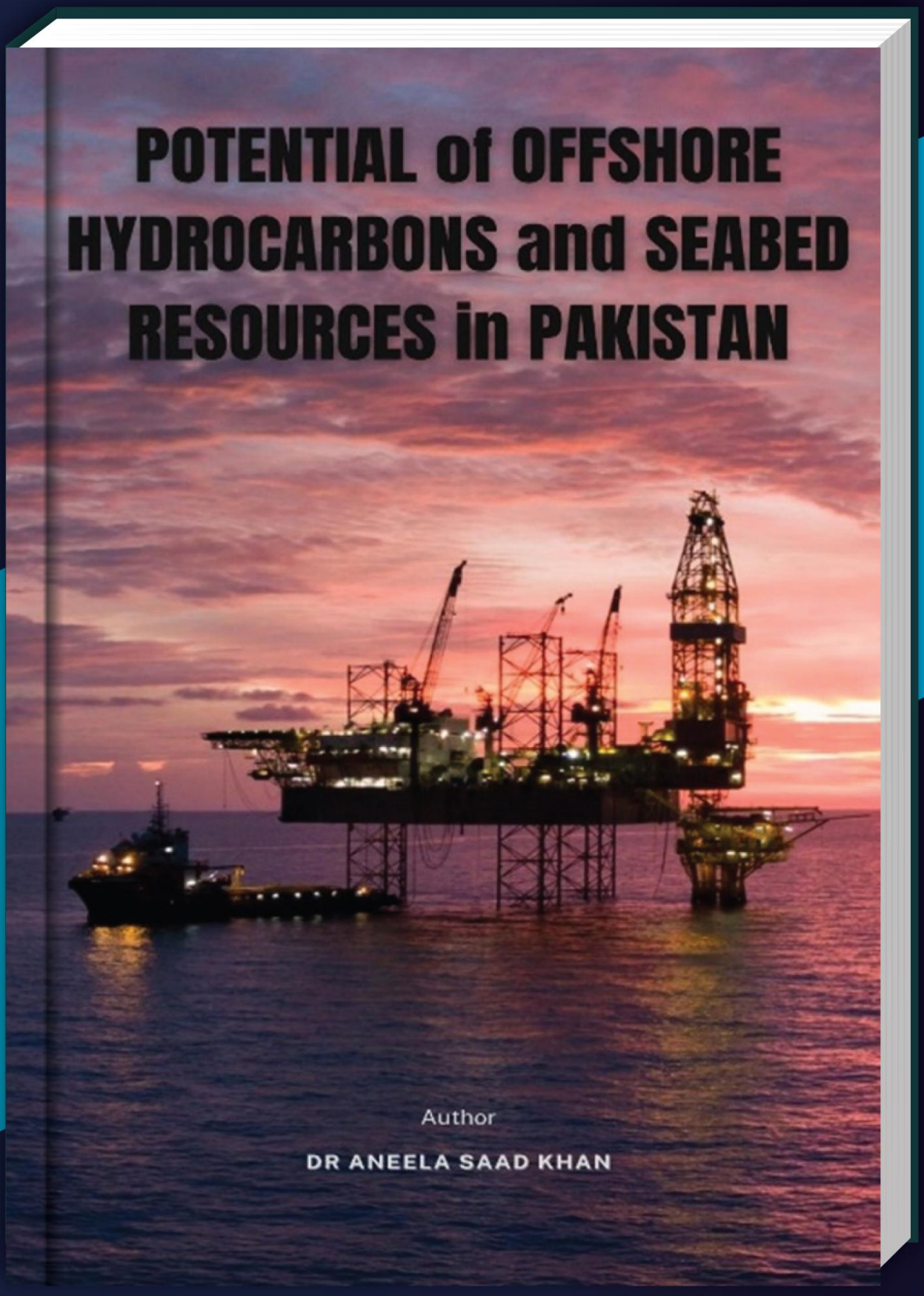
POTENTIAL of OFFSHORE HYDROCARBONS and SEABED RESOURCES in PAKISTAN
Author
DR ANEELA SAAD KHAN

List of Abbreviations

Abbreviation		Full Form
ABNJ	-	Areas Beyond National Jurisdiction
BG	-	Bazman Group
BPD	-	Barrels per day
CAGR	-	Compound Annual Growth Rate
CC	-	Cobalt-rich Fe–Mn Crusts
CCZ	-	Clarion-Clipper ton Zone
DSM	-	Demand side Management
EEZ	-	Exclusive Economic Zone
EOR	-	Enhanced Oil Recovery
GDP	-	Gross Domestic Product
GHPL	-	Government holding (private)Limited
HEC	-	Higher Education Commission
IEA	-	International Energy Agency
ISA	-	International Seabed Authority
IUCN	-	International Union for Conservation of Nature
KG	-	Krishna –Godvari
LNG	-	Liquefied Natural Gas
Ma	-	Million year ago
MMbtu	-	Million British Thermal Unit
MMCFD	-	Million cubic feet per Day
OFZ	-	Owen Fracture Zone
OGDCL	-	Oil and Gas Development Company Limited
OGRA	-	Oil and Gas Regulatory Authority
P&A	-	plugged and abandoned
PMDC	-	Pakistan Mineral Development Corporation
PMIF	-	Pakistan Mineral Investment Forum
PMN	-	Polymetallic Nodules
PMS	-	Polymetallic Sulfides
PPL	-	Pakistan Petroleum Limited
SG	-	Sultan Group

Abbreviation		Full Form
TG	-	Taftan Group
TLC	-	Technical and legal commission
TMC	-	The Metals Company
TOC	-	Total Organic Carbon
UN	-	United Nations
UNCLOS	-	United Nations. Convention on the Law of the Sea

Chapter 1

Introduction

1.1 Blue Economy

The Blue Economy represents a transformative approach to economic growth that emphasizes sustainable utilization of coastal and marine resources. It encompasses traditional sectors like fishing and tourism, alongside emerging industries such as renewable energy and marine biotechnology. This multifaceted economy not only aims to enhance livelihoods but also to protect marine ecosystems, making it a crucial component of global economic development[1]. Marine and coastal resources are organisms and nonliving oceanic materials with an intrinsic or monetary value. These resources include:

a. Biological diversity (marine biodiversity)

b. Ecosystem services from marine ecosystems, such as marine coastal ecosystems and coral reefs

c. Fish and seafood

d. Mineral resources

e. Hydrocarbons (Oil and gas)

f. Renewable energy resources, such as marine energy

g. Sand and gravel

h. Coastal and maritime tourism

1.1.1 Hydrocarbon Resources

Conventional hydrocarbons are reservoirs of oil and gas trapped in porous and permeable rock formations. Permeability is the adequate pore spaces within the grains in a rock formation to accommodate the accumulation and flow of the hydrocarbons[2].

Unconventional hydrocarbon resources are the production of oil and gas from geologically complicated reservoirs that are less permeable. They are the less permeable shale or tight sands. The low permeability prevents the oil and gas

1 “(PDF) Fostering Sustainable Growth through the Blue Economy: Balancing Prosperity and Marine Conservation,” Research Gate, ahead of print, February 26, 2025, https://doi.org/10.18178/IJSEE.2025.2.1.10-14.

2 “Reservoir Rock - an Overview | ScienceDirect Topics,” accessed July 25, 2025, https://www.sciencedirect.com/topics/engineering/reservoir-rock.

from flowing freely through rock formation[3]. Here complicated drilling techniques like horizontal drilling and fracking (hydraulic fracturing) are employed in order to push out petroleum from these pools (figure 1).

Offshore hydrocarbons are the occurrence of oil and gas pools which are located underneath the seabed, usually within the continental shelf or the oceanic basins. Exploration, drilling and production of these hydrocarbons require distinctive operations[4].

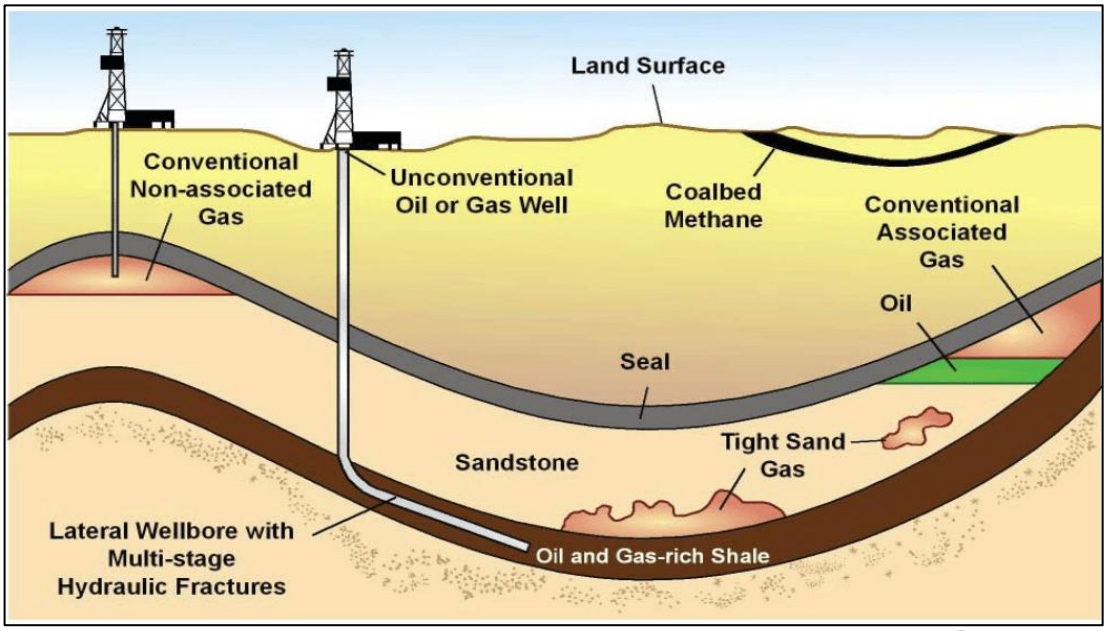

Figure 1: The geology of conventional and unconventional oil and gas[5].

1.1.2 Petroleum System

The idea of petroleum system was defined by Magoon and Dow in 1994. They discussed and identified all the elements that control the occurrence of oil and gas in a reservoir rock and trapped in a structural or geological trap[6]. Source rock presence and the type and conditions of hydrocarbon generation were discussed[7]. The migration timing and hydrodynamics of hydrocarbons, followed by entrapment and various other events that influence the accumulation of hydrocarbons was discussed (figure 2).

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3 "Unconventional Hydrocarbon Resources: Geological Statistics, Petrophysical Characterization, and Field Development Strategies | Journal of Petroleum Exploration and Production Technology," accessed July 25, 2025, https://link.springer.com/article/10.1007/s13202-021-01404-x.

4 Temoor Muther et al., "Unconventional Hydrocarbon Resources: Geological Statistics, Petrophysical Characterization, and Field Development Strategies," Journal of Petroleum Exploration and Production Technology 12, no. 6 (2022): 1463–88, https://doi.org/10.1007/s13202-021-01404-x.

5 "Conventional Vs. Unconventional Resources," accessed August 19, 2025, https://www.croftsystems.net/oil-gas-blog/conventional-energy-unconventional-energy-what-does-it-all-mean/.

6 "Petroleum System - an Overview | Science Direct Topics," accessed July 25, 2025, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/petroleum-system.

7 "Petroleum Source Rocks Characterization and Hydrocarbon Generation | IntechOpen," accessed July 25, 2025, https://www.intechopen.com/chapters/56887.

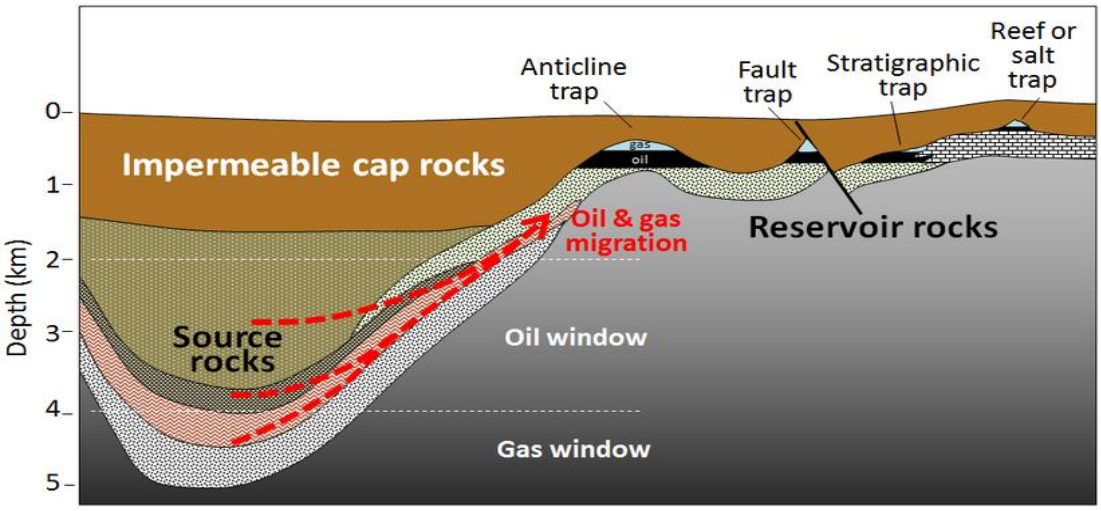

Figure 2: Petroleum system highlighting the source, reservoir and cap rock[8].

1.1.3 Seabed Mineral Resources

The phosphorites are sedimentary beddings that consist of phosphorous and concentrations of the rare earth elements that are deposited in the continental margins. Phosphorites are employed in the manufacturing of agricultural fertilizers[9]. Terrestrial sands with heavy minerals carried by rivers and deposited in the coastal and near shore environments. This sand can be employed in land reclamation coastal development and other industrial processes[10].

Polymetallic nodules have a diameter of up to 15 centimeters which are rich in manganese, copper, nickel and cobalt. These are concentrations that exist on the abyssal ocean floor plains and are considered to be the future source of the vital minerals[11]. Polymetallic sulfides are created as a product of mineral precipitation in heated mineral rich water that is discharged at the hydrothermal vents on the mid ocean ridges and back arc basins. Polymetallic sulfides are copper, lead, zinc, gold and silver rich[12]. The cobalt rich ferromanganese crusts are fumes on the top of underwater ridges like seamounts. Additionally, deep sea muds can also have rare earth elements[13].

8 “Origin of Oil,” accessed August 19, 2025, http://large.stanford.edu/courses/2013/ph240/malyshev2/.
9 “Phosphorite - an Overview | Science Direct Topics,” accessed July 25, 2025, https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/phosphorite.
10 Bradley S. Van Gosen et al., Deposit Model for Heavy-Mineral Sands in Coastal Environments, Scientific Investigations Report (US Geological Survey, 2014), https://doi.org/10.3133/sir20105070l.
11 Van Gosen et al., Deposit Model for Heavy-Mineral Sands in Coastal Environments.
12 “How Polymetallic Sulphide Deposits Form,” accessed July 25, 2025, https://deepseamining.ac/how_sulphide_deposits_form.
13 Qi Zhang et al., “Technology and Equipment of Deep-Sea Mining: State of the Art and Perspectives,” Earth Energy Science 1, no. 1 (2025): 65–84, https://doi.org/10.1016/j.ees.2024.08.002.

