurga, Tumkur, Bellary, Belgaum and North Kanara districts. Crystalline dolomitic limestone is also known in Sargur sequence.

A brief district-wise description of the major deposits is as follows:-

Belgaum District

In Belgaum district, both limestone and crystalline limestone are reported. Crystalline limestone containing 48% CaO occurs near Nagargali-Dandeli road, over a length of 4 km. White to grey coloured, fine saccharoidal limestone occurs between Bhimgad and Dharsinga.

Vast reserves of bedded sedimentary complex type limestones of various grades are exposed to the western segment of Lokapur Subgroup of Kaladgi Supergroup rocks. Some of the important occurrences viz., Ankalgi, Lokapur, Chikkashellikere and Hireshellikere were investigated. Gradewise reserves are 71 million tonnes of SMS grade an 1125 million tonnes of BF grade.

Bijapur District

High calcium limestone occurs in a 60 km long belt extending form Kuligod, Belgaum district in the west to Bagalkot, Bijapur district in the east. There are several large deposits in this tract. The deposits at Bagalkot has a maximum width of 500 m and a length of 6 km. The deposit at Kaladgi is 5.2 km long and 352 m wide and that at Lokapur is 8 km long and 1.6 km wide. The limestone at places is dolomitic particularly at Lakshanhatti (19.72% MgO) and at Lokapur. The bulk of the limestone is of cement grade (330 million tonnes) followed by SMS (150 million tonnes) and BF grade (155 million tonnes)

Chitradurga District

East of Javanahalli, a discontinuous band of high grade crystalline limestone is reported over a length of 23 km. Its width ranges from 1 to 12 m. The limestone bands are usually vertically disposed, 1 to 50 m wide and strike in NNW-SSE to NW-SE directions. The limestone bands are separated by phyllite and chert beds. The important deposits are located at Jagalur, Marikanive, Kudrekanive, Madadkere, Lakkihalli, Mattod, Kappanaikanahalli, Tarikere, Hindedevarahalli, with CaO varying from 32.01 to 50.20% and MgO 1.55 to 17.2%.

Dharwar District

Limestone deposits containing 40 to 43.73% CaO occur as bands interbedded with haematite-quartzite at Chandanmatti, Doni and Dindur.

Gulbarga District

Extensive deposits of very fine grained, pale grey to black coloured limestone deposits occur over an area of about 1000 sq.km in Gulbarga district. The Principal deposits are located around Kurkunta, Chincholi, Sedam, Malkhed, Chitapur, Shahabad, Wadi, Jevargi. The limestone is well suited for manufacture of cement. The $CaCO_3$ ranges from 80 to 90% magnesia content being about 1%. By reconnaitary survey a total of 15 billion tonnes of cement grade limestone to a depth of 7.5 m and with CaO in the range of 40-48% and MgO within 1% has been estimated.

Hassan District

Limestones are reported at Bettadapurbetta-Aerahalli and Kamanayakanahalli over a length of 8 km. Limestone outcrops covering an area of 0.14 sq.km are also noticed near Bhaktarahalli.

North Kanara District

Several bands of crystalline to dolomitic and siliceous limestone are found in the vicinity of Hebbal, Godemane, Natarge, Ganeshagudi and Castle Rock.

Shimoga District

Crystalline limestone occurs on a large scale in an E-W belt extending from Ballur to Arakere. At Bhadigunda, a deposit is being mined for use as flux in Visweswaraiah Iron and Steel Limited (VISL) and for manufacture of cement at Bhadravati. The deposit contains a few bands which are high in magnesia (MgO +8%).

Tumkur District

This district has high grade limestone of economic importance. At Voblapur the limestone containing 50% CaO is being worked. The deposits at Dodguni, Chikkanayakanahalli and Huliyur are being worked for manufacture of cement.

The total proved reserves of limestone of all grades in the State are about 694 million tonnes.

Lithium

In the Amareshwar area spodumene-bearing pegmatite occur as impersistent, tabular and lensoidal bodies emplaced in amphibolite of Gurgunta schist belt. Cumulative strike

length of 20 pegmatite bodies is of 2.5 km. Individual bodies extend in length upto 250 m and vary in width from 50 cm to 2.45 m. Spodumene occurs as bladed crystals or fibrous aggregates, transverse to the trend of the pegmatites. The Li_2O content ranges from 20 ppm to 2.12%. (Narasimha and Hans, 1983; Sadashivaiah et al, 1980; Jagannathachar, 1990; Devaraju et al, 1990).

Occurrences of spodumene crystals have been recorded from the margins of Sandur belt (Abdul Martin et al, 1988), Holenarsipur belt (Babu, 1975), other schist belts (Banerjee et al, 1994) and Kolar mines (Rama Rao and Ramachandra Rao, 1939).

