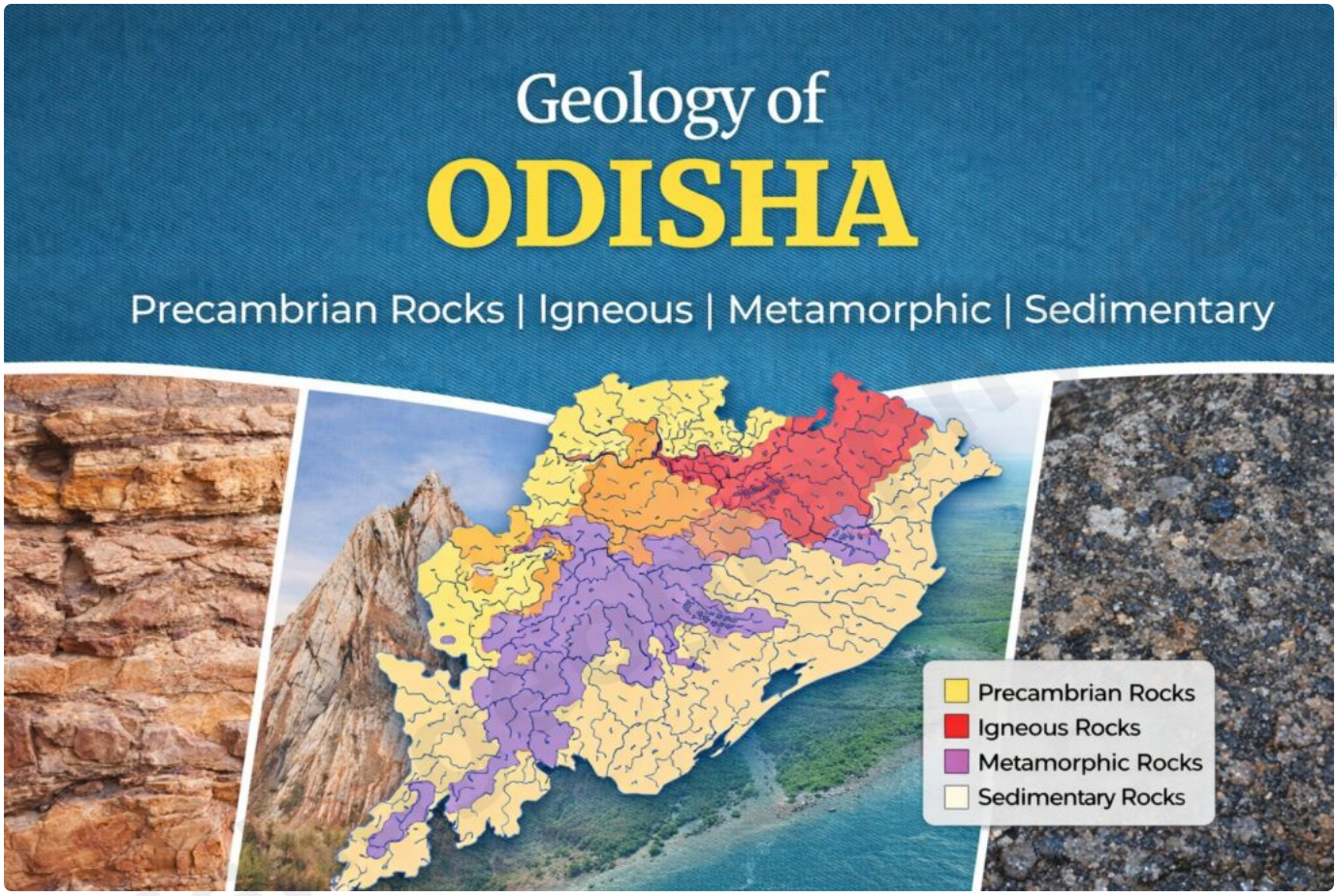
Geology of Odisha

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About 72.5% of Odisha is made of ancient Precambrian rocks, more than 540 million years old and in places over 3 billion years old, which host most of its mineral wealth. Gondwana sedimentary rocks, which hold the coal, cover about 8% of the state, and younger Tertiary and Quaternary deposits make up the rest (Directorate of Geology, Odisha).

Odisha lies on the eastern edge of the **Indian Shield**, the stable old core of peninsular India. Here several ancient crustal blocks meet: the **Singhbhum Craton** in the north, the **Bastar Craton** in the west, and the **Eastern Ghats Granulite Belt** in the south, a mountain belt that once joined India to East Antarctica in the supercontinent of Gondwana.