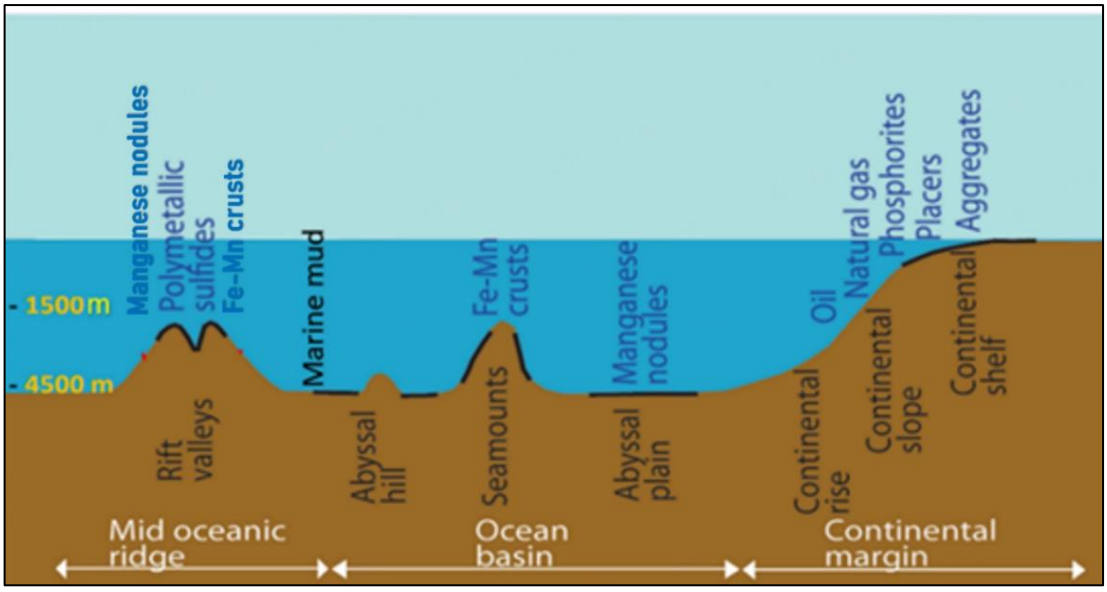

Figure 3: Seabed mineral resources[14].

1.2 What is Exclusive Economic Zone (EEZ)

The concept of EEZ is derived from the United Nations Convention on the Law of the Sea (UNCLOS) 1982, which declares that "coastal state has the jurisdiction for exploration and exploitation of all marine resources adjacent to the sea-based and its sub-soil, taken to the band extending 200 miles from the shore." In this region, "nations exercise sovereign rights for exploring and exploiting natural resources (oil and gas, minerals, fisheries, etc.), whether living or non-living[15].

1.3 Territorial Water

In UNCLOS (United Nations Convention on the Law of the Sea), the territorial sea is a 12-nautical-mile-wide strip of seawater off the coast of a state. The coastal state enjoys sovereignty over it, including the airspace above and seabed beneath, with a right of innocent passage for foreign ships[16]. UNCLOS further delineates other maritime areas such as the contiguous zone, exclusive economic zone, and the continental shelf, with respective jurisdictional rights[17].

1.4 EEZ of Pakistan

Pakistan is uniquely endowed with 1001 km of coastline and an EEZ covering 240,000 square kilometers. It is the very first country in the North Arabian Sea, endorsed by the UN for the extension of its Continental Shelf. This approval

14 Ali Haq, “Seabed Mineral Exploration,” GeoExpro, July 21, 2021, https://geoexpro.com/seabed-mineral-exploration/.
15 “PREAMBLE TO THE UNITED NATIONS CONVENTION ON THE LAW OF THE SEA,” accessed July 25, 2025, https://www.un.org/depts/los/convention_agreements/texts/unclos/part5.htm.
16 “UNCLOS+ANNEXES+RES.+AGREEMENT,” n.d., accessed July 25, 2025, https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
17 “Maritime Zones and Boundaries | National Oceanic and Atmospheric Administration,” accessed July 25, 2025, https://www.noaa.gov/maritime-zones-and-boundaries.

added an extra 50,000 square kilometers to the existing EEZ, bringing it to 290,000 square kilometers. It is an area larger than the combined land areas of Sindh and Khyber Pakhtunkhwa[18]. Due to this, it has been termed the "fifth province of Pakistan", the coastal states will investigate & exploit both biological & geological resources[19].

Hassan Mehmood (2023) highlighted the untapped economic opportunities within Pakistan's EEZ, estimating the blue economy potential at over $100 billion. The sectors mentioned include offshore oil and gas exploration, fisheries, coastal & maritime tourism, and maritime trade, but currently contribute minimally to the national GDP[20].

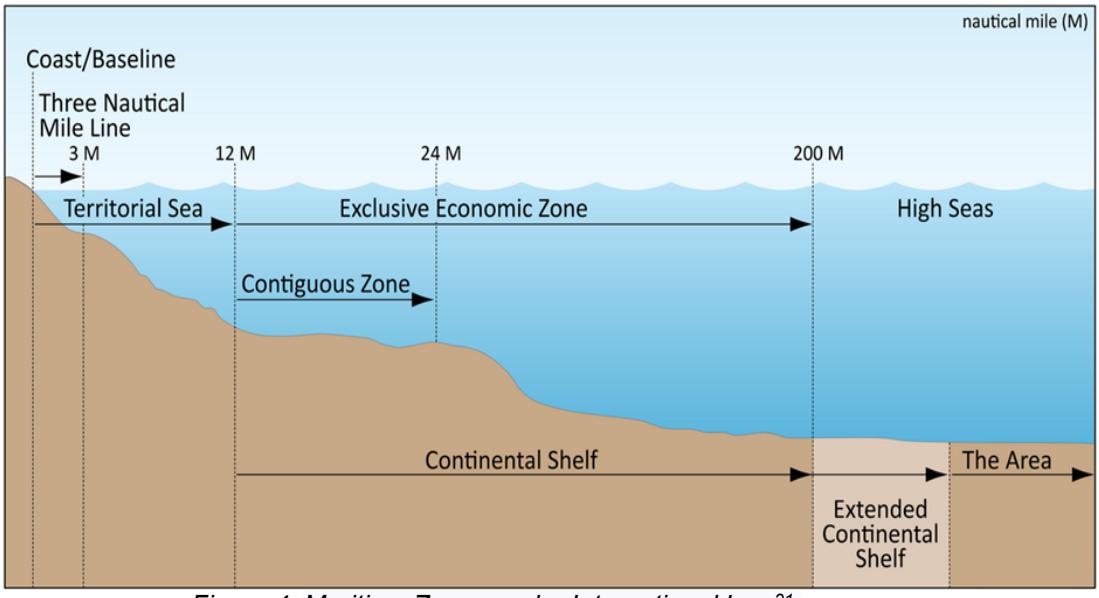

Figure 4: Maritime Zones under International Law[21].

1.5 What is ABNJ?

The part of ocean that lies beyond the EEZ is referred to as Areas Beyond National Jurisdiction (ABNJ), including the high seas and deep seabed. It is considered as the common Heritage of Mankind ensuring equitable benefit-sharing and the area is covered by the United Nations Convention on the Law of the Sea (UNCLOS)[22].

18 "ICZM.Pdf," n.d., accessed July 28, 2025, https://pc.gov.pk/uploads/report/ICZM.pdf.
19 Zakir Hussain, Geo-Strategic Significance of Gilgit Baltistan: Political, Economic and Security Interests of Pakistan, India and China (1947-2013), January 1, 2018, https://www.academia.edu/111652505/Geo_Strategic_Significance_of_Gilgit_Baltistan_Political_Economic_and_Security_Interests_of_Pakistan_India_and_China_1947_2013_.
20 Sana Alam, Journal of Asian Development Studies Vol. 12, Issue 3 (September 2023), n.d.
21 "Chapter 2: Maritime Zones – Law of the Sea," accessed August 19, 2025, https://sites.tufts.edu/lawofthesea/chapter-two/.
22 "PREAMBLE TO THE UNITED NATIONS CONVENTION ON THE LAW OF THE SEA," accessed July 28, 2025, https://www.un.org/depts/los/convention_agreements/texts/unclos/part5.htm.

1.6 Global Offshore Oil and Gas Overview

Offshore oil and gas industry refers to the exploration, and extraction of oil and natural gas offshore of under the sea primarily in the North Sea, Gulf of Mexico, and offshore of Asia-Pacific and Middle East[23]. The demand for these natural resources is pushing international market requirements, advancing technology for drilling and extraction, and maximizing the specialization of deep and ultra-deep water projects[24].

The world oil supply is estimated to be104.6 million barrels a day (bpd) in 2025, which would be an increase of 1.6 million bpd over the previous year, according to the International Energy Agency (IEA). In 2024, offshore oil production reached 28.4 million bpd, or about a third of the world's total output[25]. In 2024, with the offshore oil and gas market estimated to be around USD 140.9 billion, it will further grow to USD 152.88 billion in 2025 and will finally reach USD 293.6 billion by 2033, with nearly 8.5% CAGR[26].

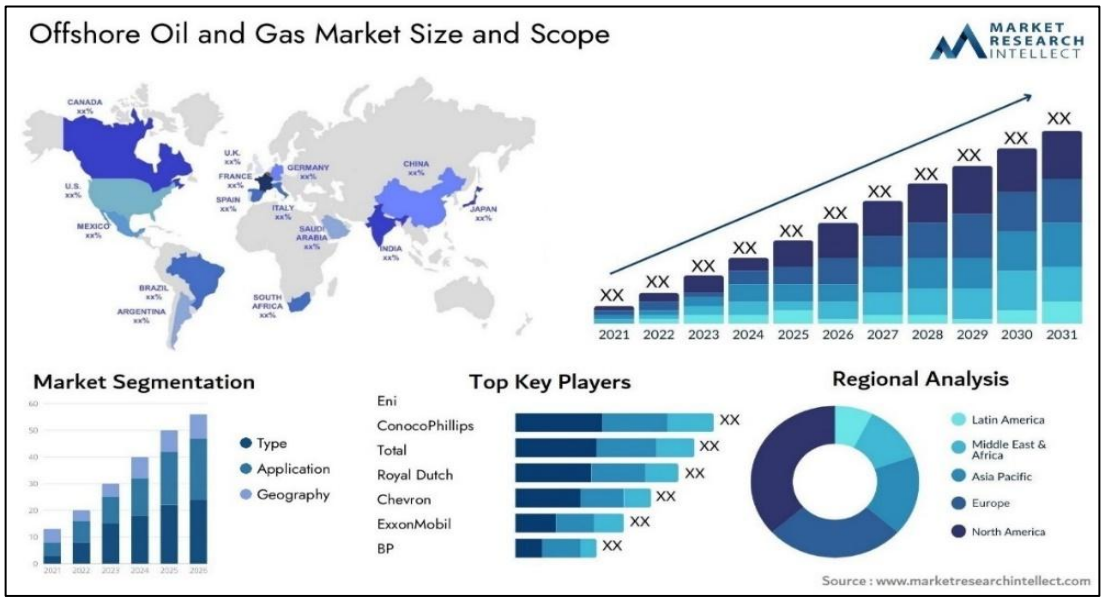

Figure 5: Offshore oil and gas market size and scope[27].

23 “Offshore Oil - an Overview | ScienceDirect Topics,” accessed July 28, 2025, https://www.sciencedirect.com/topics/engineering/offshore-oil.

24 Market Research Future https://www.marketresearchfuture.com, “Deep Water And Ultra Deep Water Exploration Production Market Size, Growth Report 2034,” accessed July 28, 2025, https://www.marketresearchfuture.com/reports/deep-water-ultra-deep-water-exploration-production-market-35271.

25 “Global Oil Supply to Rise Faster than Expected after OPEC+ Hike, IEA Says | Reuters,” accessed July 28, 2025, https://www.reuters.com/business/energy/iea-forecasts-global-oil-demand-growth-slow-650000-bpd-remainder-2025-2025-05-15/.

26 “Offshore Oil and Gas Market Size, Trend | Forecast [2025-2033],” accessed July 28, 2025, https://www.businessresearchinsights.com/market-reports/offshore-oil-and-gas-market-118706.

27 Verified Market Reports, “Offshore Oil and Gas Market Size, Outlook, Growth & Forecast,” Verified Market Reports, accessed August 19, 2025, https://www.verifiedmarketreports.com/product/offshore-oil-and-gas-market/.

The world market can be divided into Liquefied Natural Gas, Heavy Crude Oil, Light Crude Oil based on type. Depending on use, the market of the world can be divided into Ultra-Deep Water Drilling, Shallow Water Drilling, and Deep Water Drilling. Shallow drilling focused on retrieving gas & oil from seabed depths of under 500 meters. Deep between 500 to 1500 meters and ultra-deep exceeding 500 meters[28].

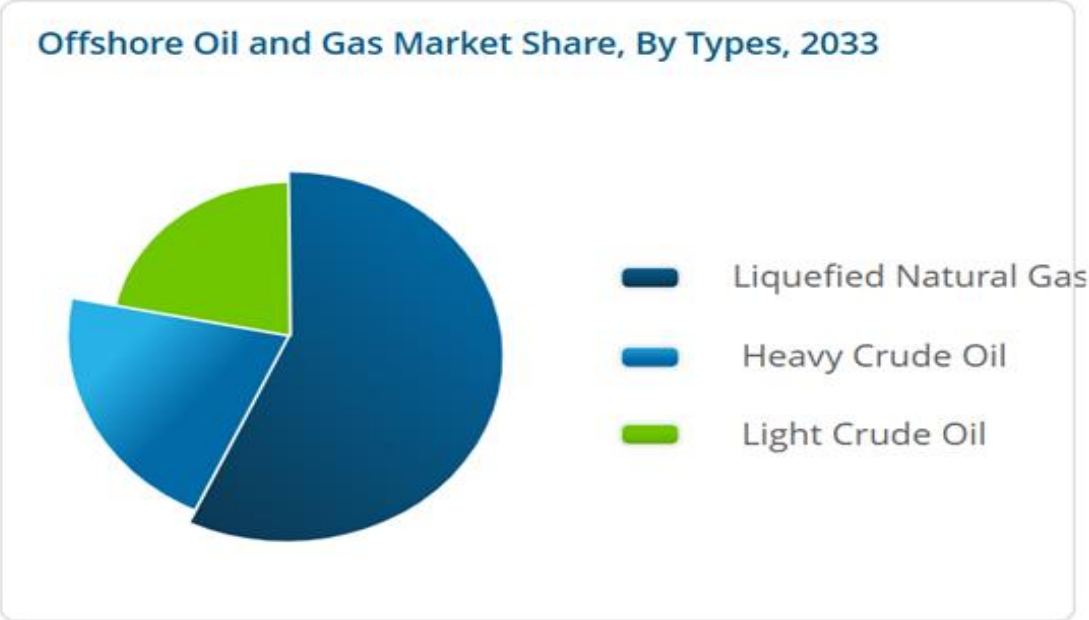

Figure 6: Offshore oil and gas market share, by types 2033[29].

The U.S. oil & gas market holds a prominent position in the global offshore sector, largely due to the Gulf of Mexico being a major venue for offshore exploration and production[30]. Europe has long been a great contributor to the Offshore Oil and Gas Market. The North Sea stands among the most well-known offshore oil-producing sites. Offshore exploration and production leaders are the United Kingdom, Norway, and the Netherlands. The mature fields undergo upgrades and extensions to maintain production levels. With countries such China, Malaysia, and Indonesia leading the charge, Asia Pacific is an emerging hub for offshore oil and gas activities[31]. India's energy sector depends greatly on offshore hydrocarbon output. India's largest offshore oil field is the Mumbai High field. Whereas the Krishna- Godvari (KG) Basin accounts for gas production[32].

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28 “Crude Oil - an Overview | ScienceDirect Topics,” accessed July 28, 2025, https://www.sciencedirect.com/topics/engineering/crude-oil.

29 “Offshore Oil and Gas Market Size, Trend | Forecast [2025-2033],” accessed August 19, 2025, https://www.businessresearchinsights.com/market-reports/offshore-oil-and-gas-market-118706.

30 “How the U.S. Oil and Gas Industry Works | Council on Foreign Relations,” accessed July 28, 2025, https://www.cfr.org/backgrounder/how-us-oil-and-gas-industry-works.

31 “Policycenter.Ma/Sites/Default/Files/2023-02/PB_09_23 %28Hamza Mjahed%29.Pdf,” n.d., accessed July 28, 2025, https://www.policycenter.ma/sites/default/files/2023-02/PB_09_23%20%28Hamza%20Mjahed%29.pdf.

32 “India’s ONGC Engages BP to Boost Production in Largest Oil Field | Reuters,” accessed July 28, 2025, https://www.reuters.com/business/energy/indias-ongc-engages-bp-boost-production-largest-oil-field-2025-01-08/.