Magnesite

Magnesite occurs as veins traversing serpentinised dunite/peridotites. Economic deposits of magnesite occur in Mysore district. Occurrence of small and impersistent veins are reported in Hassan near Kushalnagar and at Gaddehosahalli near Arkalgud in Coorg district. Many of the altered ultramafics around Kushalnagar near Torenur, Argod and Rangaswamybetta contain minor magnesite veins (Ponnuswamy, 1972).

Mysore District

Magnesite deposits are found in Dodkanya, south of Sindhuvalli, Karya, Hullahalli and Mavinahalli. MgO content ranges from 41 to 47% and SiO_2 3 to 5%. Inferred reserve at Karya and Hullahalli is 3.75 lakh tonnes.

In addition, a fairly large deposit of magnesite is reported from Kollegal taluk, occurring in hillock near Kakkeridoddi.

Magnesite reserves in the state have been estimated to be 1.229 million tonnes.

Manganese Ores

Karnataka has the largest recoverable reserves of manganese ore in the country. Managanese ore minerals in close association with haematite and carbonates occur in the lower stratigraphic level of the Chitradurga Group as stratiform, lenticular, patchy or pockety deposits of varying dimensions. Psilomelane, pyrolusite, wad and polianite are the important minerals of manganese ore.

Bellary District

The bimetallic (Fe-Mn) low-phosphorus manganese ore deposits as discontinuous bodies occur all along the western and southern margin of Sandur schist belt over a strike length of about 40 km with average width of about 500 m. The deposits in the Deogiri hill are the largest.

The manganese horizon is stratigraphically confined to Deogiri Formation whose thickness varies from 975 to 1000 m consisting of meta-greywacke, carbonates with minor interbeds of quartzites, arkose, meta-chert, basic and acid volcanic rocks.

Exploration by large scale mapping and drilling carried out by GSI has identified three distinct manganese horizons over a strike length of 15 km viz., (i) top lateritoid horizon (ii) middle reef like manganese ore and (iii) bottom clay mixed zone. Pyrolusite, cryptomelane, psilomelane are the principal ore minerals. Hausmanite, hollandite and mangano-magnetite have also been recorded.

The probable reserves of manganese ore in the entire belt are estimated to be 107.36 million tonnes (Kameshwar et al, 2000).

Shimoga and North Kanara District

Manganese ore occurrences associated with chlorite schist, dolomitic limestone, phyllite, interbedded with meta-acid volcanics are located south and east of Shikaripur town between the villages Tarlagette and Kagenahalli. The manganese ore is essentially syngenetic with a few localised concentrations of supergene ore the latter being in the form of laterite capping. The mineralisation is more or less persistent over a stretch of 18 km in the Shikaripur sector; the well known occurrences are in Kumsi, Jolihal and Shankargudda.

In North Kanara district the syngenetic manganiferous formations are in the form of Mn rich argillites forming the interbedded sequence with quartzite, carbonates and ferruginous chert. High grade manganese ore bodies directly overly on the granitoids.

The manganese belt extends for 130 km between Mirjan and Palda, in which the important deposits are located around Supa and Dandeli area.

An inferred reserve of 14.96 million tonnes of +15% Mn, with low phosphorus (0.5%) is estimated.

Chitradurga and Tumkur Districts

Manganiferous formations occur discontinuously over a length of 180 km for Doddaguni, Tumkur district, in the south to Kandavi, Chitradurga district in the north. In addition isolated occurrences are also known from Jagalur and Kappatgudda in the northern part of the belt.

Manganese ore in the area comprises secondary concentrations mostly confined to lower manganiferous phyllites of Chitradurga Group. The manganese content is low, varying from 25 to 45%. The important deposits are located in Chikkanayakanahalli, Lakkihalli, Huliyur, Bhimasamudra and Jagalur.

Molybdenite

Sparse disseminations of molybdenite have been noticed in the later phase of the Peninsular Gneiss and in younger alkali-feldspar granites or at the interface of pegmatite veins and quartz reefs; as yet no economic deposit of molybdenite has come to light.

Raichur District

Molybdenite occurs as specks in pink and grey granite at Malatgudda (Gururaja Rao and Devadu, 1975) and Ashapura (Prakash, 1996).

Kolar District

Molybdenite has been noticed occurring as patches and specks in the pegmatite veins traversing the granites of the Peninsular Gneissic Complex at Yagavkote (Vasudev and Jayaram, 1979). Values range upto 0.2% Mo.

Nickel

Sparse disseminations of nickel sulphides occur associated with mafic-ultramafic rocks at Gowanahalli, Mysore district and the Kaiga-Mothimakki area of North Kanara district. In addition, relative enrichment of nickel in saprolitic horizons of laterite profiles developed over ultramafic bodies have also been recorded from Golahalli, Byata area of Bangalore district. The thickness of saprolite zones range upto 20 m with an average of about 10 m. Nickel values of upto 1.03% with an average of 0.38% have been recorded from Golahalli-Byata area. The 'saprolite' is overlain by a birbirite capping.

Ochre

Red and yellow ochres occur associated with laterite, ferruginous shales, iron ore and banded ferruginous quartzites.