Later, rifts along the Mahanadi valley filled with coal-bearing sediments, and the coastline grew outward with sediments carried by the great rivers.

This geological history explains why Odisha is India’s mineral treasury, why its landscape has plateaus, hill ranges, river valleys and deltas, and why its soils and groundwater vary so much from place to place. This article covers the geological framework, stratigraphic succession, major rock formations, structure and seismicity, the economic importance of geology, and important geoheritage sites.

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Geological framework

Odisha can be divided into a few major geological domains: two ancient cratons, a high-grade mountain belt, a transition zone between them, younger rift basins and the coastal plain.

Domain	Area covered (approx.)	Main rocks	Significance
Singhbhum (North Odisha) Craton	Keonjhar, Mayurbhanj, Sundargarh, Jajpur, northern Dhenkanal	Old gneisses, Singhbhum and Mayurbhanj granites, Iron Ore Group, ultramafic complexes	One of the oldest pieces of crust in India (over 3 billion years); hosts iron ore, manganese, chromite and nickel
Bastar Craton	Western Odisha: Nuapada, parts of Bargarh, Bolangir, Kalahandi and Malkangiri	Granite gneisses and younger Proterozoic sedimentary basins (Khariar, Ampani, Bargarh)	Western ancient block; limestone and other sedimentary minerals
Eastern Ghats Granulite Belt	South and west: Koraput, Rayagada, Kalahandi, Kandhamal, Ganjam, Gajapati, Nayagarh, Boudh, Bolangir	Khondalite, charnockite, granite gneiss and anorthosite	A deeply eroded ancient mountain belt; bauxite, graphite, gemstones and manganese
Rengali Province (transition zone)	Angul, Deogarh, Sambalpur	Mixed granulites, gneisses and schists	Boundary zone where the Eastern Ghats belt meets the Singhbhum craton
Gangpur and other Proterozoic belts	Sundargarh	Schists, phyllites, limestone and dolomite	Limestone, dolomite and manganese for steel and cement

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Gondwana basins (Mahanadi rift)	Talcher (Angul–Dhenkanal) and Ib Valley (Jharsuguda–Sundargarh)	Sandstone, shale and coal	Odisha’s coalfields
Coastal plain and offshore basin	The coastal districts and the Bay of Bengal shelf	Tertiary sediments, laterite and recent alluvium	Fertile deltas, heavy mineral sands and offshore hydrocarbons

Stratigraphic succession

Odisha’s rocks span more than 3.5 billion years, from some of the oldest rocks on Earth to sediments still being laid down by its rivers. The generalised succession, from youngest to oldest, is:

Era / age	Approx. age	Rock formations in Odisha	Where found	Minerals
Quaternary (Recent and Pleistocene)	Last 2.6 million years	River and delta alluvium, coastal sands, dunes, lagoon (Chilika) deposits	Coastal plains, river valleys	Heavy mineral sands, clay, sand
Tertiary	66–2.6 million years ago	Baripada beds, sediments under the coastal plain and offshore; laterite capping on plateaus	Mayurbhanj (Baripada), coastal belt, plateau tops	Bauxite, laterite, china clay, offshore gas
Cretaceous	About 100–66 million years ago	Athgarh Sandstone; volcanic rocks of the Rajmahal type in the subsurface	Athgarh, Cuttack–Khordha area	Building stone
Gondwana Supergroup (Permian–Jurassic)	About 300–150 million years ago	Talchir boulder beds (glacial), Karharbari and Barakar coal measures, Kamthi sandstones	Talcher and Ib Valley basins, small outliers	Coal, fireclay
Late Proterozoic (Purana)	About 1.6 billion–540 million years ago	Chhattisgarh-type sediments: Khariar, Ampani, Bargarh basins; limestone and shale	Nuapada, Kalahandi, Bargarh	Limestone, dolomite
Early to Middle Proterozoic	About 2.5–1.6 billion years ago	Gangpur Group, Singhbhum Group, Eastern Ghats khondalites, charnockites and granites; mafic dykes	Sundargarh, Eastern Ghats region	Manganese, graphite, gemstones, limestone

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Archaean	Over 2.5 billion years ago	Older Metamorphic Group and tonalite gneisses, Singhbhum and Mayurbhanj granites, Iron Ore Group (banded iron formation), ultramafic complexes of Sukinda and Nuasahi	Keonjhar, Mayurbhanj, Sundargarh, Jajpur	Iron ore, chromite, nickel, manganese, gold

Ages are approximate, and some formations (for example the Eastern Ghats rocks) went through several episodes of metamorphism at different times.

