Assessing Geo-risks for Offshore Wind Projects in the Philippines

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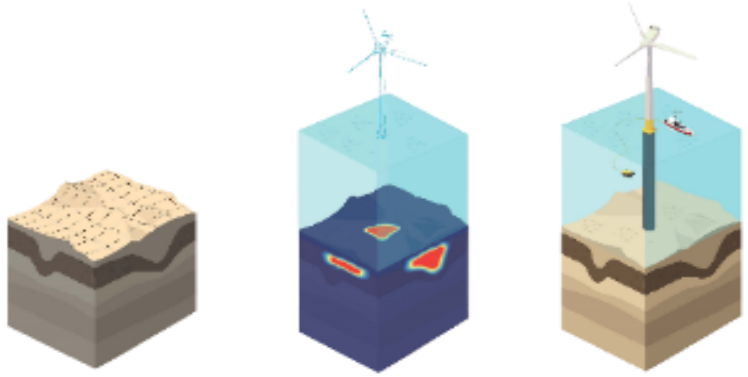
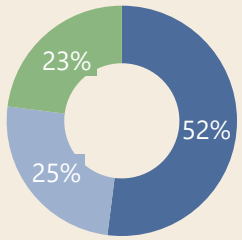
The world's leading Geo-data expert

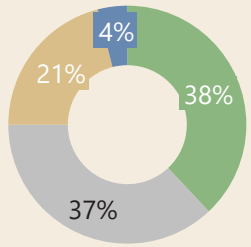
EUR 2,275 mn	EUR 484 mn	0.2x	52	11,219	>2,600
Revenue	**EBITDA**	**Net leverage**	**Countries**	**Employees**	**Geo-data engineers**



- We map, model and monitor the (sub)surface to provide critical insights into the built and natural environment
- Fugro's solutions are key for the energy transition, large scale infrastructure development and climate change adaptation



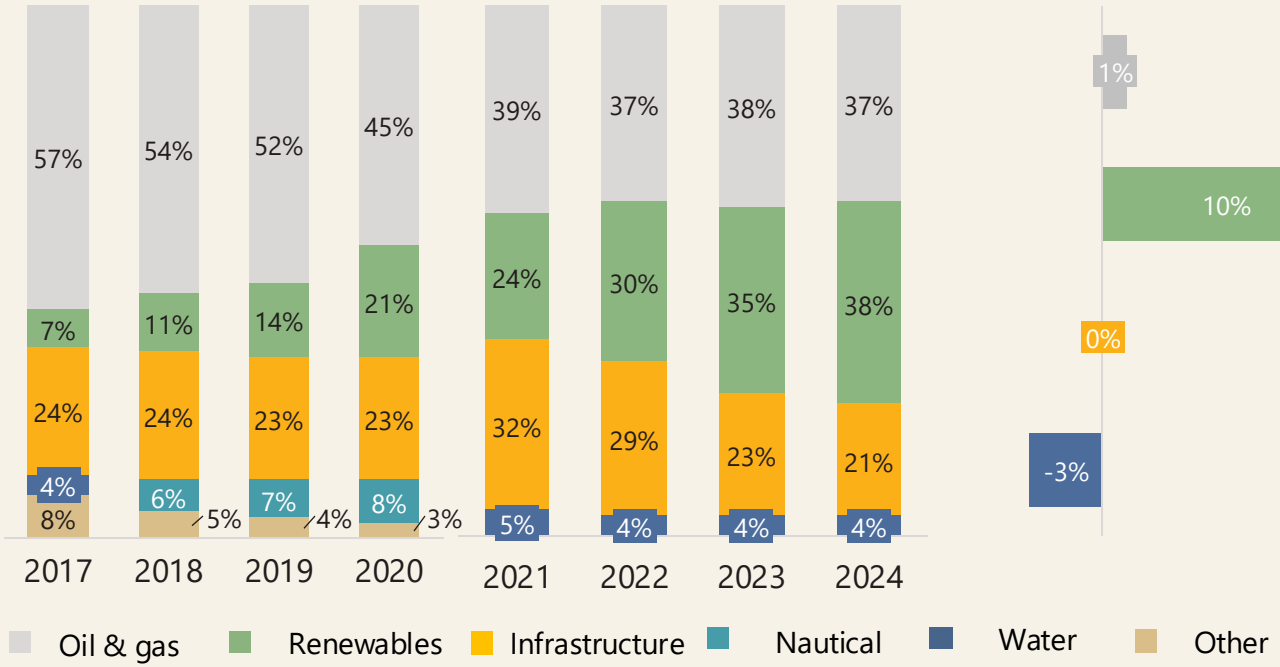
marine site characterisation | marine asset integrity | land