Bangalore District

Near Nandagudi in Hoskote taluk nodules of red ochre are seen on laterite mounds.

Bellary District

In Sandur schist belt, red ochre occurs on a large scale associated with the haematite deposits near Ettinahatti, Karadikolla and Ramandurg plateau.

Chitradurga District

Yellow ochre is found at Kenkere in Hosadurga taluk and Hanumankatte in Holalkere taluk.

Gulbarga District

Bhima shales lying in contact with Deccan Trap are reported to be suitable for use as pigment. Such deposits occur at Hirejewargiri and Shorapur.

Raichur District

At Thanlankatte and Mydardoki, red ochre associated with haematite quartzite have been reported.

Ornamental stones and Dimension stones

Granitoids, gneisses, dolerite, gabbro, pyroxenite, fuchsite quartzite, limestone and felsites can be cut to any required size, polished and used for decorative purposes. There is growing demand for ornamental stones in India and abroad. The rocks suitable for use as ornamental stones cover an area of 4262 sq.km which is about 2.22% of the total geographic area of the state.

The following rock types are particularly important for decorative purposes :

1) Pink, red and grey prophyritic and non-porphyritic granites from Closepet, Arasikere-Banavara, Chitradurga, Hosdurga, Patna, Bisanattam, Nandi and Chamundi granite outcrops.

2) Pink and grey gneisses and associated homophanous granite occurring on either side of Closepet Granite, are important. Homophanous granite, grey in colour, uniform, medium-grained textures, occurring at Muddakkanahalli, Tumkur district, Mallasamudra, Bangalore district are also useful.

3) Dolerite, gabbro, norite, pyroxenite and bronzitite occur as dykes. Dark grey or deep black varieties of dolerite gabbro and norite are commercially more important. These rock types are reported from high grade metamorphic terrain. Dolerite and gabbro possessing greenish tinge, are marketed as 'Hassan Green'; commercially the basic and ultrabasic dyke rocks are known as 'Black Granite'.

4) Grey, pink and red felsite and felsite porphyries occurs as dykes are exposed for several kilometres; these are confined to Mysore, Mandya and Bangalore districts.

5) Flaggy limestone occurring in Bijapur and Gulbarga districts, known as 'Shahabad Stone' finds use as tiles and slabs for flooring and paneling.

6) Green fuchsite quartzite forming part of Sargur Group.

The geographic distribution and geological setting of the main types of ornamental stones are tabulated below:

TABLE-VI

Commodity	Taluks in which they occur (in order of importance)	Geological Setting
Black granites (Dykes)	Chamarajnagar, Yelandur, Kollegal, Malavalli, Hunsur, Periyapatna, Kanakapura, Gundlupet, Nanjangud	High grade metamorphic terrain of Southern Karnataka
Green granites (Dykes)	Belur, Chikmagalur, Kolar, Hospet, Bellary, Challakere, Tiptur, Nagamangala, Kunigal	Granite/PGC terrain north of above
Pink and Red granites	Hungund (Ilkal),Kushtagi, Magadi, Siruguppa, Bellary, Koppal, Ramanagaram, Deodurg, Shorapur and Lingsugur	Closepet Granite and Koppal syenite
Pink, Pink-grey, porphyritic granite	Deodurg, Magadi, Tumkur, Koppal, Ramanagaram, Kolar, Gudibande, Bagepalli, Gouribidanur	Closepet Granite, Patna, Bisanattam, Nandi and Gudibande granitoids
Multicoloured granite/gneiss	Kanakapura, Channapatna, Huliyurdurga, Malavalli, Tumkur, Kushtagi, Sandur, Maddur, Bangalore (South) and Lingsugur	Closepet Granite and adjoining parts of Peninsular Gneissic Complex.

Brief descriptions of the important occurrences of ornamental stones are as follows:

Black Granite:

Dolerite and gabbro dykes of a few hundred meters to 3 km long and 10 to 20 m wide, occur near Kumbeswara colony and Ulurgud in Chamarajnagar taluk, Boraibetta, and south of Kunaghalli in Kollegal taluk, Mysore district.

In Bangalore district, 2-3 km long and 8 to 10 m wide dolerite dykes occur in Doddaballapur taluk.

'Hassan Green' variety of dolerite and gabbro dykes are reported from Hassan district.

Pink Granite

Pink granite is quarried at Uduvagere and Managalli in Magadi taluk of Bangalore district, Deodurg, Mundargi, Masarkal, Savanthagal in Deodurg taluk, several localities in Kushtagi taluk, Raichur district as well as Balkundi, Gugalmari, Hanumanal, Gudur, Chikkodagali, Sankalapura and Hosur in Hungund taluk, Bijapur district. The pink granites of Hungund, Kushtagi sectors are marketed as 'Ilkal Pink', 'Imperial Red' and "Ruby Red'.