1.7 Global Offshore Mineral Exploration

Driven by rising need for important minerals central for digital infrastructure and green energy technologies. Under the International Seabed Authority (ISA), several nations have begun or broadened exploratory activities inside their EEZs and in Areas beyond National Jurisdiction (ABNJ)[33]. Since 2011, the Norwegian Offshore Directorate has begun subsea surveys. Along the Norwegian EEZ, seafloor massive sulfides and cobalt-rich crust deposits have been found[34]. China has closely investigated the subsea resources in its EEZ and holds five exploration permits for deep-sea minerals. Near Minamitorishima, Japan, roughly 230 million tons of polymetallic nodules have been found in their EEZ[35]. Japan also retains several mineral exploration agreements in international seas. Terrestrial diamonds were first investigated in Namibia in 1908 and the offshore diamond mining began in 1990[36]. India has been actively looking on subsea minerals. In 2024, India auctioned the offshore mineral blocks found in their EEZ. India has several licenses for international water[37]. The EEZ of Saudi Arabia has highly metalliferous muds with high levels of gold, silver, copper, zinc, and nickel. Large quantities of polymetallic nodules have also been found in the American Samoa[38]. Brazil is extracting limestone and sand from coastal regions[39]. Further offshore in Brazil, cobalt-rich ferromanganese crusts have been found. Chile's enormous EEZ, roughly five times its land area, has seabed massive sulfides, cobalt rich crusts, polymetallic nodules among other minerals identified[40].

1.8 Importance of Resource Exploration for Pakistan

Though offshore exploration and development are few, Pakistan's Exclusive Economic Zone (EEZ) reportedly has great undeveloped promise for mineral and hydrocarbon resource extraction[41]. Rising demand, low domestic output, and little refining capacity explain Pakistan's high oil imports. The country's great dependence on imported oil significantly stresses foreign exchange

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33 Exploration Contracts - International Seabed Authority, March 17, 2022, https://www.isa.org.jm/exploration-contracts/.

34 “Deep Sea Mining: Data about Subsea Minerals in the Norwegian EEZ,” accessed July 28, 2025, https://deepseamining.ac/NO_EEZ_data#gsc.tab=0.

35 “Nodules in Japanese EEZ at Minamitorishima,” Deep Sea Mining, accessed July 28, 2025, https://www.deepseamining.ac.

36 “Offshore Diamond Mining in SW Africa,” accessed July 28, 2025, https://deepseamining.ac/article/55#gsc.tab=0.

37 Marzena Pyteraf, “India to Auction First Offshore Mineral Blocks,” GeoExpro, May 2, 2025, https://geoexpro.com/india-to-auction-first-offshore-mineral-blocks/.

38 “Frontiers | An Overview of Seabed Mining Including the Current State of Development, Environmental Impacts, and Knowledge Gaps,” accessed July 28, 2025, https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2017.00418/full.

39 “11 Countries Developing Subsea Minerals in Their EEZs,” accessed July 28, 2025, https://deepseamining.ac/article/50#gsc.tab=0.

40 Cobalt-Rich Ferromanganese Crusts - International Seabed Authority, March 17, 2022, https://www.isa.org.jm/exploration-contracts/cobalt-rich-ferromanganese-crusts/.

41 Get link et al., Pakistan’s Blue Economy: Vast Offshore Resources in Exclusive Economic Zone, February 11, 2019, https://www.southasiainvestor.com/2019/02/pakistans-blue-economy-vast-offshore.html.

reserves. Rising energy needs and economic ambitions call for an evaluation of the country's offshore geological structure, the identification of prospective resource-rich regions, and an analysis of current exploration and production operations[42].

1.9 Status of Pakistan

Broader economic circumstances, inflationary pressures, and supply chain changes all affect the oil industry, which saw noteworthy changes in consumption, output, and imports. Increased refinery output reflects strategic changes in import dependence, whereas the decline in consumption patterns fits with limited economic activity, high inflation, and erratic exchange rates[43].

In FY 2023-24, petroleum product consumption—covering both energy and non-energy—fell by 4% to 17.08 million tons from 17.81 million tons in the prior year (OGRA, 2024). Total petroleum use fell 4% to 17.08 million tons, a reflection of lower buying power and less industrial activity. Total refinery output grew by 14.65%, to 10.67 million tons, during FY 2023-24 compared to 9.31 million tons in FY 2022-23, therefore underlining improved local processing capacity[44]. Crude oil imports grew by 13%, from 7.53 million tons in FY 2022-23 to 8.48 million tons in FY 2023-24. By 16%—from 7.88 million tons to 6.63 million tons—imports of completed petroleum products fell during the same time[45]. Since Natural Gas is relatively clean energy source, it helps to slow down environmental deterioration. But this year, demand for natural gas has grown at a standstill because of current economic circumstances in the nation. The government has put incentives for local gas production, imported liquefied natural gas (LNG), and built cross-nation pipelines like the Iran Pakistan and TAPI projects to close the supply-demand gap[46].

Gas consumption dropped by more than 4.5 percent to 3,323 MMCFD from 3,481 MMCFD during the same time period, whereas indigenous gas supplies/production fell by nearly 8.6 percent to 2,638 MMCFD from 2,888 MMCFD for the year 2023-2024[47]. Mainly because of supply limitation and rising LNG prices on the international market, imported RLNG supplies fell by 2.59 percent to 900 MMCFD from 924 MMCFD last year. RLNG imports partially filled the gap between production and consumption[48].

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42 “Energy Resource Guide - Pakistan - Oil and Gas,” accessed July 28, 2025, https://www.trade.gov/energy-resource-guide-pakistan-oil-and-gas.
43 Afia Malik, the Impact of Oil Price Changes on Inflation in Pakistan, 6, no. 4 (2016).
44 “Petroleum Consumption Rises 7 Percent during Ongoing Fiscal Year,” The Nation, June 10, 2025, https://www.nation.com.pk/10-Jun-2025/petroleum-consumption-rises-7-percent-during-ongoing-fiscal-year.
45 Mubarak Zeb Khan, “Crude Oil Import Bill Rises 13.5pc,” DAWN.COM, 06:24:25+05:00, https://www.dawn.com/news/1920876.
46 “Article Detail,” accessed July 28, 2025, https://www.c40knowledgehub.org/s/article/How-cities-can-shift-from-gas-to-renewables-in-buildings?language=en_US.
47 “Gas Consumption up in Punjab, down in Other 3 Provinces,” The Nation, April 23, 2025, https://www.nation.com.pk/23-Apr-2025/gas-consumption-up-in-punjab-down-in-other-3-provinces.
48 “July-March of FY2025: Significant Cut in Crude Oil, Gas Extraction Recorded - Markets - Business Recorder,” accessed July 28, 2025, https://www.brecorder.com/news/40366873.

Chapter 2

Overview of Pakistan's Geology and Resource Potential

The Indus offshore consists of two Basins, namely the Offshore Indus Basin and Makran Basin. These basins are partitioned by Murray Ridge present in subsea. The Indus offshore is formed by the rifting of the Indian Plate from Africa Plate in the late Jurassic. Therefore, it is defined as a rift and passive margin basin[49].

The drift of the Madagascar away from India took place during the Cretaceous. It was succeeded by the fast northward drift of the Indian plate. This Plate went over the Reunion Hotspot in early Paleocene which resulted in the creation of the Deccan volcanic lava flows. It was the Eocene when the Indian Plate collided with the Eurasian plate. It resulted in the creation of the Karakorum - Himalayan range and associated fold and thrust belts.
[50].

The gravity and seismic data indicate that the underlying crust in the Indus-offshore is of three different types[51]. It consists of continental, translational and oceanic crust. The continental crust ranges from the region beneath the shelf to the upper slope characterized depending on the occurrence of rift pattern on the seismic record[52]. Translational crust occurs on the slope at a water depth of 1500 to 3000 m. Basin ward the oceanic crust replaces the translational crust[53]. The oceanic crust is seen through a visible gravity high and by a strong Moho reflection on the seismic record.

Murray Ridge lies between the Arabian Plate and Indian plate[54]. It is connected with the Owen Fracture Zone and Ornach-Nal Fault Zone, which shows complex geological development. As India started moving away from Africa and Madagascar, extensional tectonics resulted in the development of rift basins (e.g., the Kutch, Cambay Basins & Narmanda Basin)[55]. The Saurashtra Arch formed as a structural high between the rift basins.

The Owen Fracture Zone (OFZ) is a prominent transform fault system in the northwestern Indian Ocean, defining the boundary between the Indian Plate and the

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49 “Origin of the Northern Indus Fan and Murray Ridge, Northern Arabian Sea: Interpretation from Seismic and Magnetic Imaging | Request PDF,” accessed July 28, 2025, https://www.researchgate.net/publication/223423177_Origin_of_the_northern_Indus_Fan_and_Murray_Ridge_Northern_Arabian_Sea_Interpretation_from_seismic_and_magnetic_imaging.

50 “(PDF) India’s Northward Drift from Gondwana to Asia during the Late Cretaceous-Eocene,” accessed July 28, 2025, https://www.researchgate.net/publication/305712603_India's_Northward_Drift_from_Gondwana_to_Asia_During_the_Late_Cretaceous-Eocene.

51 “Geology and Hydrocarbon Potential of the Offshore Indus Basin, Pakistan | Petroleum Geoscience | Geo Science World,” accessed July 28, 2025, https://pubs.geoscienceworld.org/gsl/pg/article-abstract/15/2/107/382927/Geology-and-hydrocarbon-potential-of-the-offshore?redirectedFrom=PDF.

52 “Extended Crust - an Overview | ScienceDirect Topics,” accessed July 28, 2025, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/extended-crust.

53 Paul Webb, 3.2 Structure of Earth, n.d., accessed July 28, 2025, https://rwu.pressbooks.pub/webboceanography/chapter/3-2-structure-of-earth/.

54 Webb, 3.2 Structure of Earth.

55 “Intra-Plate Dynamics and Active Tectonic Zones of the Indian Plate | IntechOpen,” accessed July 28, 2025, https://www.intechopen.com/chapters/82652.

Arabian Plate. The OFZ runs from the Murray Ridge to the Carlsberg Ridge and is an important component of the regional tectonics of the Arabian Sea[56]. Rapid northward plate movement of the Indian Plate generated intense transform fault activity along the OFZ. The Murray Ridge started to rise as a result of compression at the northern end of the OFZ[57].

Somnath Ridge in the northeastern Arabian Sea is a seamount structural high created as a consequence of rifting during Gondwana breakup (~150–120 Ma) and subsequently affected by Deccan Traps volcanism (~66 Ma)[58]. Originally uplifted as the western Indian continental margin, it subsided and received marine sedimentation subsequently The Indian-Eurasian collision (~50 Ma, Eocene) resulted in additional tectonic readjustments, creating the structure of the ridge[59]. Today it remains tectonically active with occasional seismic activity, sedimentation, and oceanic action in the Arabian Sea[60].

2.1 Makran Basin

Makran is the largest accretionary prism in the world. It forms due to subduction of the oceanic sector of the Arabian Plate under the Eurasian Plate. The overriding plate is split into two blocks. The Helmand Block runs from Afghanistan to Pakistan and the Lut Block in Iran. Blocks are separated by Sistan Suture Zone. Subduction was initiated in the Paleocene[61].

A sinistral strike slip fault called the Sonne fault divides the Makran subduction zone into eastern and western part[62].The gently arcuate Makran accretionary wedge with Eocene growth covers ~1000 km in strike distance from the dextral Minab –Sabzevaran fault system to the west to the sinistral Chaman – Ornach-Nal fault system in the east[63].

The northern boundary is defined by the Iranian Jaz Murian depression's Quaternary cover and its Pakistani equivalent, Mashkel depression. From heel

56 Carmen Gaina et al., “Tectonic Interactions between India and Arabia since the Jurassic Reconstructed from Marine Geophysics, Ophiolite Geology, and Seismic Tomography,” Tectonics 34, no. 5 (2015): 875–906, https://doi.org/10.1002/2014TC003780.
57 “Characterizing Seismo-Stratigraphic and Structural Framework of Late Cretaceous-Recent Succession of Offshore Indus Pakistan,” accessed July 28, 2025, https://www.degruyterbrill.com/document/doi/10.1515/geo-2018-0014/html?lang=en&srsltid=AfmBOoqiO2ywjdhcEPVUirMOy2giP8WF32n70-oMDeguFH-2fmub5KXK.
58 Gérôme Calvès et al., Anomalous Subsidence on the Rifted Volcanic Margin of Pakistan: No Influence from Deccan Plume, November 24, 2008, https://doi.org/10.1016/J.EPSL.2008.04.042.
59 “Rapid India–Asia Initial Collision between 50 and 48 Ma along the Western Margin of the Indian Plate: Detrital Zircon Provenance Evidence,” accessed July 28, 2025, https://www.mdpi.com/2076-3263/14/11/289.
60 Zahid Rafi, ANALYSIS OF SEISMICITY IN ARABIAN SEA BASED ON STATISTICAL MODEL, 2, no. 4 (2005).
61 “Makran Subduction Zone: A Review and Synthesis,” accessed July 28, 2025, https://www.mdpi.com/2076-3263/14/8/219.
62 Mohammad Mokhtari et al., “A Review of the Seism tectonics of the Makran Subduction Zone as a Baseline for Tsunami Hazard Assessments,” Geoscience Letters 6, no. 1 (2019): 13, https://doi.org/10.1186/s40562-019-0143-1.
63 Jean-Pierre Burg, “Geology of the Onshore Makran Accretionary Wedge: Synthesis and Tectonic Interpretation,” Earth-Science Reviews 185 (October 2018): 1210–31, https://doi.org/10.1016/j.earscirev.2018.09.011.

to toe, the wedge is roughly 350 km wide. It is a product of almost convergence between Eurasia and Arabia and increases vertically and laterally by scraping and accreting off sediments off the Arabian Plate's subducting lithosphere[64]. The accretionary wedge is further sub-divided into an active submarine wedge 100–150 km wide to the south, and the 150–200 km wide onshore wedge in the north[65]. These two segments are divided by a thin (few kilometers wide) coastal belt characterized by normal faults and mud volcanoes, both offshore and onshore. North-dipping subduction of the Arabian plate under the Central Iran and Afghan blocks started in the Cretaceous and continues to the present day[66]. It has been shown that the western segment of the volcanic arc has a much greater number of volcanoes than the eastern segment (Bazman Group (BG), Taftan Group (TG), and Sultan Group (SG))[67].

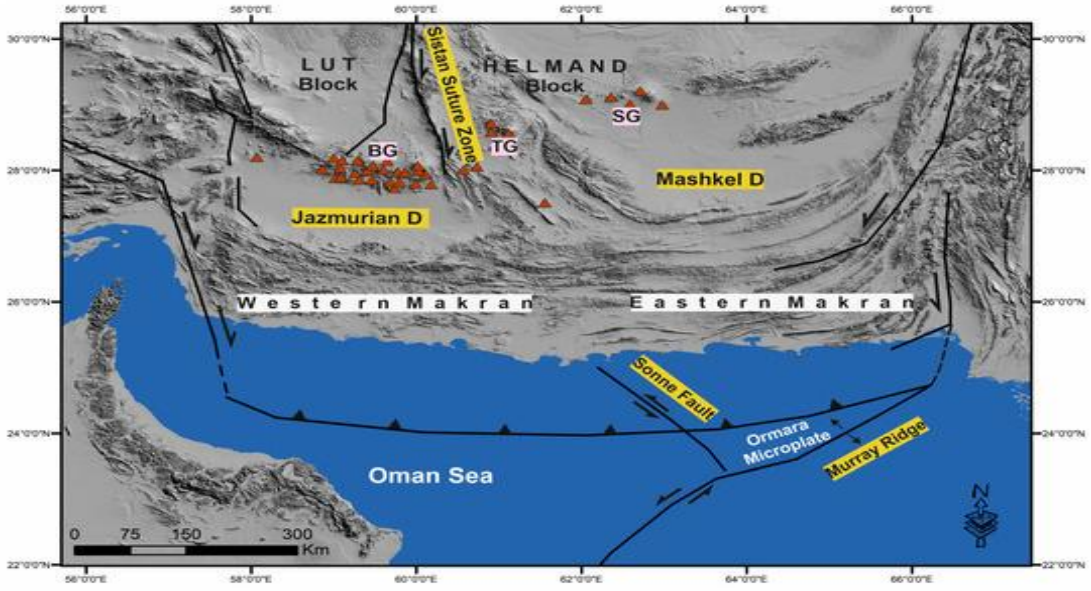

Figure 7: Makran Subduction Zone[68].