renewables | oil&gas | infrastructure | water

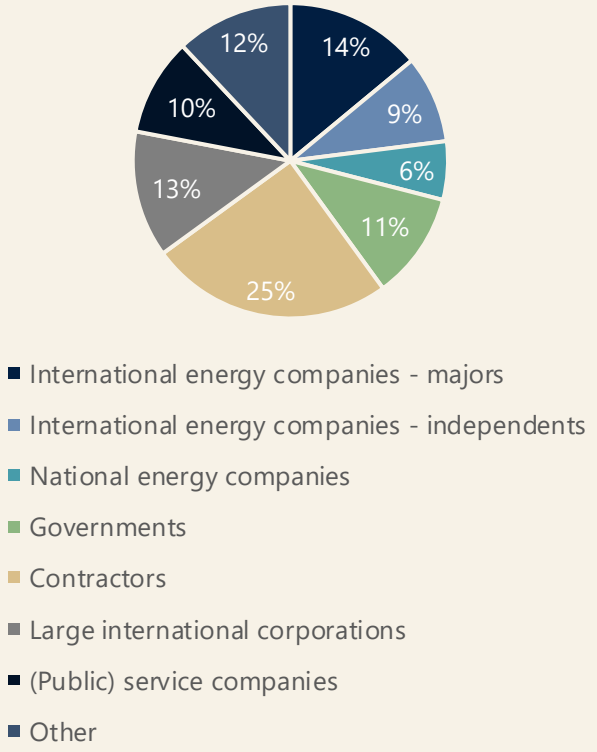
Highly diversified business

Revenue by market segment[1]



% 2024 growth by market[2]

2024 revenues by client type



1. In 2022, 'nautical' was changed to 'water'. This now also encompasses water infrastructure and water resource management services, which were previously in infrastructure, while telecom cables was moved from nautical to infrastructure. In addition, 'other' is now largely included in infrastructure
2. Growth percentage corrected for currency effect