Pink and Red porphyritic Granite

The area wherein pink and red porphyritic and coarse grained granite being quarried are : Savandurga, Kalyandevarmata, Dubbikattige, Chilur, Bhairsandra in Magadi taluk,

Nijagal, Kengal, Shivaganga in Nelamangala taluk, Bangalore district, Bandahalli, Nandihalli and Arishnabetta in Tumkur taluk in Tumkur district.

Felsite / Felsite porphyries

These rocks display either grey or pink colour as well a combination of both the colours. Generally they are highly jointed. Only thin, small sized polished tiles for flooring and wall paneling can be manufactured from them.

Large occurrences of these rocks are reported from Kirangur, Hosahalli in Srirangapatna taluk, Sadanhalli, Bannur and Mergalli in Mysore taluk of Mysore district and Malavalli and Maddur, Mandya district around Kanakapura, south of Channapatna, Satnur and Bidadi, Bangalore district.

Fuchsite Quartzite

Emerald green fuchsite quartzite on a minable scale occurs at Belvadi, and Marenahalli, Chikmagalur district, Janakal and Ghattihosahalli, Chitradurga district, Bikonahalli, Shimoga district. A total reserve of 7720 million tonnes of ornamental variety are estimated from these areas.

Phosphorites

Thin bands and lenses of phosphorite are reported to occur in Hulkal Shale Formations of Bhima Group. The maximum strike length of the bands are half a kilometer, as seen around Kalkur, Gangurti and Hulkal. The samples analysed from 6.38 to 23.9% of P_2O_5.

Barring thin insignificant phosphorite bands of a few centimeter length no economically significant deposits are reported in Kaladgi Basin.

Platinoids

Economic deposits of Platinum Group Elements (PGE) are yet to be reported from Karnataka. The information available on incidence of PGE, is in Hanumalapura area of Davangere district need to be confirmed by further detailed investigations.

Mysore District

In Sindhuvalli and Tallur areas chromite samples from the serpentinite bodies an alteration product of mafic-ultramafic rocks show the incidence of platinum and iridium.

Shimoga District

In the Masanikere area the platinoids are reported from vanadiferous magnetite, pyroxenites (talc schists) of layered ultramafic complex comprising magnetite, gabbro, gabbroic anorthosite and anorthosite, intruding the meta-sediments of Chitradurga Group.

The area was investigated by drilling for vanadiferous magnetite by GSI indicating spot values of 1.5 to 4 ppb Pt.

Quartz

Quartz reefs occurring in the vast Archaean tracts of the state constitute important sources for the mineral. The quartz reefs have variable dimensions, their widths range from 1 to 25 m and lengths vary from a few meters to 3 km. They have been worked to depths of 20 m. Quartz also occurs as well developed crystals in vugs, cavities and vesicles in the Deccan lava flows. The important occurrences of quartz reefs are as follows :

Bangalore District

There are several quartz reefs in and around Bangalore. The quartz reef and the associated pegmatite body occurring at Neralmaradadoddi are being worked. In addition several quartz reefs occur in hillocks at Kengeri and Chikbanavara.

Bellary District

Quartz reefs traversing granitic gneisses have been worked at Kanchegar-Bellagal, Haravanhalli, Lingadahalli, Ayyinahalli, Marutla, Anathapur and Avinomdugu. The total reserves in the district are placed at 6.03 million tonnes.

Gulbarga District

Quartz reefs are reported from Kolakunda, Malkapalli, Gadlamari, Siddapur, Tholdin, Arkere, Khurd, Gunjur, Khanapur, Marmakal and Milapur.

Raichur District

Quartz reefs are prominently exposed at Tawargeri, Hirelegnal and Karadehru, Sultanpur, Jagarkal, Mallapur, Walkamdinne, Udinhal, Sangalpur and Indavasi areas.

Shimoga District

Quartz reefs at Bilikabetta near Bhadravati are being worked. In addition mineral quartz occurs as stringers in a stretch of about 2 km along Tungabhadra River in Shimoga and Bellary districts.

Silica Sands

In addition to quartz reefs described above, silica sand suitable for making glass and for foundry purposes i.e. moulding sand are found along major river courses and also in the coastal stretches. Friable sandstones and quartzite are also important sources of silica for glass making and foundry purposes. Their occurrences, district wise are given below:-

Bijapur District

Deposits of silica sand are located north of Badami. Fine grained sandstone of Kaladgi is the major source of silica sand. The reserves are estimated at 5.6 million tonnes.

Gulbarga District

There are several localities in the Yadgir and Chittapur taluks wherein moulding sand is encountered in stream beds. Important occurrences are Nalwar and Sugur, Gudur, Dupalli, Hosahalli, Kyasanahal, Malhar, Mastur, Nandepalli, Nilhalli, Shethalli and Yadwarkhund.

South Kanara District

Deposits of silica sand of moulding sand type occur along the coastal belt from Mangalore to Udipi, Uliyargoli, Udiyavara, Tekkatte, Bailur and Murudeshwar.