Precambrian formations: Archaean and Proterozoic

The Precambrian rocks form the plateaus and hill ranges of northern, western and southern Odisha and contain nearly all its metallic minerals.

Singhbhum Craton (North Odisha)

- **Older Metamorphic Group and tonalite gneisses:** among the oldest rocks in India, over 3.3–3.5 billion years old, exposed around Champua (Keonjhar).
- **Singhbhum and Mayurbhanj granites:** large granite bodies, about 3.1–3.3 billion years old, forming much of the Keonjhar–Mayurbhanj plateau.
- **Iron Ore Group:** banded iron formations, shales, volcanic rocks and quartzites folded into the horseshoe-shaped **Bonai–Keonjhar synclinorium**. Leaching of these rocks over time produced the rich haematite deposits of Joda, Barbil, Koira and Gandhamardan.
- **Simlipal Complex** (Mayurbhanj): a near-circular basin of volcanic and sedimentary rocks, which forms the Similipal hills.
- **Ultramafic complexes** of **Sukinda** (Jajpur) and **Baula–Nuasahi** (Keonjhar): rocks from deep in the Earth’s mantle that host chromite, nickel and platinum-group elements.

Gangpur Group and other Proterozoic belts

The **Gangpur Group** of Sundargarh is a folded belt of schists, phyllites, limestone, dolomite and manganese-bearing rocks, about 2.0 billion years old. Its limestone and dolomite supply the cement and steel industries of Rajgangpur, Biramitrapur and Rourkela.

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Bastar Craton

Western Odisha is underlain by granites and gneisses of the Bastar Craton. On top lie younger Proterozoic sedimentary basins such as **Khariar**, **Ampani** and **Bargarh**, related to the Chhattisgarh basin, with sandstone, shale and limestone that form flat-topped plateaus like the Khariar plateau.

Eastern Ghats Granulite Belt

The Eastern Ghats are the deeply eroded roots of an ancient mountain range. Their rocks were metamorphosed at very high temperatures and pressures:

- **Khondalite** (garnet–sillimanite–graphite schists, named after the Khond people of the Khondmals): weathers into thick bauxite and laterite caps on plateaus such as Panchpatmali; also hosts graphite.
- **Charnockite:** dark, hard rock that forms many hill ranges, including the Mahendragiri and Deomali areas.
- **Anorthosite massifs** (for example near Chilika and Bolangir), and **alkaline rocks** such as nepheline syenite in Koraput and Khariar.

The Eastern Ghats belt took its final shape about 1 billion years ago, when the Indian landmass collided with East Antarctica during the formation of the supercontinent Rodinia. Matching rocks are found today in Antarctica.

Rengali Province

Between the Eastern Ghats belt and the Singhbhum Craton lies the **Rengali Province** (Angul–Deogarh–Sambalpur), a zone of mixed high- and low-grade rocks, bounded by major shear zones. It marks the suture where these two crustal blocks were joined.

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Gondwana Supergroup and the Mahanadi rift

About 300 million years ago, when India was part of the southern supercontinent Gondwanaland, the crust along the present Mahanadi valley stretched and sank, forming the **Mahanadi Graben**, a long rift valley running north-west to south-east. Rivers and swamps filled this rift with sediments, and the thick forests that grew there were buried and turned into coal.

Gondwana succession in Odisha

Formation	Rock type	Significance
Talchir Formation	Boulder beds (tillite), shales and sandstones	Deposited by glaciers; named after **Talcher**, it is the type area for India’s oldest Gondwana rocks
Karharbari and Barakar formations	Sandstones, shales and coal seams	Main coal-bearing units of the Talcher and Ib Valley coalfields
Barren Measures and Kamthi formations	Sandstones and shales with little coal	Upper Gondwana units forming ridges and plateaus
Upper Gondwana (Athgarh Sandstone)	Sandstone	Exposed around Athgarh and Cuttack; used as building stone

Coal basins

- **Talcher Coalfield** (Angul and Dhenkanal): one of India’s largest coal reserves, with very thick seams suited to opencast mining.
- **Ib Valley Coalfield** (Jharsuguda and Sundargarh): extends into Chhattisgarh as part of the larger Mahanadi basin.

