Journal of Geology & Geosciences
ISSN: 2381-8719
Das and Mohanty, J Geol Geosci 2014, 3:6
DOI: 10.4172/2329-6755.1000180
Research Article
Open Access

# Characterisation of Eluvial Corundum (Ruby) from Kermunda, Kalahandi District, Odisha, India

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## Abstract

Corundum and ruby occur sporadically in the soil horizons around Kermunda area, which is situated in Kalahandi district of Odisha. The area is constitutes a part of the Precambrian khondalite-charnockite-granite gneiss terrane of Eastern Ghats. Corundum is light pink while ruby is rose red, carmine or purple red in colour. The corundum and ruby grains contain inclusions of rutile and zircon and are often surrounded by dark coloured spinel exhibiting corona texture. Sapphirine occurs as rim around spinel as well as corundum. Veinlets of hematite and diaspore traverse spinel and sapphirine aggregates. SEM-EDS analysis indicated that (i) corundum and ruby grains contains trace amounts of Fe and Cr, (ii) spinel is pleonaste and chromium pleonaste types and (iii) sapphirine is silica- poor and magnesian rich. The corundum-spinel intergrowth showing corona texture suggests that under high P-T gradient in granulite facies metamorphism, corundum reacted with either phlogopite or garnet to form spinel by the reactions: (i) Corundum + Phlogopite= Spinel + K-feldspar + Water or (ii) Corundum+Garnet = Spinel. Sapphirine is possibly a reaction product of (i) Corundum+Spinel+Garnet= Sapphirine or (ii) Spinel+Silica= Sapphirine.

**Keywords:** Corona Texture; Spinel; Sapphirine; SEM-EDS; Kermunda; India

## Introduction

Gemstones, especially the quality gemstones are most sought after minerals throughout ages due to their astrological and ornamental importance. The quality of gemstones is determined by its natural origin, beauty, durability, uniqueness, rarity, hardness, colour, size, structural defects and chemical resistance.

In India, Odisha state is famous for occurrences of varieties of gem stones and among them ruby and sapphire are conspicuous. The entire resource of ruby (5348 tonnes) is located in the state of Odisha, mainly in Kalahandi and Nuapara districts [1]. The important localities of corundum and ruby bearing zones are Jhillngdhar, Hinjlibahal, Banjipadar and Kermunda in Kalahandi district and Sinapalli and Sardapur in Nuapara district. At Jhillingdara, Mishra and Mohanty [2] reported occurrences of ruby and corundum mineralization at the contact between metapyroxenite and granite gneiss and also eluvial placer ruby in the surrounding soil horizons. Mazumder and Mathiew [3] reported corundum (ruby) crystallization in the brecciated pegmatite at contact zones of granite gneiss of Bastar craton near Sardapur area.

The NW margin of Odisha represents a cratonic mobile belt contact where high grade granulite facies rocks of Eastern Ghats Mobile belt are juxtaposed upon the low grade greenstone supracrustal rocks of Bastar craton. Several authors have studied the geology of Eastern Ghats mobile belt of India [4], and references therein]. Corundum-spinel-sapphirine bearing Mg-Al rich granulites occur sporadically at different localities in the high grade metamorphic rocks of Eastern Ghats belt of Odisha [5]. The mineral assemblages in the Mg-Al rich rich rocks include: cordierite, phlogopite, orthopyroxene, corundum, spinel, sapphirine, kyanite, cummingtonite, gedrite, paragsite, garnet, sillimanite, rutile and quartz. Figure 1 is the geological map around Kermunda and the rock types- granite gneiss, mafic granulites and vein quartz- belong to Eastern Ghats belt [6]. Kermunda area is rugged and is extensively covered by soil and alluvium. At a number of localities small to large pits and trenches were dug illegally to pick out the corundum / ruby and garnet varieties form the soil zones. In this paper, we report macroscopic and microscopic textures and mineral chemistry of eluvial corundum/ruby grains from Kermunda area.