Radioactive and Rare Earth minerals

Radioactive minerals such as allanite, pitchblende and monazite have been found disseminated sparsely in pegmatites at Yediyur, near Bangalore, near K.R.Pet, Mandya district, Yelwar, Tagadur, Mysore district. Allanite is relatively more common mineral which contains rare earth elements and occurs as specks in the younger granites and associated pegmatites. Columbite-tantalite has been reported in pegmatites occurring at Yelawal and north of Karighatta hill in Mysore district (Banerjee et al, 1987; Banerjee et al, 1994; Chanchal Sarbajna and Krishnamurthy, 1996; Chanchal Sarbajna et al, 2000).

The quartz-pebble conglomerate (QPC) at the base of the Dharwar Supergroup is uraniferous and auriferous. Detrital uraninite and pitchblende are present in the QPC. Thirty radioactive QPC zones have been located in different schist belts. The QPC occurrences along the Western Ghat schist belt from Muski to Badigund are reported to be uraniferous by the Atomic Mineral Division. The occurrence at Arbail being the most prominent.

Primary zones of uraniferous NeoProterozoic crushed calcitic phosphorites near Gogi in northern Karnataka, Gulbarga district, has been located recently by AMD (Sharma et al, 1998).

Steatite (Soapstone)

The manganese ores of Sandur and sulphidic magnetite body of Lakkikoppa (Haveri district) show concentration of REE because of their scavenging character of manganese.

Steatite is a massive variety of talc (hydrothermally altered ultramafic rock). Steatite occurs associated with ultramafic rocks of the Sargur Group and Bababudan Group.

Bellary District

There are four well known occurrences in this district. These are : 1) at about 1 km and 2) 11 km south of Narasimhadevarubetta in Harpanahalli taluk, 3) on Nilgunda hill and 4) 500 m west of Harpanahalli.

Hassan District

Steatite is widely distributed to the southwest of Arsikere particularly in the stretch from Dudda to Halebid, near Bageshpura and around Honnavalli.

Mysore District

There are several extensive bands of steatite near Yayapura, Kadakola, near Sargur and Varuna.

Shimoga District

Well known occurrences of extensive steatite bands are located near Saulanga, Kudli, Hoskoppa, Honnali taluk near Kaviledurga, Tirthahalli taluk and near Bhadravati.

Tin

Tourmaline rich pegmatites in the Mangalur schist belt are reported to have yielded 50 to 1000 ppm of tin and the granites of the Sirwar are reported to contain upto 500 ppm of Tin.

Titaniferous and Vanadiferous Magnetite

Titaniferous-vanadiferous magnetite bodies occur as late stage differentiation of a mafic-ultramafic complexes and are associated with both Dharwar and Sargur Group of rocks.

Titanium and Vanadium bearing magnetite deposits occur associated with layered gabbro-anorthosite complexes which have intruded the Nuggihalli and Shimoga schist belts. The layered gabbro-anorthosite complexes comprise: 1) magnetite-gabbro in which magnetite is found as dissemination, thin layers and lenticular masses, 2) gabbro, 3) gabbroic anorthosite and 4) anorthosite. The Ti-V magnetite deposits are the result of magmatic differentiation of basic magma.

Shimoga District

There are several layered gabbro-anorthosite bodies with V-Ti magnetites in this district at Devarnarsipura, Ubrani, Masanikere–Tavarekere–Magyathahalli and Sakrebyle. Drilling by GSI has indicated reserves of 14.58 million tonnes containing Ti less than 12% and V less than 1.04% and 43-58% of Fe.

In the Masanikere block, vanadiferous titanium bearing magnetite has been proved over a strike length of 1 km by three series of boreholes testing at vertical depths of 60, 100 and 200 m. The average width of the orebody is about 16 m.

Reserves of 8.2 million tonnes of vanadiferous titaniferous magnetite with 0.34% Cu has been estimated. The copper content in the ferro gabbro ranges from 40 ppm to 0.18%.

Tungsten

Incidence of scheelite associated with gold mineralisation is known from the Kolar Gold Field, Hutti Gold Mines, Gadag Gold Field and Chitradurga schist belt. Incidence of tungsten mineralisation is reported from Gulbarga district also.

Kolar District

In the Kolar Gold Field significant scheelite mineralisation is reported from Champion, Nandydoorg and Mysore mines in the Champion lode and its offshoots, Mundy's lode, E.Lode, New Quartz E.lode, Muscoom and Mc.Taggart's West lode. Scheelite occurs either within the gold reef or in wall rock near the lode content.

Reserves in these mines are estimated to be 0.266 million tonnes with 0.18% $W0_3$.

Raichur District

In the Hutti Gold Mines scheelite mineralisation occurs in some sections of the gold lodes and in the adjacent wall rock. Reserves of 0.102 million tonnes are estimated in the Middle reef and Strike reef.

Vermiculite

Vermiculite has been noticed at the contact of ultrabasic rocks with the intruding pegmatite/aplite veins. Vermiculite forms narrow lenticular masses and patches varying from a few centimeters to 8 m wide. Economically significant deposits are confined to Mysore and Hassan districts.