Geo-data is a small but influential part of wind farm cost

Cost breakdown for a typical wind farm

What geo-data provides

Site screening studies

Wind, wave and current measurements

Seabed composition and characteristics

Earth models

Marine ecology studies

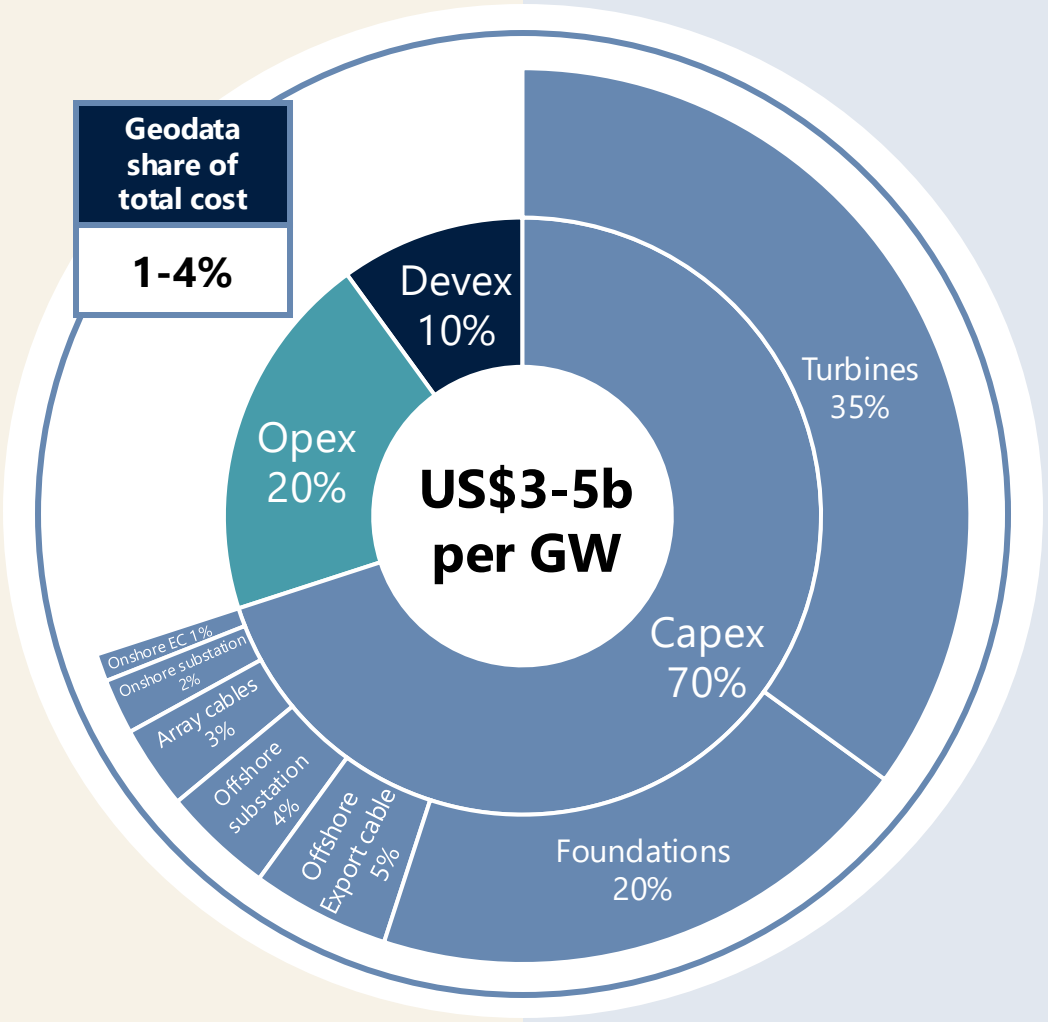
Interpretative analyses and insights

Engineering design inputs

Construction risk mitigation

Asset condition surveillance

Biodiversity monitoring



What geo-data influences

Wind resource quantification

Turbine selection

Foundation and cable design

Floater and mooring selection

Development consent applications

Layout optimisation

Business cases and investment decisions

Operational planning

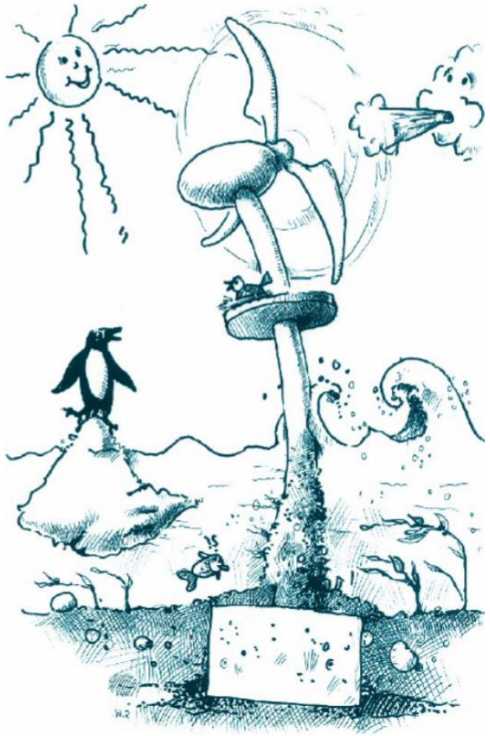
Maintenance regimes and budgets

Asset performance and lifespan

Source: GWEC, BNEF, IRENA, OffshoreBiz News, enriched with internal intelligence

Why Geo-risks?