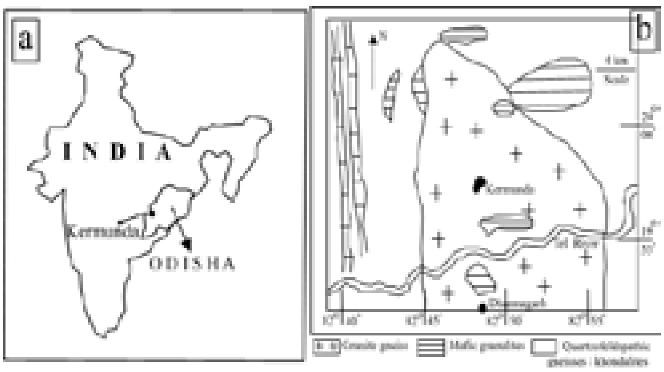


**Figure 1:** (A) Map of India showing location of Kermunda in Odisha state and (B) Geological map around Kermunda [6].

## Materials and Methods

Corundum and ruby samples were collected by hand picking from different pits and trenches dug within alluvium zone. The size of the samples ranges between 20 to 3 mm. In the laboratory the samples were washed with dil. HCl to remove the ferruginous clay coatings followed by cleaning with water in ultrasonic bath. Thin sections of the grain mounts were prepared. Polished sections were made for study under ore microscope and Scanning Electron Microscope (SEM). Semi-quantitative analysis of the mineral phases was done by Energy Dispersive Spectrometer (EDS) attached to SEM.

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**Received** September 29, 2014; **Accepted** October 18, 2014; **Published** October 29, 2014

**Citation:** Das SK, Mohanty JK (2014) Characterisation of Eluvial Corundum (Ruby) from Kermunda, Kalahandi District, Odisha, India. J Geol Geosci 3: 180. doi: 10.4172/2329-6755.1000180

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**Figure 2:** Basal sections of corundum grains. Scale: 5 mm.

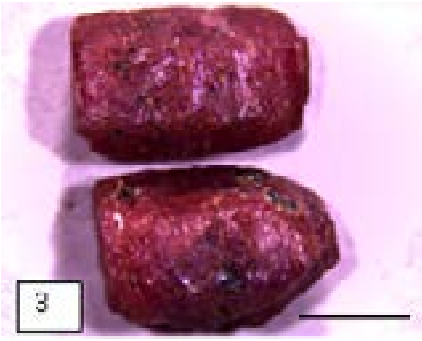


**Figure 3:** Barrel shaped corundum grains. Scale: 5 mm.


**Figure 4:** Red colour ruby grains. Scale: 5 mm.

## Results

### Macroscopic study

The colour of the corundum grains is light pinkish and the grains are barrel, hexagonal, rhombohedral and irregular shaped (Figures 2 and 3). Basal parting is prominent in the hexagonal and barrel shaped grains. Small dark colour mineral (rutile) is noted in corundum. The colour of the ruby grains is red to crimson red. The grains are mostly subrounded, elliptical and angular in nature (Figure 4). Occasionally, dark green spinel partially covers the ruby surface (Figure 5). Some ruby grains show distinct corona texture due to presence of spinel rim (Figure 6).

### Microscopic study

Under transmitted light microscope, the colour of the corundum grains is faint pinkish while the ruby grains are crimson red. Fractures are prominent in both corundum and ruby grains (Figures 7 and 8).