The study area and its structural characteristics are represented, including the Sistan Suture Zone, the Jazmurian Depression (Jamarion D), the Mashkel Depression (Mashkel D), the Sonne Fault, the Ormara Micro plate, and the

64 Renier Viltres et al., “Present-Day Motion of the Arabian Plate,” Tectonics 41, no. 3 (2022): e2021TC007013, https://doi.org/10.1029/2021TC007013.
65 “New Constraints for the On-Shore Makran Subduction Zone Crustal Structure - Priestley - 2022 - Journal of Geophysical Research: Solid Earth - Wiley Online Library,” accessed July 28, 2025, https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021JB022942.
66 Edoardo Barbero et al., “A Review of Mesozoic Geodynamic Evolution of the North Makran (SE Iran): A Tale of a Neo-Tethyan Ocean Vanished Due to Two Coexisting Subduction Zones,” Gondwana Research 141 (May 2025): 74–101, https://doi.org/10.1016/j.gr.2025.01.016.
67 “Seismic Evidence for Arc Segmentation, Active Magmatic Intrusions and Syn-Rift Fault System in the Northern Ryukyu Volcanic Arc | Earth, Planets and Space | Full Text,” accessed July 28, 2025, https://earth-planets-space.springeropen.com/articles/10.1186/s40623-018-0830-8.
68 Peyman Namdarsehat et al., “Makran Subduction Zone: A Review and Synthesis,” Geosciences 14, no. 8 (2024): 219, https://doi.org/10.3390/geosciences14080219.

Murray Ridge. Brown triangles represent volcano locations in the Bazman Group (BG), the Taftan Group (TG), and the Sultan Group (SG)[69].

Methane hydrates are one of the natural structures with high concentrations of methane, referred to as natural gas, and water, in the solid form of ice. Methane hydrates are crystalline solids that occur at low temperatures but moderate (e.g., for water depth exceeding 530 m for low latitudes and 250 m in high latitudes e.g., in the Arctic) and temperatures below but above the freezing point of water[70]. Dissipating land mineral reserves as well as the continued growing need for metals and minerals brought renewed interest in searching for marine mineral resources. Most of the seas' resources like Polymetallic Nodules (PMN), Polymetallic Sulfides (PMS), and Cobalt-rich Fe–Mn Crusts (CC) occurring in the "Area" outside the national territory of maritime states, the task of International Seabed Authority (ISA) in regulating the challenge in a socially responsible and creative manner is significant[71].

One of the research investigations conducted by the National Institute of Oceanography (NIO), along with the China Geological Survey, was on the Makran Continental Margin, off Pakistan, an actively tectonic area influenced by subduction of the Arabian Plate under the Eurasian Plate. This area, which is part of the Makran Accretionary Wedge within the northern Indian Ocean, is famous for its rapid sedimentation, anticline ridges, and active gas seepage and hence is a natural laboratory for the investigation of submarine mud volcanoes and pockmarks. The research used a multidisciplinary approach that incorporated geophysical, geological, and geochemical methods. Multibeam echo sounder surveys (EM302 system) produced high-resolution bathymetry and backscatter maps, and acoustic water column data indicated gas flares over active sites. Seismic reflection profiling with a multi-channel Seal428 system yielded subsurface images that identified faults, gas chimneys, acoustic blanking zones, and Bottom Simulating Reflectors (BSRs), which confirmed the existence of natural gas hydrates[72].

Seafloor observations made with a TV grab camera captured chemosynthetic assemblages like mussels, tubeworms, and squat lobsters, in addition to carbonate slabs and gas bubble venting. Further, modeling of gas hydrate stability with CSMHYD software and CTD-derived profiles of water temperature was employed to estimate GHSZ depth. This combined approach allowed for a

69 “The Study Area and Its Structural Features Are Shown, Highlighting the...,” Research Gate, accessed July 28, 2025, https://www.researchgate.net/figure/The-study-area-and-its-structural-features-are-shown-highlighting-the-Sistan-Suture_fig1_383207057.
70 “Methane Hydrates,” World Ocean Review, n.d., accessed July 28, 2025, https://worldoceanreview.com/en/wor-1/energy/methane-hydrates/.
71 Zenghui Liu et al., “Deep-Sea Rock Mechanics and Mining Technology: State of the Art and Perspectives,” International Journal of Mining Science and Technology 33, no. 9 (2023): 1083–115, https://doi.org/10.1016/j.ijmst.2023.07.007.
72 Tingting Wu et al., “Distribution and Development of Submarine Mud Volcanoes on the Makran Continental Margin, Offshore Pakistan,” Journal of Asian Earth Sciences 207 (March 2021): 104653, https://doi.org/10.1016/j.jseaes.2020.104653.

thorough evaluation of the distribution, morphology, activity, and governing mechanisms of mud volcanoes and pockmarks in the Makran offshore area[73].

In another study conducted by NIO, jointly with the Guangzhou Marine Geological Survey (GMGS), examined submarine pockmarks in the Makran accretionary prism, northern Arabian Sea. The approach used integrated multibeam bathymetric mapping and multichannel seismic profiling. Bathymetry data were recorded during 2018–2019 China–Pakistan joint cruise with the EM302 echo sounder and processed using CARIS software to create seafloor morphology maps and estimate pockmark properties at a 20 m grid size. Seismic data were recorded with the Seal 428 system and complemented by Pakistani data; these were processed using Echos2017 software and routine seismic processing workflows. Seismic profiles were employed to detect subsurface structures like faults, gas chimneys, mud diapirs, and Bottom Simulating Reflectors (BSRs), which serve as fluid migration pathways. The use of the integrated methodology enabled the scientists to delineate the morphology, distribution, and evolution of 87 pockmarks and examine their genetic connection to tectonics, sediments, and fluid escape processes[74].

2.2. Exploration of Hydrocarbons in Pakistan

The exploration of hydrocarbons in Pakistan has evolved over several decades, with significant efforts undertaken in various geological basins across the country[75]. These exploration activities have been driven by the need to meet rising energy demands and reduce dependency on imports.

a. Indus Basin Exploration

The Indus Basin is the most significant sedimentary basin in Pakistan, serving as the country's primary region for hydrocarbon exploration and production. Accounting for the majority of the oil and gas output, it spans approximately 800,000 square kilometers and is subdivided into the Upper, Middle, and Lower Indus sub-basins[76].

Each sub-basin of the Indus Basin has distinct geological features. The Upper Indus Basin includes the Potwar Plateau and Kohat areas in northern Punjab and Khyber Pakhtunkhwa. It is one of the earliest

73 Tingting Wu et al., “Distribution and Development of Submarine Mud Volcanoes on the Makran Continental Margin, Offshore Pakistan,” Journal of Asian Earth Sciences 207 (March 2021): 104653, https://doi.org/10.1016/j.jseaes.2020.104653.
74 Zhen Zhang et al., “A Preliminary Study on Geomorphological Characteristics and Genetic Mechanism of Pockmarks in the Makran Accretionary Prism, Northern Arabian Sea,” Geo-Marine Letters 41, no. 3 (2021): 27, https://doi.org/10.1007/s00367-021-00704-9.
75 Fraz Khalid et al., “Petroleum Source Rock Characterization and Hydrocarbon Generating Potential of Sediments from Surghar Range, Kohat Plateau, Upper Indus Basin,” Physics and Chemistry of the Earth, Parts A/B/C 138 (June 2025): 103853, https://doi.org/10.1016/j.pce.2025.103853.
76 Umair Bin Nisar et al., “Identification of Sealing Potential through Fault Seal Analysis: A Case Study of Badin Area, Lower Indus Basin, Pakistan,” Geofísica Internacional 58, no. 2 (2019): 139–50, https://doi.org/10.22201/igeof.00167169p.2018.58.2.1966.

explored regions, hosting the Khaur, Dhulian, and Toot field[77]. Later discoveries include Dhurnal and Ratana in Punjab and Chand and Makhori fields in the Bannu- Kohat sub basin. The Middle Indus Basin spans central Punjab and parts of northern Sindh, while the Lower Indus Basin covers southern Sindh and houses major gas fields like Mari, Sui, Kandhkot, Swan, Khaskheli, Bobi, Zamzama, Bhit, Bhadra, Qadirpur [78].

b. **Balochistan Basin Exploration**

The Balochistan Basin remains underexplored due to its harsh terrain, political instability, and logistical constraints. Despite being home to the famous Sui Gas Field discovered in 1952 and still a major contributor to national gas supplies the region has seen limited exploration[79]. The Makran Coastal Belt and Kharan trough possess favorable geological settings for hydrocarbon generation but lack adequate seismic and drilling data[80].

The Geological Survey of Pakistan has emphasized the need for focused surveys and security arrangements to encourage investment in the region. Offshore Makran, in particular, is attracting growing interest for future exploratory efforts, especially with advancements in deep water drilling technologies[81].

c. **Potwar Plateau Exploration**

The Potwar region is historically significant as one of the first areas explored for oil in South Asia. This fold-and-thrust belt is characterized by complex tectonics and relatively shallow oil reservoirs. Exploration in this area has largely been led by Pakistan Petroleum Limited (PPL) and Oil and Gas Development Company Limited (OGDCL) and Pakistan Oil Limited (POL) [82]. Oil fields like Toot, Adhi, Balkassar and Meyal have contributed to domestic oil output but are now facing production decline, necessitating enhanced oil recovery (EOR) techniques[83].

d. **Kirthar Fold belt and Offshore Exploration**

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77 Arshad Maqsood Malik and Nazir Ahmed, PALEOCENE CARBONATE OF KOHAT-POTWAR SUB-BASIN OF UPPER INDUS BASIN, PAKISTAN, n.d.

78 Fode Tounkara et al., “Analyzing the Seismic Attributes, Structural and Petrophysical Analyses of the Lower Goru Formation: A Case Study from Middle Indus Basin Pakistan,” Frontiers in Earth Science 10 (January 2023), https://doi.org/10.3389/feart.2022.1034874.

79 “Humapub.Com/Admin/Alljournals/Grr/Papers/Fulltexts/HxIrBwKJUl/,” accessed July 28, 2025, https://www.humapub.com/admin/alljournals/grr/papers/fulltexts/HxIrBwKJUl/.

80 “Frontiers | Characteristics of High Saturation Hydrate Reservoirs in the Low-Angle Subduction Area of the Makran Accretionary Prism,” accessed July 28, 2025, https://www.frontiersin.org/journals/earth-science/articles/10.3389/feart.2022.861162/full.

81 “Geological Survey of Pakistan - GSP,” accessed July 28, 2025, https://gsp.gov.pk/.

82 Amjad Ali, STRUCTURAL ANALYSIS OF THE TRANS-INDUS RANGES: IMPLICATIONS FOR THE HYDROCARBON POTENTIAL OF THE NW HIMALAYAS, PAKISTAN, n.d.

83 Fact Sheet, Fact Sheet, Fact Sheet (2000).

The Kirthar region, which lies between the Lower Indus Basin and Balochistan, has been the focus of exploration in the western margin. Companies such as ENI and PPL have drilled in the area with limited but promising results[84]. The region presents opportunities for natural gas discoveries, especially in tight reservoirs. Offshore exploration in Pakistan's Exclusive Economic Zone (EEZ) in the Arabian Sea has gained momentum, although no commercial discoveries have been made to date[85].

The Kekra-I well, drilled in 2019 by a consortium of ENI, ExxonMobil, OGDCL, and PPL, showed geological promise despite yielding dry results. Experts suggest that with further seismic surveys and advanced deep water drilling capabilities, the offshore frontier could become viable[86].

One of the research projects is based on interpretation of more than 5000 km of multi-channel seismic, sub-bottom profile, and multi-beam bathymetric data from the China–Pakistan joint expedition and additional Pakistani seismic data. The datasets were utilized to identify and categorize diapiric structures mud diapirs, mud volcanoes, and gas chimneys based on their morphology, seismic reflection characteristics, and tectonic relations.

2.3. Exploration of Mineral Resources in Pakistan

Minerals industry has been one of the major source of economic growth of various developed nations; China, Italy, Turkey, Spain, Brazil etc. Most of the nations are importing minerals from other nations, processing, and value addition and then exporting. Pakistan is blessed with vast reserves of minerals spanning an outcrop area of 600,000 sq. Kms[87]. They consist of 92 recognized minerals of which 52 are being mined commercially with a combined output of 68.52 million metric tons annually. All mineral resources (except the radioactive/nuclear minerals and petroleum) are responsibility of federating units/provinces (Balochistan, North Punjab, South Punjab, Sindh, Khyber Pakhtunkhwa), Capital Islamabad, Gilgit Baltistan and Azad Kashmir while the Radioactive minerals and Petroleum (oil and gas) are under the jurisdiction of Federal government of Pakistan[88].

Minerals are generally categorized into following three groups:

84 “Overview of Offshore Exploration in Pakistan,” n.d., accessed July 28, 2025, https://saifenergy.com/overview-of-offshore-exploration-in-pakistan/.
85 Waleed Sami, “Pakistan’s Offshore Oil Reserves and What It Means for County’s Energy Future,” Modern Diplomacy, September 18, 2024, https://moderndiplomacy.eu/2024/09/18/pakistans-offshore-oil-reserves-and-what-it-means-for-countys-energy-future/.
86 ZAFAR BHUTTA, “Govt Targets Offshore Drilling with New Partners,” The Express Tribune, July 25, 2025, https://tribune.com.pk/story/2557752/govt-targets-offshore-drilling-with-new-partners.
87 “Untapped Minerals Economy - Opinion - Business Recorder,” accessed July 28, 2025, https://www.brecorder.com/news/40338169.
88 M Sadiq Malkani and Zafar Mahmood, MINERAL RESOURCES OF PAKISTAN: PROVINCES AND BASINS WISE, n.d.

a. Metallic minerals
b. Non-metallic minerals, and,
c. Energy / strategic minerals".

Metallic minerals comprise metalliferous ores, aluminum, chromium iron etc, whereas non-metallic mineral comprise dimensional stones, clay, salt silica etc. and energy/strategic minerals comprise coal etc.

Pakistan possesses massive reserves of various minerals and natural resources such as coal, gold, copper, bauxite, mineral salt, chromite, iron ore, and many more. Pakistan also extracts many precious and semi-precious minerals such as ruby, topaz, and emerald. Pakistan possesses a comparative advantage of its mineral resources available in multiple varieties, colors and patterns[89]. The nation boasts the second largest in the world of salt mines and fifth largest reserves of copper and gold, and second largest coal reserves, and it also has estimated billions of barrels of crude oil. But with immense potential, Mineral sector of Pakistan contributes only 3.2 percent to GDP and 0.1 percent to global exports. The country is now aiming to tap into this underutilized potential[90].

In the year 2017, Pakistan's total mineral exports were 0.5 billion USD as compared to the world's 401 billion USD. The most potential and valuable minerals of Pakistan include Marble, Granite, Coal, Chromite, Gypsum, Copper, Gold, Iron Ore, Lead zinc, Bauxite, Crude oil and Natural gas. There are billions of commercially extractable reserves of these minerals that give both comparative and competitive advantages to Pakistan in the global perspective[91].

The convergence of Indo-Pakistan subcontinent (northward moving) plate with Asian (stable) plate created many tectonic metallic zones, basins and consequently significant mineralization in the area[92].

2.4. Latest Exploration in Pakistan

Exploration activities across different regions of Pakistan have yielded mixed results, with the Indus Basin continuing to be the most prolific. While areas like Balochistan and offshore zones remain underexplored, they offer considerable long-term potential. Pakistan is expanding its natural resource exploration to include critical minerals, reflecting a strategic shift toward diversifying its

89 Zainab Haseeb, "Mineral Resources of Pakistan | $6 Trillion Minerals Retained," Paradigm Shift, October 28, 2023, https://www.paradigmshift.com.pk/mineral-resources-in-pakistan/.
90 Press Release, "Mining Sector: Vast Reserves of Minerals Provide Solid Foundation: OGDCL," Brecorder, 03:03:45+05:00, https://www.brecorder.com/news/40352446.
91 "Strategy for Mineral Sector Development in Pakistan | PDF | Gemstone | Mining," Scribed, accessed July 28, 2025, https://www.scribd.com/document/426403394/STRATEGY-FOR-MINERAL-SECTOR-DEVELOPMENT-IN-PAKISTAN.
92 M Sadiq Malkani, Natural Resources of Khyber Pakhtunkhwa, Gilgit-Baltistan and Azad Kashmir, Pakistan, n.d.

economic base[93]. In March 2025, substantial antimony deposits were discovered in Balochistan, marking a key milestone in the country's mineral development efforts. A joint venture between the Oil and Gas Development Company Limited (OGDCL) and the Pakistan Mineral Development Corporation (PMDC) was launched to explore and develop these deposits, positioning Pakistan to become a regional supplier of this high-demand mineral. Antimony plays a vital role in the production of flame retardants, semiconductors, and defense-related materials[94].