Odisha’s Gondwana coal is mostly high-ash, non-coking coal used in thermal power plants, and together these basins hold about a quarter of India’s coal reserves.

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The ancient Mahanadi rift still influences the landscape: the Mahanadi and Brahmani rivers follow its trend, and the boundary faults of the graben are among the state's main structural lines.

Younger formations: Tertiary, laterite and Quaternary

After India broke away from Antarctica about 130 million years ago, Odisha's eastern edge became a passive continental margin. Its coastal plain and offshore shelf have been building outward ever since, with sediments carried down from the plateaus.

Tertiary formations

- The **Baripada beds** (Mayurbhanj) are Miocene clays and limestones with marine fossils such as shark teeth and shells, showing that the sea once reached inland.
- Thick Tertiary sediments lie beneath the coastal plain and the **Mahanadi offshore basin**, where exploration has found natural gas.

Laterite and bauxite

Under a hot, wet tropical climate, long weathering of khondalite, basalt and other rocks leached out silica and left iron- and aluminium-rich crusts. These form:

- **Laterite** caps on plateaus and uplands around Khordha, Bhubaneswar, Cuttack, Dhenkanal and Keonjhar. Laterite was the main building stone of many historic temples and forts.
- **Bauxite** caps on the high Eastern Ghats plateaus (Panchpatmali, Baphlimali, Niyamgiri, Gandhamardan), making Odisha India's leading bauxite state.

Quaternary alluvium and the coast

- **Deltas:** the Mahanadi, Brahmani–Baitarani, Subarnarekha and Rushikulya rivers have built broad deltas of fertile alluvium. Their old and new channels, levees and backswamps shape the coastal landscape.

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- **Beach ridges and dunes:** a series of old shorelines and sand dunes runs parallel to the coast, especially in Puri, Ganjam and Balasore.
- **Chilika Lake:** a large brackish lagoon formed over the last few thousand years as a sand barrier (spit) grew across a bay of the sea.
- **Heavy mineral sands:** the beaches of Ganjam (Chhatrapur), Puri and Kendrapara contain ilmenite, rutile, zircon, monazite, sillimanite and garnet, eroded from Eastern Ghats rocks and sorted by waves.
- **Mudflats and mangroves** at Bhitarkanika and the river mouths, where fine sediments settle.

Structure, tectonics and seismicity

Odisha lies on a stable part of the Indian Plate, far from the active Himalayan plate boundary, but old faults and shear zones still shape its rivers, hills and occasional earthquakes.

Major structural features

- **Mahanadi Graben faults:** the north-west–south-east boundary faults of the Gondwana rift, followed by the Mahanadi and Brahmani valleys.
- **Shear zones** separating the crustal blocks: for example the shear zones bounding the Rengali Province and the Eastern Ghats belt, and the **Sukinda thrust** zone.
- **Folded belts:** the Bonai–Keonjhar horseshoe synclinorium of the Iron Ore Group and the folded Gangpur belt in Sundargarh.
- **Lineaments and fractures** that guide river courses, waterfalls and groundwater flow across the plateaus.

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Hot springs

Deep faults let groundwater circulate to warm depths and rise as **hot springs**, such as **Atri** (Khordha), **Taptapani** (Ganjam), **Tarabalo** (Nayagarh) and **Deulajhari** (Angul). They are popular pilgrimage and tourist spots and have some geothermal potential.

Seismicity

Most of Odisha falls in **Seismic Zone II (low hazard)**, while parts of the coast and the Mahanadi rift region fall in **Zone III (moderate hazard)** under the Bureau of Indian Standards' earthquake zoning. The state has felt only small and moderate earthquakes, mostly along old faults in the rift and the Eastern Ghats margin. Its main natural hazards are cyclones and floods rather than earthquakes, though the coast is exposed to tsunamis from distant earthquakes in the Bay of Bengal, as in 2004.

Geology, landscape and economy

Geology underpins Odisha's minerals, landforms, soils, groundwater and even its temple architecture.