**Figure 5:** Skin of spinel on the ruby. Scale: 5 mm.

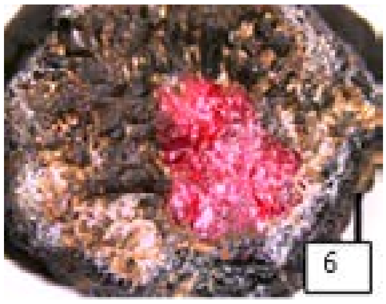


**Figure 6:** Corona texture around the ruby grain. Scale: 5 mm.

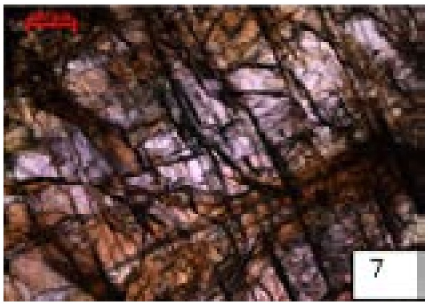


**Figure 7:** Reticulating fractures in corundum.

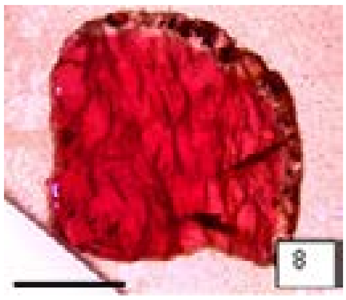


**Figure 8:** Pink ruby with fractures. Scale: 5 mm.

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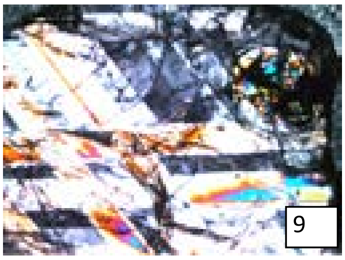


**Figure 9:** Twinning in corundum.

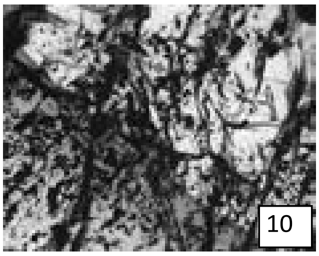


**Figure 10:** Corundum with rutile and zircon inclusions.

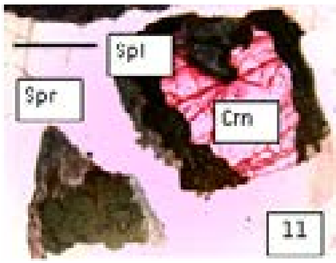


**Figure 11:** Spinel (Spl) and sapphirine (Spr) coronas around ruby (Crn). Left hand side grain: sapphirine around spinel (Spl).

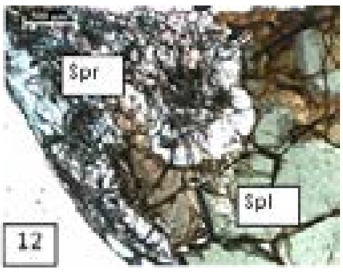


**Figure 12:** Tabular and granular sapphirine grains (Spr) around xenoblasstic spinel (Spl).

A few grains show well developed twinning feature (Figure 9). Rutile and zircon are major mineral inclusions within corundum (Figure 10). Corona texture is well documented in which spinel partially to completely mantle the host corundum and ruby grains (Figure 11). Spinel is green to deep green in colour and occurs as coarse xenoblastic crystals (Figure 12). In some samples, sapphirine grains are noted which exhibits distinct pleochroism from blue, pale yellow to sapphire blue. It occurs as reaction rim around both spinel and corundum with characteristics of tabular, radiating sheaths to granular aggregates (Figures 12 and 13).

## SEM study

The SEM micrographs (BSE images) of corundum and ruby grains are shown in Figures 14-22. BSE images have the advantage of distinguishing the mineral phases which show minor differences in the brightness and contrast values. Moreover, EDS analysis of coarse to very fine grains helps in identification of mineral phases. Successive rims of spinel and sapphirine around ruby grains are shown in Figure 14. The contact between the different mineral phases is irregular and sharp. Partial rim of sapphirine around corundum grain is shown in Figure 15. Sapphirine also grows within corundum as Y-shaped grains. This corundum grain contains inclusions of minute phlogopite