The joint venture was officially introduced during the Pakistan Minerals Investment Forum 2025 (PMIF-25), signaling Pakistan's increasing commitment to strengthening its critical mineral supply chains. OGDCL, in collaboration with the Ministry of Energy, led the organization of PMIF-25, alongside key partners including the Special Investment Facilitation Council (SIFC), Government Holdings (Private) Limited (GHPL), Pakistan Petroleum Limited (PPL), and Mari Energies Limited (MEL)[95].

Mining and minerals have become a national priority for Pakistan, aiming to stimulate economic development, reduce dependency on imports, and increase exports[96]. Under the leadership of the SIFC—a civil-military body established in 2023—several strategic initiatives are underway. These include securing ten mineral-rich blocks in Gilgit-Baltistan, developing iron, copper, and gold deposits in Chiniot (Punjab), and forming partnerships with Oman for refining antimony, thereby addressing domestic infrastructure limitations[97].

To support the sector's growth, Pakistan is aligning higher education programs with international standards through collaboration with the Higher Education Commission (HEC), aiming to develop a skilled technical workforce. These developments will be featured at PMIF-25, underscoring the government's long-term commitment to mineral sector reform[98].

Simultaneously, global interest in deep-sea mining is accelerating. Companies have already invested approximately $2 billion in seabed exploration for strategic minerals like nickel, cobalt, and copper. Industry stakeholders are pushing for the International Seabed Authority to finalize global regulations by

93 Naqib Ullah Khan et al., "A Comprehensive Evaluation of Sustainable Mineral Resources Governance in Pakistan: An Analysis of Challenges and Reforms," Resources Policy 88 (January 2024): 104383, https://doi.org/10.1016/j.resourpol.2023.104383.
94 Monitoring Desk, "Antimony Deposits Discovered in Balochistan, OGDCL, and PMDC to Launch Joint Venture for Mineral Exploration," Profit by Pakistan Today, March 25, 2025, https://profit.pakistantoday.com.pk/2025/03/25/antimony-deposits-discovered-in-balochistan-ogdcl-pmdc-to-launch-joint-venture-for-mineral-exploration/.
95 "OGDCL Hosts Landmark Pakistan Mineral Investment Forum 2025 | OGDCL," accessed July 28, 2025, https://ogdcl.com/news/ogdcl-hosts-landmark-pakistan-mineral-investment-forum-2025.
96 "US Interagency Delegation to Arrive in Islamabad next Week to Attend Pakistan Minerals Investment Forum," Arab News, accessed July 28, 2025, https://www.arabnews.com/node/2596059/amp.
97 "Pakistan Announces Discovery of Strategic Antimony Reserves Used in Making Military Equipment," Arab News, March 29, 2025, https://arab.news/p889s.
98 "News Minister IT Calls for Novel, Urgent Interventions to Increase Employability of IT Graduates," accessed July 28, 2025, https://www.hec.gov.pk/english/news/news/Pages/Minister-IT.aspx.

2025[99]. With an Exclusive Economic Zone spanning more than 240,000 square kilometers, Pakistan is positioning itself to harness its underutilized maritime resources, contributing to energy security and enhancing its role in international mineral markets[100].

The most recent news in Pakistan's mines and minerals industry involves substantial expected investment from the US after a recent bilateral tariff deal brought down bilateral tariffs on Pakistani exports to 19%, which is the lowest among rivals in the US market. Commerce Minister Jam Kamal Khan underlined the US interest in making investments in mining, especially copper, as refined copper has been exempted from the 50% tariff earlier applied, and exports of value-added copper products such as refined copper, bars, rods, and alloys are more favorable. Pakistan, with fifth position in the world in terms of copper reserves, hopes to transition from solely exporting raw ores of copper to China to cornering profitable markets in the US, Europe, and the Middle East through production boost using advanced mining technology and facilities. The government has also assigned the task of detailed geological mapping to the Geological Survey of Pakistan to locate as yet untapped reserves and is streamlining regulations as well as enhancing infrastructure like mine access roads and power supply to invite private sector participation. This development is in line with increasing global copper demand fueled by clean energy technologies and is likely to enhance Pakistan's export revenues, minimize trade imbalances, and establish the country as a credible supplier within the international minerals market. The revised tariff rates are also likely to enhance Pakistani exports' penetration of the competitive US market, particularly textiles, further solidifying economic links between Pakistan and the US[101].

99 Monitoring Desk, “$2 Billion at Stake as Firms Push for Deep-Sea Mining Rules by 2025,” Profit by Pakistan Today, January 19, 2025, https://profit.pakistantoday.com.pk/2025/01/19/2-billion-at-stake-as-firms-push-for-deep-sea-mining-rules-by-2025/.

100 Safia Mansoor, “Employing Space Technology to Harness Marine Resources: Pakistan’s Space Policy in Perspective,” Modern Diplomacy, July 20, 2024, https://moderndiplomacy.eu/2024/07/20/employing-space-technology-to-harness-marine-resources-pakistans-space-policy-in-perspective/.

101 “Govt Expects Investment in Mines, Export of Refined Copper to US - Pakistan - DAWN.COM,” accessed September 1, 2025, https://www.dawn.com/news/1930100.

Chapter 3

Hydrocarbon Resources: Exploration, Production, and Potential

3.1 Key Stakeholders in Offshore Hydrocarbon and Mineral Exploration and Exploitation

In Pakistan the Ministry of Energy is tasked with the production and transmission across the country[102]. It is arranged into two broad divisions, the Petroleum Division and Power Division. The Petroleum Division is tasked with the development and exploitation of hydrocarbon and mineral resources. However, the Power division has faced criticism for the supply and generation of electricity[103]. For the exploration, exploitation, production and distribution of hydrocarbon and mineral resources a number of departments are involved as shown in the figure below:

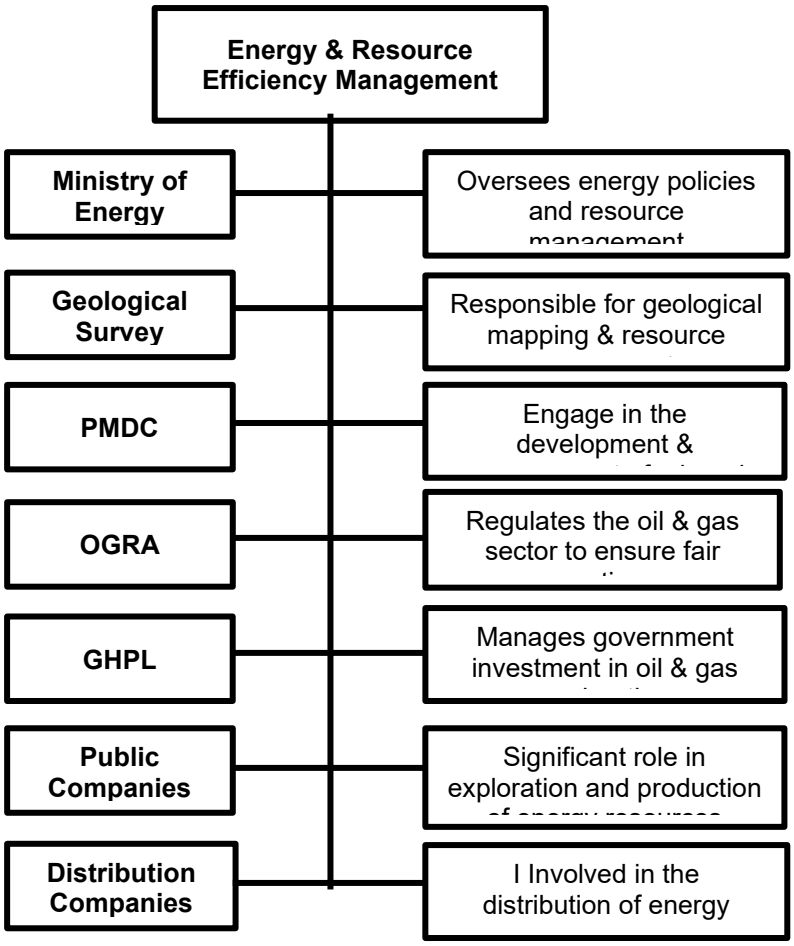

Figure 8: Government departments involved in the exploration, exploitation, production, and distribution of hydrocarbon and mineral resources in Pakistan.

102 "Understanding Power System & Tariff Structure in Pakistan (Design).Pdf," 2024., accessed July 21, 2025, https://sdpi.org/assets/lib/uploads/Understanding%20Power%20System%20&%20Tariff%20Structure%20in%20Pakistan%20(Design).pdf.

103 "Rr-044-Gas-and-Petroleum-Market-Structure-and-Pricing.Pdf," n.d., accessed July 21, 2025, https://file.pide.org.pk/pdfpideresearch/rr-044-gas-and-petroleum-market-structure-and-pricing.pdf.

3.2 Pakistan's Petroleum Exploration and Production Policies, Rules & Regulations, and Framework

For effective development of the hydrocarbon industry Pakistan's petroleum industry functions under complete legal and policy regime[104]. The foundation is the Act of petroleum in 1948. The fiscal and operating guidelines are contained in the changing Petroleum Policies such as 1991, 1992, 1993, 1994, 1997, 2001, 2007, 2009, and 2012. The policies are supplemented by the issuance of different Exploration and Production Rules in 1949, 1986, 2001, 2009, and 2013. The Tight Gas Policy was further introduced in 2024 to enable the exploration and production of Pakistan's unconventional resources[105].

Some additional Policies and legislations governing Pakistan's energy industry are numerous, with some of the key ones being the Petroleum Act 1948, E&P Rules (1949, 1986, 2001, 2009, 2013), Offshore Rules (2003 & 2023), several Petroleum Policies (1991, 1992, 1993, 1994, 1997, 2001, 2007, 2009 & 2012), as well as specialized policy frameworks such as the Tight Gas Policy 2024, Flare Gas Guidelines, Low BTU Gas Policy, Marginal Field Guidelines, and Pakistan Petroleum E&P Rules to boost national energy production[106].

The Pakistan Offshore Petroleum (Exploration and Production) Rules, 2023, superseded the previous 2003 rules and included an important provision concerning royalty sharing[107]. Rule 43(2) of the new rules dealt with the old question of how royalties from offshore oil and gas exploration should be divided between the federal and provincial governments[108]. It provides that if the exploration block is within the territorial waters of Pakistan (within 12 nautical miles from the coast), then the federal government is required to consult the related province and divide the royalty as per their respective proportion[109].

But if most of the block is outside the territorial waters (in deeper waters), then royalty is given only to the federal government and not to the provinces[110]. This stipulation basically resolves the jurisdictional and financial conflicts between the two governments when exploration takes place in deep waters, where the mineral resources are also mostly located[111]. Though these regulations were

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104 Rahimullah Khan and Shabidullah Wazir, Reforming the Energy Sector and Cost Effective Sources of Energy for Industrial Development, 3, no. 3 (2024).
105 Government Policies – PPIS, n.d., accessed July 21, 2025, https://ppisonline.com/government-policies/.
106 Government Policies – PPIS.
107 “Title Final Final,” n.d., accessed July 21, 2025, https://www.sindhenergy.gov.pk/wp-content/uploads/2023/04/Petroleum-EP-Policy-2007.pdf.
108 “Draft Pakistan Upstream Policy 2006,” n.d., accessed July 21, 2025, http://www.mpnr.gov.pk/SiteImage/Misc/files/Petroleum%20Policy%202012%20-%20Amended%20Feb%202024.pdf.
109 “Printing - LAW OF THE SEA (National Legislation) © DOALOS/OLA - UNITED NATIONS,” n.d., accessed July 21, 2025, https://www.un.org/depts/los/LEGISLATIONANDTREATIES/PDFFILES/PAK_1976_Act.pdf.
110 “Draft Pakistan Upstream Policy 2006.”
111 Oludayo Amokaye, “Sovereignty and Jurisdiction over Offshore Natural Resources in a Federal State: A Case Study of Nigeria,” SSRN Scholarly Paper no. 1581404 (Social Science Research Network, August 30, 2006), https://doi.org/10.2139/ssrn.1581404.

drafted under Section 14 of the erstwhile repealed Territorial Waters and Maritime Zones Act, 1976, the said clause has been kept in Section 32 of the newly enacted Pakistan Maritime Zones Act, 2023[112]. Therefore, the legal basis for the regulations still holds good and intact despite the repeal of the previous law[113].

3.3 Overview of Pakistan's Offshore Hydrocarbon Resources

There are only 18 exploration wells, of which three were deep water and 15 were shallow-water wells which have been drilled. Just one shallow water well, Pak Can 1, had reported the encounter of insignificant gas and was plugged in and abandoned (P&A) by Oil and Gas Development Company Ltd in February 1986[114]. Kekra 1 was the most recent offshore well drilled in the nation which was P&A by Eni in May 2019 after experiencing gas shows. It was a deep water well at the depth of 1,900 m water in the Offshore Indus-G block and the license was later relinquished[115].

Pakistan's offshore comprises two separate basins, Makran and Indus, and these both encompass area more than 282,623 sq km. Pakistan issued offshore block bid round in February 2025 & offering 40 blocks in Indus and Makran basins for exploration licenses[116].

3.3.1 Indus Offshore Blocks

The Indus Offshore Basin, extending from the Saurashtra Volcanic Arc to the Murray Ridge, is a geologically diverse passive margin basin along Pakistan’s 700 km Arabian Sea coastline. It features Miocene deltaic systems, carbonate build-ups, and deep-water turbidities plays. Traps include fault blocks, rollovers, and pinch-outs, supported by source rocks with TOC ranging from 1–9.75%[117].

With a resource potential of 10–40 TCF, the basin offers multiple exploration opportunities. Proven reservoirs in Pakcan-01 (gas flow of 3.7 MMscfd), Kekra-01, and PakG2-01 indicate the viability of the petroleum system. A total of **26 blocks** are offered in the **Shallow, Deep,** and **Ultra-Deep** offshore regions.

a. **Petroleum system**

(1) **Source Rocks**

112 “Printing - LAW OF THE SEA (National Legislation) © DOALOS/OLA - UNITED NATIONS.”
113 “Microsoft Word - CP 5812-2015-Final.Doc,” n.d., accessed July 22, 2025, https://caselaw.shc.gov.pk/caselaw/view-file/MTIzODEyY2Ztcy1kYzgz.
114 Amokaye, “Sovereignty and Jurisdiction over Offshore Natural Resources in a Federal State.”
115 “Pakistan, Turkiye Sign Offshore Bidding Pact for Joint Oil and Gas Exploration,” Arab News, accessed July 24, 2025, https://www.arabnews.com/node/2596657/amp.
116 Arab News, “Pakistan, Turkiye Sign Offshore Bidding Pact for Joint Oil and Gas Exploration.”
117 “Indus Offshore,” n.d., accessed July 25, 2025, https://ppisonline.com/wp-content/uploads/2025/02/Indus-Offshore-Bidding-Blocks1.pdf.

According to the research there are three types of source rocks in the Offshore Indus Basin, i.e., Cretaceous, Paleocene–Eocene, and Miocene source rocks[118]. Two wells in the Offshore Indus Basin have encountered very thin Cretaceous mudstone source rocks. Cretaceous source rock characteristics are primarily compared with those from the Lower Indus Basin. The Paleocene–Eocene shale source rocks are primarily compared with those from the neighboring Kutch Basin[119]. Yet the Kutch basin's shale does hold coal seams. Type-Ⅲ organic matter was encountered within Paleocene–Eocene mudstones. The source rocks of the Miocene have been established to exist through Pakcan-1 well drilling, with mudstone thickness at 300 m, an average of TOC up to 2%[120].

(2) **Reservoir Rocks**

The structure of reservoir accumulation is optimal. There are two kinds of reservoirs in the Offshore Indus Basin, i.e., shelf delta-subaqueous fan clastic rock reservoirs and Paleocene–Eocene carbonate rock reservoirs. Among them, the Paleocene–Eocene carbonate rock reservoirs are primarily located at the reef limestone over the volcanic rock buried hills[121]. There are two wells in the Offshore Indus Basin that have hit carbonate rock reservoirs, and the lithology of one of the carbonate rock reservoirs is biotic muddy limestone, biotic grain limestone, biotic framework reef limestone, muddy-grain limestone, and biotic framework pores and grain interstitial pores[122].