Hassan District

Vermiculite deposits of moderate size have been worked at Malvanagatta, near Holenarsipur, NW of Kalyadi and Somarigudda.

Mysore District

There are eight areas in which vermiculite has been mined intermittently. These are Gopalapura/Mavinahalli area, Thoravalli area, Dodkanya, Thalur area, Uttanahalli, Varuna area, Anaganahalli–Bommanahalli area, Chuchunkatte and Chattanagere area. Of these, the first four deposits are economically significant.

SECTION-2

GEOLOGY AND MINERAL RESOURCES OF GOA

1. Introduction

The State of Goa comprises a narrow strip of land measuring about 100 km in north-south direction and 20-50 km east-west direction, along the West Coast. It lies between latitudes 14°54'15" and 15°47'30" North and longitudes 73°40'45" and 74°20'00" East, covering an area of 3,701 sq.km. J.M.Maclaren (1906) was the first to describe the rocks of the 'Dharwar System' from the Castle rock area of Karnataka across Goa border. L.L.Fermor (1908) examined the iron ore deposit at Bicholim for a comparative study with the Caste rock deposit of Savantwadi area and the iron and manganese ore deposits of Goa. In the fifth decade of nineteenth Century a few Portugese geologists like Dhepe also surveyed the territory of Goa and briefly described the geology of Goa in 1953 with particular reference to iron and manganese ore deposits. They also attempted geological mapping of the entire territory and published the Geology of Goa, under the title 'A Geologia do Distrito de Goa'.

Soon after the liberation of Goa in 1961, systematic geological mapping of the State on 1:63,360 scale was carried out during 1962-68 by a team of officers of Geological Survey of India, namely A.R.Gokul, M.D.Srinivasan, K.Gopalakrishnan and L.S.Viswanathan, followed by second generation mapping during 1980.

2. Physiography

Goa, though famous for its beaches, is essentially a rugged hilly and mountainous tract with narrow valleys and sandy linear plains along the coast. The Western Ghats run in a general north-south direction from Salginim to Surla ghat along the eastern margin of the territory. This segment of Sahyadri ranges are clad with evergreen forests with altitude ranging from 600 m to over 800 m. The highest peak Mamai Devi is 832 m height. In the western margin of the territory, there are long and narrow strips of sandy plains and low flat topped laterite hills ranging in altitude from 50 m to 100 m.

Some of the finest sea beaches of the country are located in Goa. The terrain is undulating with alternate chain of hills and long, narrow valleys. The hills range in altitude from 250 m to 400 m. The Vageri hill near Valpoi, is located much to the west of the Western Ghats and is connected by a narrow link with the Surla ghat.

The state receives an annual rainfall of about 4200 mm, mostly from southwest monsoon and is drained by several west flowing rivers. The eastern border of the state generally marks the water divide between easterly and westerly flowing rivers.

3. Geology

Geologically the state constitutes the northwesterly extension of the granitoid-greenstone terrain of Karnataka, comprising rocks of Precambrian age viz., gneisses, migmatites, granitoids, granites, schists, meta-volcanics (both acid and basic), meta-greywackes, banded ferruginous quartzites associated with manganiferous phyllites / argillites, limestones, dolomites and thin bands of quartzite intruded by granite and mafic-ultramafic complex. Deccan Trap is exposed on the NE border of Goa.

Peninsular Gneisses are well exposed in Anmod Ghat section along the Panaji-Ponda-Londa highway. Qupem in central Goa and Chauri in the south, when Ranebennur Subgroup of Shimoga belt further extend north and northwesterly into Goa in response to the variation in their litho-spectrum and in accordance to the stratigraphic guidelines, they are assigned with the local name called 'Goa Group' which is further divided into four formations. The details of lithology are given in the accompanying Table-1.

The rocks of Peninsular Gneissic Complex and Goa Group are intruded by mafic-ultramafic complexes.

TABLE-1

Regional Stratigraphy of Goa

Eon/Era/Epoch	Supersuite/Suite/ Group	Formation	Lithoassemblage
Quaternary			Beach sands and river alluvium
Pliocene to Pleistocene			Laterite and aluminous laterite
Late Cretaceous to Paleocene	Deccan Trap		Continental flood basalts-mainly tholeiitic type with dykes
Palaeo Proterozoic to Meso Proterozoic	Closepet Granite	Chandranath Granite, Dudsagar Granite, Canacona Granite	Alkaline granites mainly; also variants from monzo granite to granodiorite
Archaean to Palaeo Proterozoic	Mafic-ultramafic Layered Complex		Peridotite-chromitite, dunite-gabbro-norite, pyroxenite
	Goa Group ≈ Chitradurga Group Of Dharwar Supergroup	Vageri	Carbonate-quartz-chlorite schist/greywacke
		Bicholim	Dolomitic limestone
			Quartz-sericite schist
			Banded Iron Formation
			Quartz-chlorite-biotite schist inter-layered with chert, iron and Mn oxides, carbonates, meta-basalt and meta-gabbro
		Sanvordem	Quartzite/greywacke with conglomerate
		Barcem	Quartz-chlorite schist
			Meta-acid volcanic (meta-rhyodacite), quartz porphyry, tuff
			Meta-basalt, meta-gabbro and meta-anorthositic gabbro, quartzite
Archaean	Peninsular Gneiss-II	Ankola Gneiss, Anmod Ghat Gneiss	Migmatite and granites (s.1); tonalite-trondjhmite-granodiorite