**Figure 13:** Tabular sapphirine (Spr) around spinel (Spl).

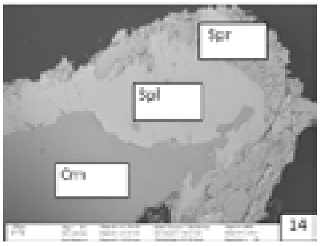


**Figure 14:** Successive rims of spinel (Spl) and sapphirine (Spr) around corundum (Crn).

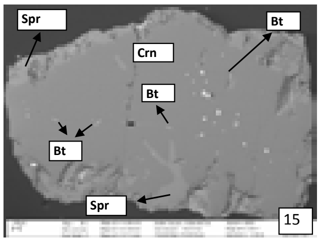


**Figure 15:** Sapphirine rim around corundum. Y-shaped-sapphirine protruding corundum. Note biotite (Bt) inclusions.

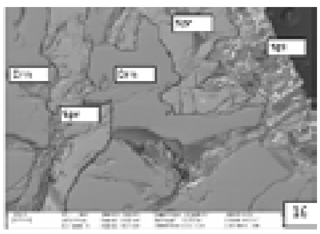


**Figure 16:** Grain boundary contact between corundum-sapphirine, sapphirine-spinel and corundum-spinel.

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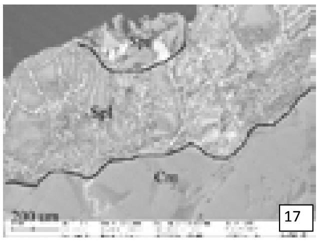


**Figure 17:** Corundum with rim of corroded spinel and small part showing clusters of subhedral sapphirine grains.

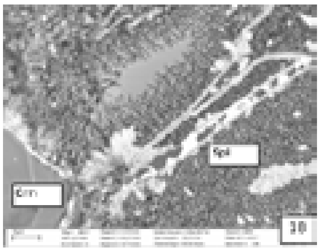


**Figure 18:** Contact between corundum and the corroded spinel. Note hematite veinlets.

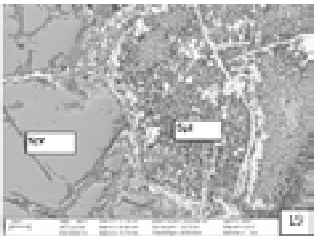

**Figure 19:** Contact between sapphirine and corroded spinel. Note hematite veinlets.

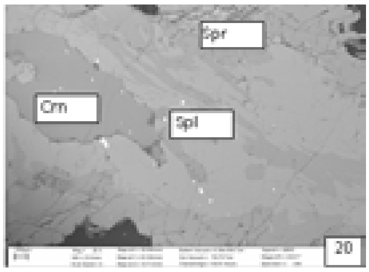


**Figure 20:** Corundum surrounded by patchy spinel - and sapphirine intergrowth.

laths and subrounded rutile grains. Grain boundary contact between corundum-spinel, spinel-sapphirine and corundum-sapphirine is depicted in Figures 16-19. Fractures are common in both corundum and sapphirine. Spinel grains frequently exhibit corroded patterns which are possibly due to brecciation and chemical weathering. Fine veinlets and irregular masses of hematite are common within spinel grains (Figures 18,19). The patchy and inter-fingering intergrowth of spinel-corundum-sapphirine and spinel-sapphirine are shown in Figures 20 and 21 respectively. Rutile grains occur as inclusion within the corundum, spinel and less commonly within sapphirine grains. Coarse rutile grains are also noted along the grain boundaries of polygonal spinel grains (Figure 22). Besides rutile, the other minerals noted as inclusions in corundum, spinel and sapphirine are: zircon, monazite, ilmenite and Y-W oxide. Diaspore veinlets and masses are observed mostly in association with spinel and sapphirine (Figure 23). Diaspore is a hydration product of corundum and spinel and formed during chemical weathering.