(3) **Cap Rocks**

The faults, unconformities, and sandstone in the subaqueous distributary channel at the area of study are well developed and constitute a good pathway for migration of oil and gas[123]. Hydrocarbons accumulate in the Lower Cretaceous sandstone,

118 Jian-ming Gong et al., “Exploration Prospects of Oil and Gas in the Northwestern Part of the Offshore Indus Basin, Pakistan,” China Geology 3, no. 4 (2020): 633–42, https://doi.org/10.31035/cg2020051.
119 Jian-ming Gong et al., “Exploration Prospects of Oil and Gas in the Northwestern Part of the Offshore Indus Basin, Pakistan,” China Geology 3, no. 4 (2020): 633–42, https://doi.org/10.31035/cg2020051.
120 “Fig. 6. Sedimentary Environment of Source Rocks in the Offshore Indus...,” ResearchGate, accessed July 24, 2025, https://www.researchgate.net/figure/Sedimentary-environment-of-source-rocks-in-the-Offshore-Indus-Basin-and-its-adjacent_fig4_348750883.
121 Jing Sun et al., “The Volcanic Rocks and Hydrocarbon Accumulation in the Offshore Indus Basin, Pakistan,” Journal of Marine Science and Engineering 12, no. 8 (2024): 8, https://doi.org/10.3390/jmse12081375.
122 Fanyang Meng et al., “A Study on the Sedimentary Environment and Facies Model of Triassic Carbonate Rocks in the Mangeshlak Basin,” Applied Sciences 15, no. 14 (2025): 14, https://doi.org/10.3390/app15147788.
123 Yahui Fan et al., “Sedimentary Characteristics and Petroleum Geological Significance of the Middle–Upper Triassic Successions in the Wushi Area, Western Kuqa Depression, Tarim Basin,” Applied Sciences 15, no. 14 (2025): 14, https://doi.org/10.3390/app15147895.

Paleocene–Eocene carbonate rocks, and Miocene–Pliocene channel sandstone that are topped by thick sequences of Upper Cretaceous shale, Cretaceous–Paleocene volcanic rocks, and Lower Miocene and Pliocene mudstone after migration through the pathway. The Oligocene sediments are also said to serve as the seal rocks[124].

(4) **Traps**

Both structural and stratigraphic traps occur in the Offshore Indus. The structural traps are rollover anticlines and drape structures. The anticlines are caused by the extensional regime close to the shore and the drape structures occur over the carbonate banks and seamounts of the Eocene[125]. The stratigraphic traps are pinch-outs occurring against the Murray Ridge caused by the depositional trends. The Plio-Pleistocene Channel levee complex is also responsible for stratigraphic traps within the area.

Lower to upper Cretaceous Goru shales are the main cap rocks tied with the Sembar and lower Goru sandstones. Ranikot and Kirther Shale Units overlaying the carbonate buildup. Miocene and Pliocene Mudstone/Shale are cap rock for Indus Deltaic sand reservoirs[126].

124 Thomas E. Ewing and William E. Galloway, “Chapter 16 - Evolution of the Northern Gulf of Mexico Sedimentary Basin,” in The Sedimentary Basins of the United States and Canada (Second Edition), ed. Andrew D. Miall (Elsevier, 2019), https://doi.org/10.1016/B978-0-444-63895-3.00016-4.
125 Muhammad Tayyab Naseer et al., “Appraisal of Reservoir Quality for Hydrocarbon-Bearing Deep-Water Miocene Sandstones Incised Valley, South-East Asian Offshore Indus: An Application of Seismic Attributes and Instantaneous Spectral Porosity Quantitative Reservoir Simulations,” Heliyon 10, no. 9 (2024): e29554, https://doi.org/10.1016/j.heliyon.2024.e29554.
126 Waqas Naseem et al., “The Early Cretaceous Sembar Formation, Southern Indus Basin, Pakistan: Biomarkers and Trace Element Distributions to Investigate the Sedimentary Palaeo environment and Organic Matter Input,” ACS Omega 9, no. 38 (2024): 39430–51, https://doi.org/10.1021/acsomega.4c02995.

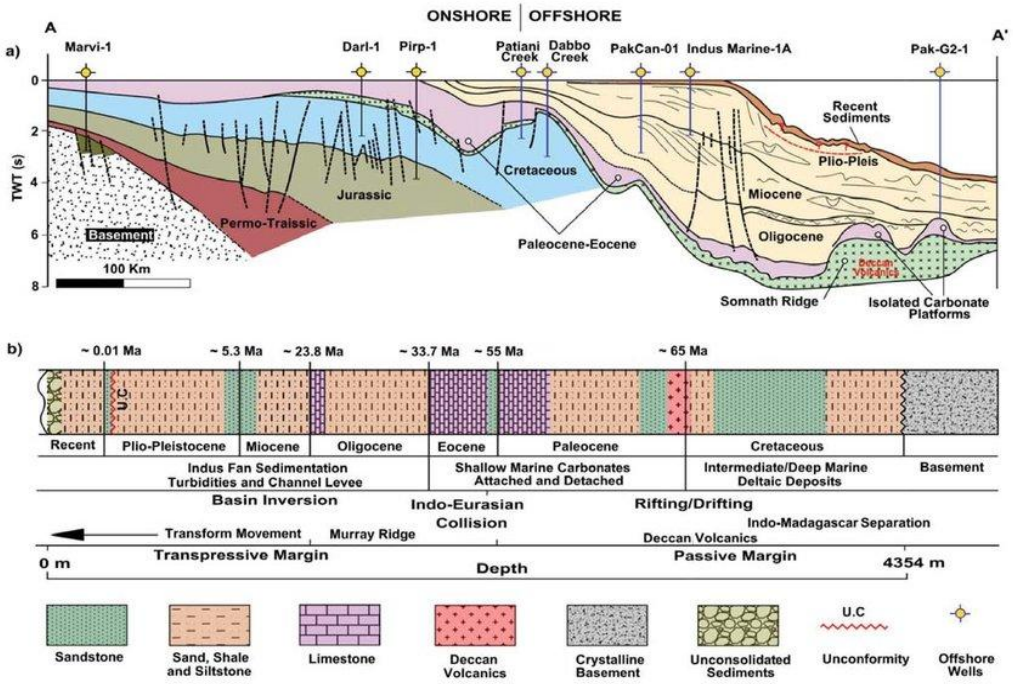

Figure 9: Tectono-Stratigraphic Cross-Section of the Indus Offshore Basin[127].

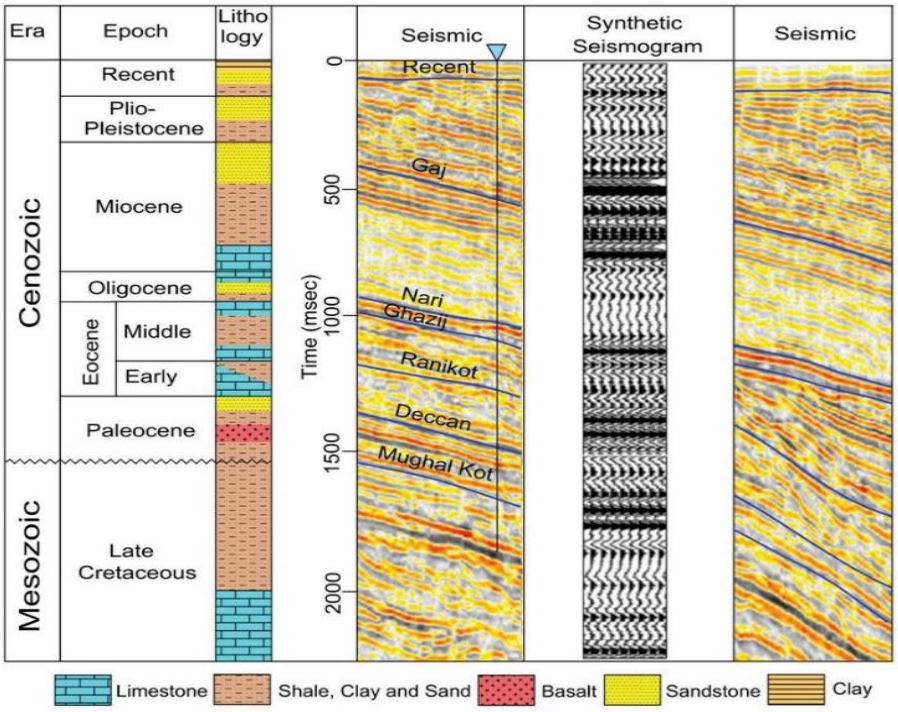

Figure 10: Litho-Stratigraphic and Seismic Correlation[128].

127 “Figure 2. Regional Cross Section of Offshore Indus Basin and Adjacent...,” research gate, accessed August 19, 2025, https://www.researchgate.net/figure/Regional-cross-section-of-Offshore-Indus-Basin-and-adjacent-onshore-regions-modified-from_fig1_341726323.

128 “Litho stratigraphic Chart Showing the Simplified Stratigraphy of the... | Download Scientific Diagram,” accessed August 19, 2025, https://www.researchgate.net/figure/Lithostratigraphic-chart-showing-the-simplified-stratigraphy-of-the-Slyne-Basin-age-of_fig2_364994411.

3.3.2 Makran Offshore Blocks

The Makran Offshore Basin, situated west of the Murray Ridge on the Makran Accretionary Prism, is a component of Pakistan's 700 km-long offshore province. It has intricated structural and stratigraphic tectonic compression-influenced traps. The petroleum system of the basin is maintained through Miocene shales (Hoshab/Siahan & Parkini formations) as source rocks, Miocene sandstones as reservoirs, and intra-formational shales and mudstones as seals[129].

While underexplored, the Makran Basin offers low to moderate exploration risk in shallow regions and moderate to high risk in ultra-deep domains. Seismic work indicates substantial untapped potential, especially in biogenic gas and increasingly mature offshore petroleum systems[130]. A total of 18 blocks are offered in the Shallow **and** Ultra-Deep Makran Offshore region.

These blocks are thought to have undrilled carbonate buildups, biogenic gas in younger Tertiary aged formations, and mature source rocks, showing great hydrocarbon potential[131].

Until the on- and off-shore of Makran has not been investigated thoroughly. Four wells have been drilled in the Makran Offshore but they have failed. In the same way, five onshore wells have failed to date. But off-shore, the oil and gas seeps have been observed. Number of blocks are up for grabs this year. The Makran basin is constructed over the accretionary prism[132].

The Makran basin has formed over the accretionary prism. Sediment section from Cretaceous to recent is approximately 7 km in thickness. Sedimentary sequence occurs upon the Cretaceous or more ancient basement exposed north of Makran within the Hamun-e-Mashkel depression[133].

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129 “Indus Offshore,” n.d.
130 Jianqiang Wang et al., “Characteristics of Deep water Oil and Gas Distribution along the Silk Road and Their Controlling Factors,” Water 16, no. 2 (2024): 2, https://doi.org/10.3390/w16020240.
131 “Emr-Scoping-Study-Unconvential-Oil-Gas-Potential-Yukon_0.Pdf,” n.d., accessed July 25, 2025, https://yukon.ca/sites/default/files/emr-scoping-study-unconvential-oil-gas-potential-yukon_0.pdf.
132 Ahmed Abdelmaksoud and Mohammed Y. Ali, “Petroleum System Analysis of Fujairah Basin, Eastern Offshore of the United Arab Emirates,” Marine and Petroleum Geology 170 (December 2024): 107157, https://doi.org/10.1016/j.marpetgeo.2024.107157.
133 Rahil Mokhtarzadeh et al., “Imaging the Seismic Structure of the Western Makran Subduction Zone,” Geophysical Journal International 242, no. 2 (2025): ggaf196, https://doi.org/10.1093/gji/ggaf196.

a. **Petroleum System**

(1) **Source Rock**

Source rocks includes the shales of Panjgur of Miocene and Hoshab of Oligocene can be source rock. Hoshab formation has TOC up to 6% and can contain more organic content offshore. Miocene calcareous mudstone of Parkini Formation has a thickness of approximately 3 km. It possesses the features of working both as a source rock as well as a seal. Approximately 0.46- 0.98% TOC is present in onshore outcrops[134].

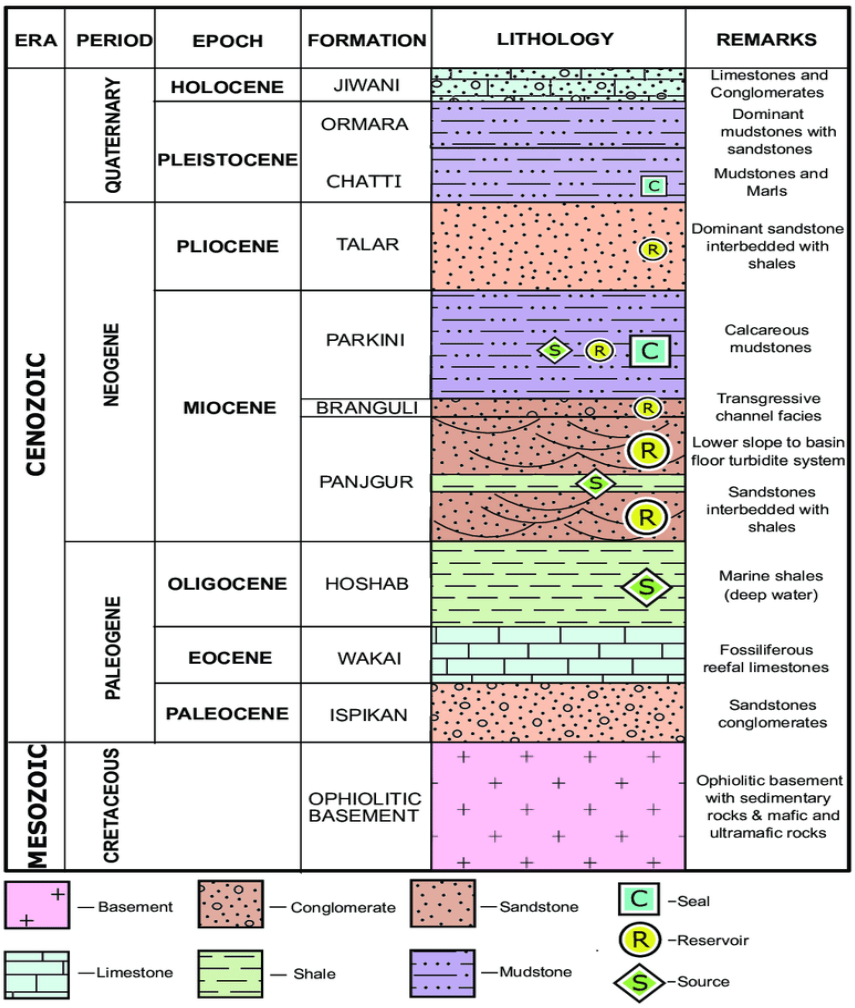

Figure 11: Stratigraphic Column and Hydrocarbon Potential of the Makran Basin.

(2) **Reservoir Rock**

Panjgur Miocene sandstones and upper Parkini Formation may be used as reservoir rocks. The Panjgur sandstone thickness is 450 m to 2-3 km. The reservoir contains good primary porosity

134 "Organic Geochemistry and Source Rock Potential Assessment of Late Paleocene Patala Formation in Margalla Hill Range, North Pakistan," accessed July 25, 2025, https://www.sciopen.com/article/10.3969/j.issn.1673-9736.2021.04.03.

with good secondary porosity by dissolution of calcite. Pliocene Talar sandstone formation may also serve as a probable reservoir rock[135].

(3) **Seal Pairs**

Intraformational shales and Miocene Punjgur mudstone can serve to seal the Miocene sands. Pleistocene mudstone also has the capability to serve as seal rock.

(4) **Trap Geometries**

Makran is a multi-faceted variety of structural and stratigraphic traps. The hanging wall anticlines and growth developed as a result of folding of the sediments with the development of the accretionary prism serve as the structural traps. The channel and levee system and pinch-outs provide the stratigraphic barriers for the hydrocarbons within the region[136].