The mafic-ultramafic complexes include (i) layered dunite-peridotite (harzburgite/ Iherzolite), pyroxenite-gabbro complex with chromitite lenses, as seen in the Usgaon area, and (ii) the layered pyroxenite-gabbro-anorthosite with titaniferous-vanadiferous magnetite complex observed in the Karnal Ghat, Aven and Landa area of Goa.

The younger intrusive granite viz., Chandranath Granite, Dudhsagar Granite and Canacona Granite have been respectively dated at 2650±100 Ma, 2565±96 Ma and 2395±390 Ma (Dhoundiyal et al, 1987) correspond to Closepet Granite and Chitradurga Granite of Karnataka.

A small northeastern segment of the Goa between Vainguinim to Choreundem has been covered by Deccan basalts at an elevation of 600-700 m above m.s.l.; atleast four flows of 'Pahaehoe' type dipping northwesterly are recorded in the vertical sections.

Almost, all rock types of Goa has been lateritised to some extent. In general, iron-manganese phyllites (schistose rocks of Dharwar Supergroup) show the laterite profile of about 100 m depth; laterite cover is seen over a depth of 10 m in ultramafites and 5 m over Deccan Trap. The Quaternary formations are represented by beach sands and alluvium, all along the coastal zone of Goa and along the river courses respectively.

The general strike of the rocks is NW-SE in the northern, eastern and southeastern parts of the state and E-W over a limited area in the southern and southwestern parts of the state. The regional configuration of the rocks is that of northwesterly plunging synclinorium (F_1) in which a number of antiforms and synforms plunging both towards ESE and WNW have been superposed (F_2). A third phase of folding (F_3) has given rise to small scale, open warps with northerly plunge.

4. Mineral Resources

Though Goa has a limited area of 3701 sq.km, it is well endowed with economic mineral deposits, particularly iron and manganese ores. The *in situ* reserves of about 967 million tonnes of the haematite, 187 million tonnes of magnetite and 83.1 million tonnes of manganese ore respectively constitute 8.00%, 3.08% and 22.4% of the total resources estimated for the country. Because of their proximity to the sea port, they are being mined extensively for export.

Besides iron and manganese, a number of deposits of bauxite, silica sand, low grade limestone, clays, low grade chromite and quartzite are also known from Goa.

Bauxite

Bauxite generally occurs as irregular pockets within a length of about 130 km. *In situ* deposits formed from and occur over meta-basalt, phyllite and greywacke. The thickness of laterite ranges upto 15 m of which the bauxite horizon is seen 9 m below the surface

level with the thickness ranging from 3 to 5 m. Bauxite underlies ferruginous laterite and overlies a clay horizon.

Geographically, bauxite deposits can be categorised into three groups:

1. North Goa deposits : Mopa, Pernem, Morgim, Ibrampur, Dargalim and Koragaon.
2. Central Goa deposits : Consua and Quelossim.
3. South Goa deposits : Betul plateau, Palolem and Galgibaga plateau.

The North Goa deposits are more promising than the others. The recoverable reserves estimated are 28.09 million tonnes.

Chromite

Two chromite bodies occurring within serpentinised dunite have been delineated in the area about 1 to 2 km east and northeast of Bondla, (i) over a strike length of about 2.4 km with an average width of about 600 m (ii) about 250 m to the east of the above ore body, over a strike length of about 350 m with a width of about 200 m. The Cr_2O_3 content ranges from less than 10% to about 28% (Balakrishnan et al, 1990).

Clays

Small and lenticular deposits of clay are recorded from a number of places in Goa. The major deposits are at Camarconda, Concem and Befora in Ponda taluk, Kakora in Quepem taluk and Colvale in Bardez taluk. A two to six meters thick mantle of hard, brown to cherry red laterite forms the overburden and cover almost all these deposits. The Camarconda (south) and Kakora (north) deposits constitute high grade refractory material. The clay from Camarconda (south) shows white colour, low drying shrinkage, low water absorption, high vitrification and pale white colour after firing. This clay can be used in paper, textile, paint, linoleum and rubber industries.

Reserves are estimated to be 0.164 million tonnes of washed clay.

Iron Ore

Iron and manganese ore deposits are reported along a 95 km long NW-SE trending belt extending from Saliginim to Noibaga. The larger and better iron ore deposits occur in North Goa between Advolapale and Usgaon. There is a gradual decrease in the concentration of iron and increase in the concentration of manganese towards south.