## EDS analysis of the minerals

The range and average chemical composition of corundum, spinel, sapphirine, phlogopite and rutile are given in Table 1. Both corundum and ruby contain trace amounts of Fe, Mg and Cr. Two types of spinels (Mg-Al rich and Cr-Zn rich) are identified from the chemical composition. The Mg-Al rich variety contains high amounts of alumina ($Al_2O_3$= 64.83%) and moderate amounts of Fe (FeO(t)= 13.70%) and Mg (MgO= 19.85%) and minor chromium ($Cr_2O_3$= 1.19%) and Zn (ZnO =0.06%). It has average atomic composition of $Mg_{72.12}$ and falls in the pleonaste range. The Cr-Zn spinel is distinctly rich in Cr ($Cr_2O_3$= 6.17%), Zn (ZnO= 2.91%) and Ni (NiO= 1.57%). It is chromium pleonaste in composition and moderately magnesian ($X_{Mg}$= 50.83). Patel et al. [5] also noted spinel with variable Mg number ($X_{Mg}$= 0.48-0.85) in the silica-deficient high grade Mg-Al rich rocks of

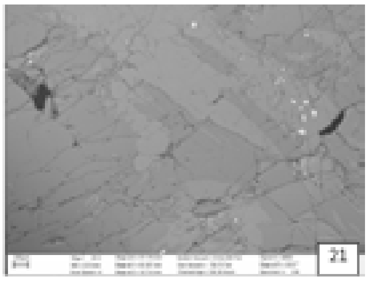


**Figure 21:** Inter-fingering intergrowth of sapphirine and spinel.

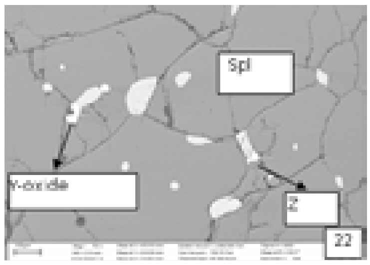


**Figure 22:** Rutile along grain boundary and inclusions in spinel. Note small Y-oxide and zircon (Z).

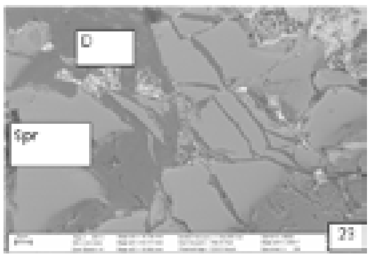


**Figure 23:** Diaspore (D) masses and veins and sapphirine.

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| | Corundum (3) | | | Spinel (7) | | | Spinel | Sapphirine (6) | | | Rutile (4) | | | Phologopite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Range | | Av. | Range | | Av. | | Range | | Av. | Range | | Av. | |
| | ↔ | | | ↔ | | | | ↔ | | | ↔ | | | |
| $SiO_2$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 10.50 | 13.47 | 12.42 | ------ | ------ | ------ | 35.62 |
| $TiO_2$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 96.42 | 98.66 | 97.32 | 2.71 |
| $Al_2O_3$ | 98.34 | 99.00 | 98.96 | 62.8 | 67.79 | 64.83 | 53.84 | 65.04 | 67.43 | 64.18 | ------ | ------ | ------ | 19.22 |
| $Cr_2O_3$ | 0.15 | 0.87 | 0.37 | 0.35 | 2.41 | 1.19 | 6.17 | 0.15 | 2.66 | 0.82 | 0.00 | 1.20 | 0.30 | ------ |
| FeO(t) | 0.20 | 0.51 | 0.38 | 10.63 | 16.63 | 13.70 | 21.87 | 2.17 | 5.42 | 3.64 | 0.00 | 1.02 | 0.55 | 5.83 |
| MgO | 0.00 | 0.93 | 0.48 | 18.33 | 22.99 | 19.85 | 12.70 | 18.1 | 19.91 | 19.00 | ------ | ------ | ------ | 23.29 |
| CaO | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| ZnO | ------ | ------ | ------ | 0.00 | 0.08 | 0.06 | 2.91 | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| NiO | ------ | ------ | ------ | ------ | ------ | ------ | 1.57 | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| $Na_2O$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 1.13 |
| $K_2O$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 9.93 |
| $ZrO_2$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | 0.00 | 0.09 | 0.07 | ------ |
| Total | | | 100.19 | | | 99.57 | 99.06 | | | 100.06 | | | 98.14 | 97.73 |