Table 1: *Source, reservoir, and seal rock characteristics of the Indus Offshore and Makran Offshore basins.*

Indus Offshore Basin	**Makran Offshore Basin**
1. Source Rock a. Sember Shale/Mudstone (Cretaceous) Mudstone b. Ghazij-equivalent Shales(Paleocene–Eocene) c. Gaj Mudstone (Miocene)	**1. Source Rock** a. Hoshab Shales (Oligocene) b. Panjgur Shales (Miocene) c. Parkini Mudstone (Miocene)
2. Reservoir a. Carbonate Reservoirs (Paleocene-Eocene) b. Clastic Delta-fan Sandstones (Miocene/Pliocene)	**2. Reservoir** a. Panjgur Sandstone (Miocene) b. Talar Sandstone (Pliocene)
3. Seal a. Grou Shales (Cretaceous) b. Ranikot and Kirther Shale Units (Paleocene- Eocene) c. Miocene and Pliocene Mudstone/Shale (Neogene)	**3. Seal** a. Parkini Mudstone (Miocene) b. Chatti Mudstone (Pliocene)

3.4 Analysis of existing exploration and production activities in Indus offshore

135 “Photomicrographs of Sand-Size Volcanic Lithic Fragments from the Makran... | Download Scientific Diagram,” accessed July 25, 2025, https://www.researchgate.net/figure/Photomicrographs-of-sand-size-volcanic-lithic-fragments-from-the-Makran-arenites-a_fig1_222326632.
136 Jonas Ruh, “The Makran Accretionary Wedge: An Ideal Natural Laboratory to Study Accretionary Processes.,” Tectonics and Structural Geology, n.d., accessed July 25, 2025, https://blogs.egu.eu/divisions/ts/2020/06/16/the-makran-accretionary-wedge-an-ideal-natural-laboratory-to-study-accretionary-processes/.

Pakistan's Offshore Indus Basin has experienced limited but technically meaningful exploration and production operations. The latest well to be drilled in the basin was Kekra-1 in the Indus-G block, which was drilled in May 2019 by a consortium comprising ExxonMobil, ENI, OGDCL, and PPL. Although some shows of gas were reported, the well proved to be non-commercial and was plugged and abandoned. Before this, Pakistan's offshore activities had witnessed wells such as Sadaf-1 (1989), Pak-G2 (2003), and Anne-1X (2007), but none of these were successful and led to commercially exploitable discoveries. A total of about 18 wells have been drilled offshore—three in deep water and fifteen in shallow—but no successful production has been developed[137].

For the first time there are 40 offshore blocks that are available for bidding.

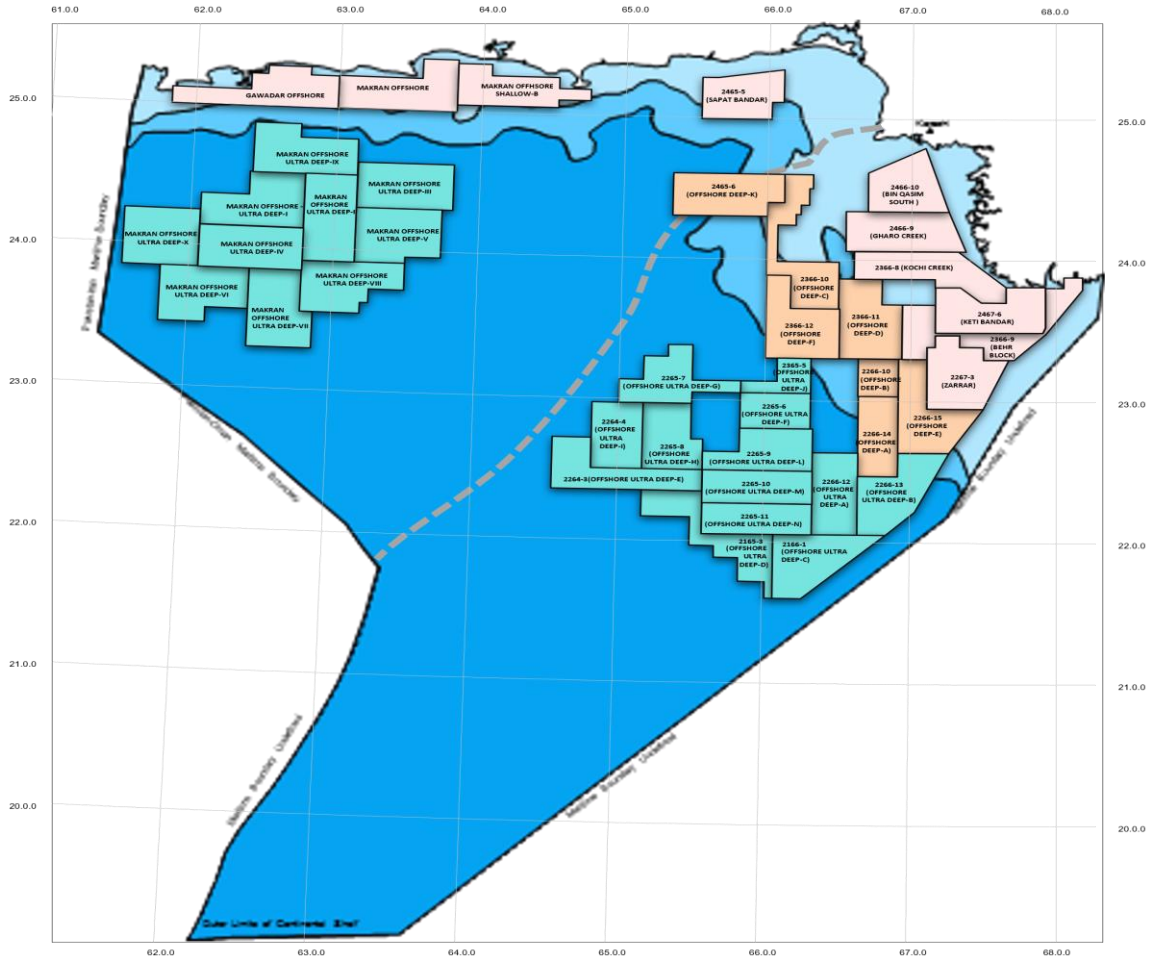

Figure 12: Offshore Petroleum Exploration map of Pakistan[138].

137 "No Oil, Gas Reserves Found off Pakistan Shore," accessed July 25, 2025, https://tribune.com.pk/story/1975799/18th-drilling-attempt-fails-find-oil-gas-reserves-off-pakistan-shore.

138 Bids Invited – PPIS, n.d., accessed August 19, 2025, https://ppisonline.com/bidding-blocks/.

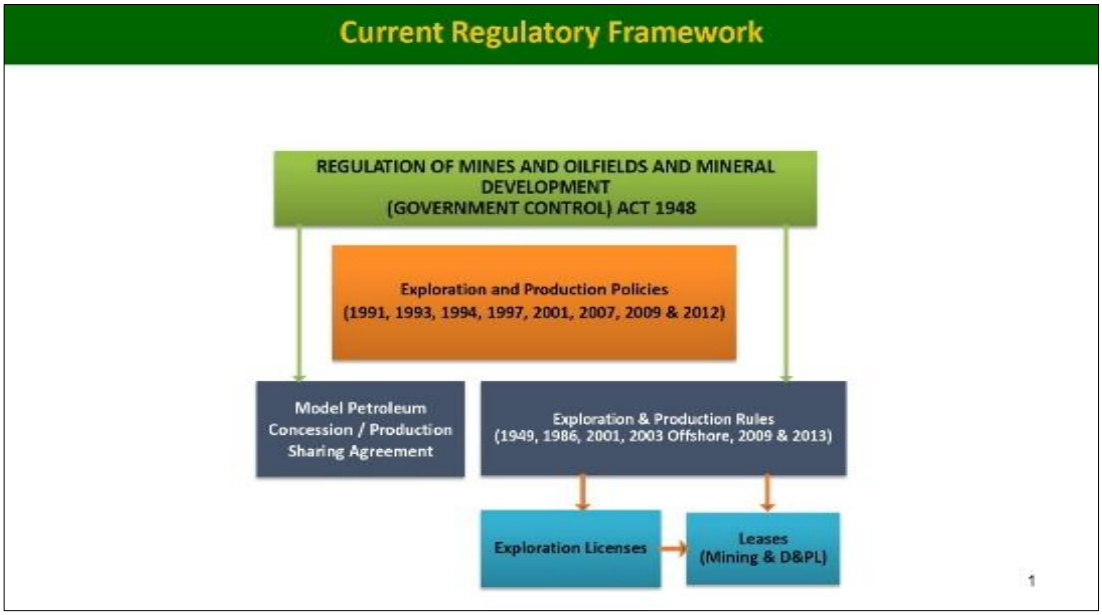

Figure 13: Current regulatory framework[139].

In order to raise the confidence of the foreign investors and draw foreign investment for the oil and gas industry in Pakistan several provisions have been made[140]. With regulatory approvals, the firms will have the capability to sell the discovered hydrocarbons to third party. Without any limitations the investors will be able to repatriate dividends and profits, and the government has provided timely payment of gas to the investors in US dollars[141].

The investor is allowed to keep a maximum of 95% of the profit and also enable cost recovery of approximately 85%. Additionally, no royalty for the first four years is applicable. Based on the factor, the price of the gas shall be between $7 and $9 per MMBtu[142]. The Pakistan government has provided bonanza of $1 per MMBtu to the sanctioned price of gas for the initial three offshore discoveries. In an effort to cut down the costs of operations, there will only be 5% import on equipment and machinery required for the hydrocarbon projects[143].

139 “Mines Act 1923,” n.d., accessed August 19, 2025, https://www.pec.org.pk/wp-content/uploads/2021/05/The-Mines-Act-1923.pdf.
140 Wen Xuwu, “Protections and Facilitations for Foreign Investors: Legal Perspective under Pakistani Laws,” Journal of Development and Social Sciences 3, no. I (2022): 52–63, https://doi.org/10.47205/jdss.2022 (3-i)05.
141 “Govt Notifies Sale of 35pc Gas Output to Private Parties - Business - DAWN.COM,” accessed July 25, 2025, https://www.dawn.com/news/1886024.
142 “Woodmac Energy,” n.d., accessed July 25, 2025, https://energyproducers.au/wp-content/uploads/2025/05/AEP-Australias-Natural-Gas-Investment-Competitiveness-Final.pdf.
143 “Pakistan’s Gas Discoveries Eliminate Import Need | Oil & Gas Journal,” accessed July 25, 2025, https://www.ogj.com/home/article/17233581/pakistans-gas-discoveries-eliminate-import-need.

Chapter 4

Deep- Sea Mining

According to Part V of the United Nations Convention on the Law of the Sea (UNCLOS), the coastal states have sovereign rights over natural resources within their EEZ. They can explore, exploit and manage these resources in their EEZ. However, under UNCLOS Article 194 the countries must ensure that the mining activities do not cause significant harm to the marine environment.

Article 194
Measures to prevent, reduce and control pollution
of the marine environment
"States shall take, individually or jointly as appropriate, all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source, using for this purpose the best practicable means at their disposal and in accordance with their capabilities, and they shall endeavour to harmonize their policies in this connection.
States shall take all measures necessary to ensure that activities under their jurisdiction or control are so conducted as not to cause damage by pollution to other States and their environment, and that pollution arising from incidents or activities under their jurisdiction or control does not spread beyond the areas where they exercise sovereign rights in accordance with this Convention" [144]

The laws and policies governing seabed mining in the EEZ varies in different countries. However, due to environmental concerns, some countries have banned or paused sea-bed mining. The seabed beyond the EEZ is referred to as "The Area" which is regulated by the International Seabed Authority (ISA). Without an ISA contract no country can claim exclusive mining rights. ISA was established in 1994 and was created under the United Nations Convention on the Law of the Sea (UNCLOS) 1982.[145]

Article156
Establishment of the Authority
1. There is hereby established the International Seabed Authority, which shall function in accordance with this Part.
2. All States Parties are *ipso facto* members of the Authority.
3. Observers at the Third United Nations Conference on the Law of the Sea who have signed the Final Act and who are not referred to in article 305, paragraph 1(c), (d), (e) or (f), shall have the right to participate in the Authority as observers, in accordance with its rules, regulations and procedures.
4. The seat of the Authority shall be in Jamaica.

144 United Nations, *United Nations Convention on the Law of the Sea* (Montego Bay, Jamaica: United Nations, 1982), https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
145 Caitlin Keating-Bitonti, *Seabed Mining in Areas Beyond National Jurisdiction: Issues for Congress*, CRS Report R47324, Library of Congress, April 25, 2025, https://www.congress.gov/crs-product/R47324.

5. The Authority may establish such regional centres or offices as it deems necessary for the exercise of its functions. [146]

The main responsibility of ISA is to regulate and manage seabed resources in the deep below 200 meters. This involves the development of rules and regulations for the exploration and seabed resources and protecting the marine environment from the damaging effects of mining activities.

4.1 ISA Organs

The ISA Assembly consists of all the member countries and is empowered to make general policies. The ISA council consists of 36 countries which make more specific decisions about the mining projects. These countries are further grouped in five groups (A, B, C, D and E)[147]. It rejects and approves the mining applications. There is ISA Secretariat which is headed by the Secretary General. Then there is the Finance Committee, the Enterprise and the Legal and Technical Commission.

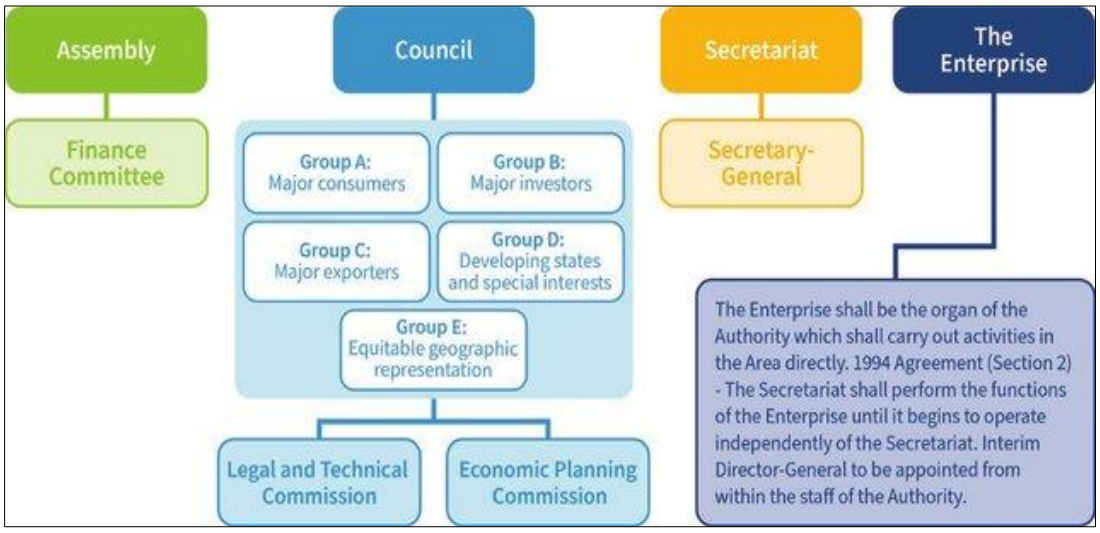

Figure 14: The ISA body[148].

Valuable minerals are found in the deep seabed including polymetallic nodules (PMN), polymetallic sulphides (PMS) and cobalt-rich ferromanganese crusts (CFC). These reserves contain important metals such as nickel, copper, cobalt and rare elements which are essential for various industries including renewable energy and technology manufacturing.

Currently ISA hasn't issued any approval for commercial exploitation due to various regulations still under development surrounding the governance of deep-sea mining. However, ISA has issued certain exploration contracts in

146 United Nations, *United Nations Convention on the Law of the Sea* (Montego Bay, Jamaica: United Nations, 1982), https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
147 International Seabed Authority, "Structure and Mandate of the Council," *International Seabed Authority*, accessed July 14, 2025, https://www.isa.org.jm/structure-and-mandate/
148 "ISA 540 (Revised) Implementation Support: Flow Charts and Diagram | IAASB," April 17, 2019, https://www.iaasb.org/publications/isa-540-revised-implementation-support-flow-charts-and-diagram-1.

order to assess the potential of deep sea mineral resources. 21 contractors are given 32 contracts sponsored by 20 countries for the exploration and search for three types of mineral resources in the Area: PMNs (19 contracts), PMS (7 contracts) and CFC (5 contracts).