The iron ore deposits consist essentially of haematite and partially of magnetite, limonite and goethite. They occur as lensoid bodies on the crests and slopes of hills. The deposits were formed as residual concentration and enrichment process called lateritisation of the banded ferruginous quartzite and phyllite of the Goa Group of meta-sediments.

The iron ore bodies are massive, bedded, platy, brecciated, earthy laminated (biscuity) concretionary and powdery (blue dust) in nature. Generally hard lumpy ore occurs at the surface followed by friable and powdery one at depth. On these deposits the average iron content is about 59%. The titanium, sulphur and phosphorous contents are low. The powdery ores are deep blue in colour and have an average Fe content of 63%.

The width of the ore bearing zone varies from place to place. It is 3.5 to 4.4 km from north of Assonora upto River Madei. South of River Madei, there are two strips, each about 1 km wide; occurring in a 'V' shape. The northeastern one extends from Balcornem to Sonal. The southwestern band extends from Poicul to Sancordem, south of Molem and Darbandora road. The zone extends in a roughly E-W direction between Viliena to Bargacho Dongar for a length of 280.92 m in east-west direction and Curdi to Salginim in north-south direction. There are also isolated small occurrences along the coast near Betul and Canaguinim.

The important deposits in North Goa are Bicholim, Sanquelim, Velguem and Palle.

Detailed exploration carried out by GSI for iron ores in North Goa resulted in establishing in situ reserves of 1061 million tonnes of 62.62% Fe grade haematite ore; and 144 million tonnes of low grade magnetite ore with 35.91% Fe. A total of 680 million tonnes of ores of all grades are estimated in South Goa.

Large resources of low grade magnetite ore with 25-40% Fe content are available in the Dhave-Sonal area. Besides that, there are other ore bearing potential areas, which may collectively contribute substantially large tonnes of low grade limonitic and siliceous ores on beneficiation.

Limestone

A limestone band about 50 m thick, extends over a strike length of about 20 km from Ivore khurd in the west to Derodem in the east, closely following the structural pattern of the Precambrian rocks. It carries numerous bands, lenses, veinlets and streaks of intercalated chert and quartzite, erratically distributed within the main body of the limestone. It is mostly a magnesium rich crystalline limestone containing Ca0 33%, Mg0 12.8%, with a few cement grade zones in the Surla Ghat.

The estimated reserves of all grades of limestone are about 80 million tonnes.

Manganese Ore

Manganese ore deposits of Goa are lateritoid type and found on or near the surface, in areas occupied by Fe-Mn phyllites. They occur as irregular lensoid bodies and pockets of varying dimensions.

The deposits comprise laterite at the surface with concretions of black coloured iron and manganese ores followed at depth by bouldery manganese ore and then by manganiferous

clay called 'Wad'. The ore minerals are mainly pyrolusite, psilomelane and partly cryptomelane, biannite and manganite. The grade of ore ranges from metallurgical to black iron ore with total Fe+Mn content of 42-45%. The iron content varies inversely with manganese in general.

All deposits of economic significance are confined to the southern part of Goa viz., Rivona, Canvorem, Salginim, Verlem, Columba, Netrolim, Muriem, Pirla and Cosmor areas.

The Salginim and Verlem deposits contain high grade ore, with upto 55% Mn. Recoverable reserves are estimated to be about 23.56 million tonnes.

Platinoids

A mafic-ultramafic complex extending over a strike length of 20 km with the maximum width of 4 km is observed near Usgaon. The major constituents include dunite, peridotite, pyroxenite and gabbro. The ultramafic variants, dunite and harzburgite host chromite mineralisation at Usgaon and Bondla.

Occurrences of Pt, Pd, Rh, Ir and Ru is detected from the chromite samples of the Bondla area.

Quartzite

Quartzites suitable for the manufacture of coloured glassware, ferro-silicon and refractory bricks are reported around Concem and Shiroda in Ponda taluk. The quartzite is hard, massive and almost white in colour. A reserve of 14.55 million tonnes, with 96.18% to 97.64% silica and 0.84 to 1.06% iron content, is estimated upto a depth of 10 m.

Silica Sand

Silica sand deposits of considerable magnitude are reported along the coast of Goa. The important deposits are: (1) Calanguta, Baga sector extending from Agoada in the south to Baga in the north and (2) Betul, Pali sector extending from Betul in the south to Pali in the north.

In the Betul-Pale sector a sandy tract about 26 km long and 300 to 800 m wide has been observed. The sand is fine grained and light grey to light honey yellow in colour. The frequency curves of grain size show a general reduction in the grain size of sand from south to north and west to east. The chemical analysis shows SiO_2 93.20-96.48%, Fe_2O_3 0.53-1.67%, Al_2O_3 0.21-2.08% and TiO_2 0.11-1.20%. The estimated recoverable reserves are 17.02 million tonnes.

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