**Table 1**: EDS analysis of different mineral phases. Nos. in parantheses- No. of points analysed.

Hatimunda and Jhilingdara area. Sapphirine contains high amounts of alumina ($Al_2O_3$= 64.18%), Mg (MgO=19.00%) and less iron (FeO(t)= 3.64%) with $X_{Mg}$ value of 90.30 which is comparable with sapphirine of Hatimunda hill [5]. The rutile grain contains small amounts of Zr and traces of Cr and Fe. Phlogopite is magneisan rich ($X_{Mg}$ = 87.64) variety.

## Discussion

Corundum mineral is encountered in wide variety of rock types. It is relatively common in metamorphic rocks and its P-T stability domain is vast. Sapphirine is a metamorphic mineral and occurs in rocks of granulite facies metamorphism of Mg-Al rocks containing cordierite, phlogopite, corundum, garnet, gedrite, cummingtonite, orthopyroxene, spinel and aluminosilicate minerals [7]. On the basis of texture, grain contact and mineral association in the Mg-Al rich rocks several types of metamorphic reactions have been proposed for the formation of these minerals [8-10]. From the textural studies of the eluvial corundum and ruby samples of the study area, it is difficult to uniquely deduce reactions / metamorphic conditions leading to the formation of different minerals. In the surrounding soil horizons, besides corundum the other dominant coarse minerals are quartz, garnet and phlogopite with small amounts of goethite, titaniferous magnetite and altered feldspars.

The textural observation in the studied corundum and ruby grains suggests that the spinel is derived from reaction between corundum and other silicate minerals. In one corundum grain phlogopite inclusion is recorded. Spinel grains contain significant amounts of Fe and Mg suggesting that spinel might have been formed by reaction of corundum and Mg-Fe containing silicate mineral, phlogopite or garnet. The following reactions singularly or in combination might have given rise to the observed corundum-spinel textural features. The reactions are: (a) Phlogopite + Corundum = Spinel + K-feldspar +water [7] or (b) Corundum + Garnet = Spinel.

Sapphirine occurs as rims around spinel as well as corundum. It might have been formed by the following reactions: (i) Spinel + Silica = Sapphirine or (ii) Corundum+Spinel+ Garnet= Sapphirine [10]. These reactions are based on the fact that garnet and quartz are abundant in the surrounding soil suggesting possible reaction with spinel to form sapphirine in the host rocks.

## Conclusions

(1) The eluvial corundum grains are faint pinkish whereas ruby grains are purple red in colour. They are highly fractured and contain abundant rutile and minor amounts of zircon, monazite, Y-oxide and ilmenite inclusions.

(2) Well developed corundum-spinel corona texture suggests reaction of corundum and biotite or garnet to form spinel during high grade metamorphic condition of the protolith.

(3) The spinel grains belong to pleonaste to chromium pleonaste type as indicated by their composition.

(4) Sapphirine occurs in contact with corundum and also as rim around spinel. Sapphirine is formed by reaction of spinel and quartz or garnet under granulite facies metamorphic conditions.

From the mineralogical and chemical studies, it is concluded that the eluvial ruby grains from Kermunda area are of low quality due to presence of fractures, random mineral inclusions and corona texture.

**Acknowledgement**

The authors are grateful to Prof. B.K. Mishra, Director, IMMT, Bhubaneswar for his encouragement and kind permission to publish this paper. The authors thank Mr. M.K. Senapati, Joint Director, Directorate of Geology, Govt. of Odisha for discussion and Mr. Mund at Bhawanipatna for sample collection.

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