The States sponsoring these contracts include Belgium, China, the Cook Islands, France, Germany, India, Japan, Kiribati, the Republic of Korea, Nauru, Poland, the Russian Federation, Singapore, Tonga and the United Kingdom. Bulgaria, Cuba, Czechia, Poland, the Russian Federation and Slovakia also sponsor a contract through the Interoceanic metal Joint Organization.[149] The areas subject to exploration are Clarion-Clipper ton Zone (CCZ), the Indian Ocean, the Mid-Atlantic Ridge and the Northwest Pacific Ocean. ISA and its member states are deeply committed to the development of a comprehensive regulatory framework known as the mining code to govern deep-seabed mining. In recent years negotiations ranging from complex discussions over critical issues such as over environmental protection, equitable benefit-sharing, institutional oversight and liability mechanism, have intensified significantly. The major aim or goal is to ensure that any future exploitation of resources in the Area aligns with the principles of sustainability, transparency and principles of UNCLOS. At its most recent session conducted in March 2025, the ISA council continued to work in accordance with its July 2023 decision (ISBA/28/C/24) which set the aim of completing and finalizing the mining code during the thirtieth session of 2025 if the regulations are ready for adoption

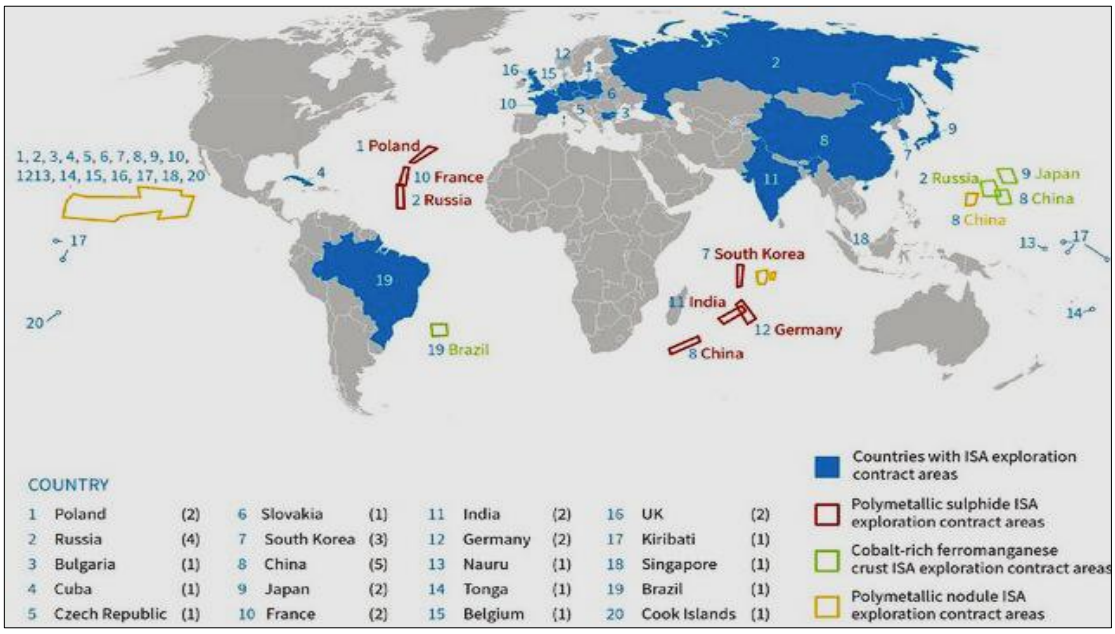

Figure 15: International Exploration Contracts from the ISA (adopted from Lubchenco and Haugan (2023))[150].

149 Phillip Gales, "Top 9 Countries Developing Subsea Minerals in International Waters," *Deep Sea Mining* (published last year), https://deepseamining.ac/article/51#gsc.tab=0.

150 " International Exploration Contracts from the ISA. (Note:...," Research Gate, accessed August 20, 2025, https://www.researchgate.net/figure/nternational-Exploration-Contracts-from-the-ISA-Note-Countries-with-international_fig1_371034480.

Nauru a small island state in the Caribbean in 2021 used the two year rule on the behalf of The Metal Company (a Canadian mining firm) which gave ISA two year to conclude the mining regulations. The two years were completed in 2023, but ISA has not completed the mining regulations. Two year law can be called upon by the ISA member states to request the ISA to allow them for mining activities. The ISA is still obliged to consider the work plan even if no mining code is available submitted after the two year period. [151]

4.2 Moratorium on Deep Sea Mining

A moratorium is a rule that calls for a delay, pause or cease of an activity. In international law, a moratorium can be temporary or permanent, legally binding or non-binding or it can freeze or reverse a decision[152].

Many countries and experts are in the view that DSM should be paused until the environmental impacts of mining are fully understood. There are some examples in the past where the activities should be stopped, for example like mining in Antarctica. However, if the moratorium does not take place the discussions can lead to stricter rules in order to safeguard the oceans.

Scientists and experts are calling for temporary haul to DSM because they believe that DSM can cause serious and irreversible harm to the marine environment. Also, more research is needed as there is still not much information on how DSM can affect marine life. The ISA mining codes (rules for DSM) are still being formed and without strong rules and regulations mining can be harmful. Moreover, it is still under discussion that how equitable sharing of resources will take place among countries.

4.3 Why Should a Pause be Legal?

In September 2021, at the IUCN World Conservation Congress in Marseille, France Resolution 122 was adopted by the IUCN members on a moratorium on deep-sea mining (issuing of new exploitation and new exploration contracts).

From the **IUCN Director General's open letter** (March 6, 2023) describing the vote: "In September 2021 at the IUCN World Conservation Congress, IUCN Member States, civil society and Indigenous organizations overwhelmingly voted in support of a moratorium on deep seabed mining to protect life in the ocean" [153]

151 Helen Reid, "Pacific Island of Nauru Sets Two-Year Deadline for U.N. Deep-Sea Mining Rules," *Reuters*, June 29, 2021, https://www.reuters.com/business/environment/pacific-island-nauru-sets-two-year-deadline-deep-sea-mining-rules-2021-06-29/.

152 Pradeep A. Singh, Aline Jaeckel, and Jeff A. Ardron, "A Pause or Moratorium for Deep Seabed Mining in the Area? The Legal Basis, Potential Pathways, and Possible Policy Implications," *Ocean Development & International Law* 56, no. 1 (2025): 18–44, https://doi.org/10.1080/00908320.2024.2439877.

153 IUCN, "IUCN Director General's Open Letter to ISA Members on Deep-sea Mining," *IUCN*, March 6, 2023, accessed July 14, 2025, https://www.iucn.org/dg-statement/202303/iucn-director-generals-open-letter-isa-members-deep-sea-mining

The objective was to protect the deep sea ecosystems unless there is a full understanding of the risks associated with mining. The “Polluter Pay” principle should be considered for DSM. In the circular economy policies regarding reuse and recycling of minerals should be included. Moreover, the general public should be part of the process. Transparency, accountability and environmental responsibility should be an integral part of DSM governance.

The call for moratorium is based on articles of the International Seabed Authority (ISA) and in accordance with various global conventions and resolutions. The article 136 and 145 of the UNCLOS is based that The ISA should protect the marine environment. According to Article 136

> “Sea area and its resources area are common heritage of mankind”

Article 145 states

> “Necessary measures shall be taken in accordance with this Convention With respect to activities in the Area to ensure effective protection for the Marine environment from harmful effects which may arise from such Activities. To this end the Authority shall adopt appropriate rules, regulations And procedures for inter alia:
> (a) The prevention, reduction and control of pollution and other hazards to the marine environment, including the coastline, and of Interference with the ecological balance of the marine environment, Particular attention being paid to the need for protection from Harmful effects of such activities as drilling, dredging, excavation, Disposal of waste, construction and operation or maintenance of Installations, pipelines and other devices related to such activities;
> (b) The protection and conservation of the natural resources of the Area And the prevention of damage to the flora and fauna of the marine Environment.

These include protection of the marine environment including the coastline from the harmful effects of mining and related activities.

Also, Article 5 of Cooperation of Convention on Biological Biodiversity states that all parties should cooperate with one another with respect to ABNJ for the sustainable use and protection of deep sea ecosystems.

> Each Contracting Party shall, as far as possible and as appropriate, cooperate with other Contracting Parties, directly or, where appropriate, through competent international organizations, in respect of areas beyond national jurisdiction and on other matters of mutual interest, for the conservation and sustainable use of biological diversity[154].

154 Convention on Biological Diversity, Article 5, “Cooperation,” *Convention on Biological Diversity*, accessed July 14, 2025, https://www.cbd.int/convention/articles/default.shtml?a=cbd-05

And Production) and SGD 14 (Life below water) have concerns regarding ocean mining. In 2012, Resolution 5.079 was adopted by IUN World Conservation Congress. The main objective was to protect the deep sea environment from the threats posed by mining.

However, considering the articles from UNCLOS people are in favor of mining as well. **Article 150** that suggests developing deep sea sources

> Activities in the Area shall, as specifically provided for in this Part, be Carried out in such a manner as to foster healthy development of the world Economy and balanced growth of international trade, and to promote International cooperation for the overall development of all countries, Especially developing States

And **Article 153** that declares that ISA should arrange and manage the mining activities.

> Activities in the Area shall be organized, carried out and controlled by the Authority on behalf of mankind as a whole in accordance with this article as well as other relevant provisions of this Part and the relevant Annexes, and the rules, regulations and procedures of the Authority. [155]

4.4 Arguments in Favor of Mining

However, according to experts some people believe that UNCLOS encourages DSM. For example, that the Article 150 is centered on developing the deep-sea resources. Also, Article 153 states that the ISA should manage the ocean mining activities. However now the international environmental laws have become strong and these set of rules where design long back.

a. **Article 150** talks about developing deep-sea resources.

> Article 150
> Policies relating to activities in the Area
>
> Activities in the Area shall, as specifically provided for in this Part, be carried out in such a manner as to foster healthy development of the world
> economy and balanced growth of international trade, and to promote International cooperation for the overall development of all countries, especially developing States, and with a view to ensuring:
> (a)The development of the resources of the Area;
> (b) orderly, safe and rational management of the resources of the Area,
> including the efficient conduct of activities in the Area and, in75 accordance with sound principles of conservation, the avoidance of

155 United Nations, *United Nations Convention on the Law of the Sea* (Montego Bay, Jamaica: United Nations, 1982), https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.

unnecessary waste.[156]

b. **Article 153** says ISA should organize and manage mining activities.

Article 153 System of exploration and exploitation 1. Activities in the Area shall be organized, carried out and controlled by the Authority on behalf of mankind as a whole in accordance with this article as well as other relevant provisions of this Part and the relevant Annexes, and the rules, regulations and procedures of the Authority.[157]

Hence if new technology can do mining without much environmental harm, then ISA can allow it. However, if a consensus is built that mining will cause irreversible harm then ISA could choose to ban it permanently. As of the year 2025 there is no formal moratorium on deep sea mining, but consensus is there among government and international organizations and mining companies that there should be a pause on the mining activities until the environmental concerns ae addressed and regulatory framework is finalized. Thirty seven countries have officially supported the moratorium on deep-sea mining at the UN Ocean Conference 2025. Keeping in view the incomplete regulations, environmental concerns and increasing calls by nations for precautionary measures the deep sea mining is unlikely to take place in the immediate future.

Further, all eyes are on the 30th session of ISA which will be held in July to find a consensus for the member states on the exploitation of deep-sea minerals At the ISA sessions Pakistan has given statement that the mining should not proceed until the mining legal framework ensures that the deep-sea ecosystems will be conserved and equitable sharing of economic benefits for mankind will be there.[158]

This year the 30th sessions of the ISA were held in two parts. Part 1 was held in March, and the Part 2 was conducted in July at the headquarters in Jamaica.

Table 2: Global opposition to deep-sea mining: 38 countries have expressed formal objections to deep-sea mineral exploitation

156 United Nations, United Nations Convention on the Law of the Sea (Montego Bay, Jamaica: United Nations, 1982), https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
157 United Nations, *United Nations Convention on the Law of the Sea* (Montego Bay, Jamaica: United Nations, 1982), https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf.
158 International Seabed Authority, "Statement at the Thirtieth Session of International Seabed Authority Council, Part II," press statement by Secretary-General Leticia Carvalho (Kingston, Jamaica, July 7, 2025), *International Seabed Authority*, accessed July 14, 2025, https://www.isa.org.jm/news/statement-at-the-thirtieth-session-of-international-seabed-authority-council-part-ii/

Global Tide of Opposition to Deep Sea Mining 38 Countries Say No to Deep-sea Mining			
2022	2023	2024	2025
Palau	Vanuatu	Kingdom of Denmark	Luxembourg
Fiji	Dominican Republic	Greece	Slovenia
Samoa	Switzerland	Peru	Cyprus
Chile	Sweden	Malta	Latvia
Costa Rica	Ireland	Honduras	Marshall Islands
Ecuador	Canada	Tuvalu	
Federated States of Micronesia	Brazil	Guatemala	
Spain	Finland	Austria	
New Zealand	Portugal		
France	Monaco		
Germany	United Kingdom		
Panama	Mexico		

4.5 ISA Council and Assembly Meetings Resumes

From July 15 to August 2, nations from around the world had gathered in Kingston, Jamaica for the International Seabed Authority's (ISA) pivotal Council and Assembly meetings. Even amidst the rising opposition by the global community regarding concerns over deep sea-mining industry, the limitations of ISA's role as a regulatory body along with absence of scientific understanding, a minority of states and mining companies are still forcing highly destructive and unnecessary activity in our ocean.

The momentum for a moratorium has reached a record high due to the council meeting efforts as 38 countries called for a pause/ban on the industry in international waters. Greece and Peru are the latest ones to join the opposition.

The divergence amongst the views of states on the future of deep sea mining has only grown. During the council meeting the states continued to debate over the terms and principles of the mining code which is criticized for its gaps and omissions, therefore leading to no clear resolve in the foreseeable future.

On the other hand, The Metals Company (TMC) has indicated the intention to apply for a deep sea mining license through the United States' Deep Sea Hard Mineral Resources Act in the second quarter of 2025, while also keeping the option of submitting through the ISA in June 2025 to begin commercial mining operations disregarding all warnings of the consequences.

It is important therefore that a general policy should establish the rules and conditions that must be fulfilled before deep sea mining is even considered. This would ensure that the policy and scientific gaps are filled and the state's environmental obligations are met.

At the same time, the ISA due to its inefficiency has resulted in the erosion of trust in it as an institution for the management of the common heritage of humankind. The assembly of ISA is currently falling short of its commitments and legal obligations leading to a lack of transparency, accountability, inclusiveness and responsible operations management.

ISA is expected to make major decisions over the next decade which would determine the long term impact on the health of the oceans; therefore it is urgently required for ISA member states to carefully consider the allegations and open a transparent and inclusive review of concerns over how the organization is run. It has become clear though that ISA isn't equipped for the task it has to perform, and it lacks the scientific knowledge to effectively protect the deep sea, much less regulate a risky and complex industry.

Therefore, these issues emphasize the need for a moratorium until they can be resolved and addressed.[159]

4.6 Pakistan and the Need for a New Authority for Deep Sea Exploration

Without a proper authority, Pakistan faces the risk of falling behind in sea mining. Other countries are making progress therefore if Pakistan doesn't act soon, it might lose valuable opportunities. Deep sea minerals can provide significant economic growth, but Pakistan requires the determination for a proper system to take advantage of it.

The current system ruling Pakistan's activities are slow and unprepared. Pakistan must create a new efficient authority to handle and overlook offshore (deep-sea) mining. The authority must:

a. Lead the research and development program by working and collaborating with local firms for deep sea exploration

b. Coordinate and follow the ISA/international rules and submit proper comprehensive plans

c. If any concern either legal or technical is raised, Pakistan would have to defend its plan internationally

d. Diplomatic channels must be used to negotiate and resolve issues if neighboring countries object to Pakistan's deep-sea mining plans.

e. It must seek ISA representation and work with Pakistan's foreign ministry to get a seat in ISA's council and its technical and legal commission (TLC) in order to have a stronger voice internationally.

159Deep Sea Conservation Coalition, "ISA Council and Assembly | July 2024," *Deep-Sea Conservation Alliance*, published July 2024, accessed July 15, 2025, https://deep-sea-conservation.org/isa-july-2024-meetings/.

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