Geological unit	Landscape	Minerals	Soils	Groundwater
Singhbhum Craton (north)	Plateaus and ridges of Keonjhar, Mayurbhanj, Sundargarh	Iron ore, manganese, chromite, nickel	Red and lateritic	Limited; in weathered zones and fractures
Eastern Ghats belt (south-west)	High hills and plateaus, Deomali, Mahendragiri	Bauxite, graphite, gemstones, manganese	Red, laterite and hill soils	Poor; mainly in fractures and valley fills
Bastar Craton and Proterozoic basins (west)	Undulating plains and flat plateaus (Khariar)	Limestone, dolomite	Red and mixed red–black	Moderate in limestone; poor elsewhere
Gondwana basins (centre-north)	Low ridges and valleys in Talcher and Ib	Coal, fireclay	Red and yellow	Moderate in sandstones
Coastal alluvium	Flat deltas, beach ridges, Chilika	Heavy mineral sands, clay	Fertile alluvium; saline near the sea	Rich, but saline near the coast and at depth

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Building stone and heritage

Odisha’s temple builders used local rocks. **Khondalite** was used for the Sun Temple at Konark and many Bhubaneswar temples, **laterite** for compound walls, forts and foundations (as at Jagannath temple, Puri), and **sandstone** from the Athgarh area for many shrines. Today, granite, charnockite and decorative stones from Bolangir, Kalahandi, Keonjhar and Mayurbhanj are quarried as dimension stone.

Hazards linked to geology

- **Coastal erosion** at places such as Satabhaya and Pentha (Kendrapara) and around Puri and Ganjam.
- **Fluoride** in groundwater in parts of Nuapada, Bolangir, Bargarh, Angul and Nayagarh, and **salinity** along the coast.
- **Landslides** on steep Eastern Ghats slopes during heavy rain, and subsidence and fires in old coal mines.

Geoheritage and notable geological sites

Site	District	Geological interest
Pillow lavas of Nomira	Keonjhar	Ancient underwater lava flows of the Iron Ore Group; a Geological Survey of India geo-heritage site
Gonasika and Khandadhar	Keonjhar, Sundargarh	Iron-rich hills of the Bonai–Keonjhar belt; Khandadhar falls tumble over banded iron formation
Satkosia Gorge	Angul–Boudh	The Mahanadi cuts a deep gorge through the Eastern Ghats rocks
Simlipal hills	Mayurbhanj	Circular Simlipal Complex of ancient volcanic and sedimentary rocks
Udayagiri–Khandagiri caves	Khordha	Rock-cut caves in sandstone near Bhubaneswar, dating from the 1st–2nd century BCE

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Deomali and Panchpatmali	Koraput	Highest peak of Odisha and bauxite-capped khondalite plateau
Taptapani and Atri	Ganjam, Khordha	Fault-related hot springs
Chilika Lake	Puri, Khordha, Ganjam	Lagoon formed behind a growing sand barrier
Gahirmatha and Rushikulya coasts	Kendrapara, Ganjam	Active beach and delta processes, heavy mineral sands

Conclusion

Odisha’s geology tells a story spanning more than 3.5 billion years: ancient continental crust in the north, a mountain belt shared with Antarctica in the south, coal-filled rift valleys in the centre and young deltas on the coast. This long history has given Odisha its plateaus and hills, its fertile deltas and, above all, its exceptional mineral wealth. Understanding it is key to using these resources wisely, managing groundwater and protecting geoheritage sites for the future.

Quick facts for exam aspirants

- About 72.5% of Odisha is covered by Precambrian rocks; Gondwana rocks cover about 8%.
- Oldest rocks: Older Metamorphic Group and gneisses of the Singhbhum Craton (over 3.3 billion years).
- Iron ore occurs in the Iron Ore Group of the Bonai–Keonjhar belt.
- Chromite and nickel occur in the Sukinda and Baula–Nuasahi ultramafic complexes.
- Bauxite forms by laterisation of khondalite on Eastern Ghats plateaus.
- Khondalite is named after the Khond people of the Khondmals (Kandhamal).
- The Talchir Formation (type area: Talcher) contains glacial boulder beds, the oldest Gondwana rocks.
- Coalfields: Talcher and Ib Valley, in the Mahanadi Graben.

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- Heavy mineral sands: Chhatrapur (Ganjam).
- Hot springs: Atri, Taptapani, Tarabalo, Deulajhari.
- Seismic zones: mostly Zone II, parts in Zone III.

Sources

- Directorate of Geology, Odisha: Geology and Mineral Resources of Orissa
- Odisha Steel & Mines Department
- Geological Survey of India, publications on the geology and geo-heritage sites of Odisha

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