Site and geological conditions often cited as a significant insurer and financing consideration:



Site conditions typically explored

Wind

Speed and consistency (generating potential)

Severe weather e.g. typhoons (extreme loads)

Turbulence and losses due to nearby landmasses or infrastructure (operating performance)

Sea

Water depths and seabed topography (foundation selection)

Waves, tides and currents (dynamic and extreme loads)

Wildlife and marine habitats (biodiversity)

Ground

Seabed composition and soil / rock properties (foundation selection)

Sediment mobility (cable and foundation integrity)

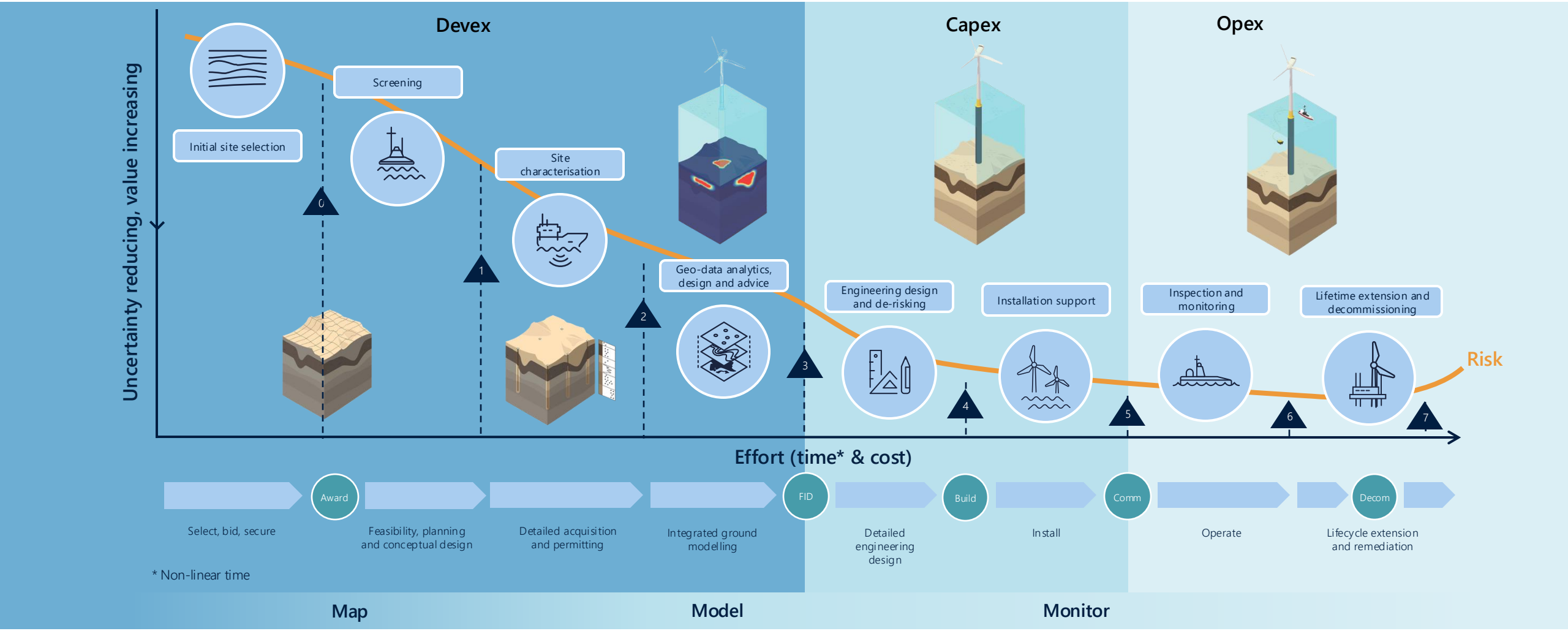
Volcanicity and seismicity (extreme loads)

Other seabed infrastructure e.g. pipelines and cables (layout design)

USD50m-100m/GW

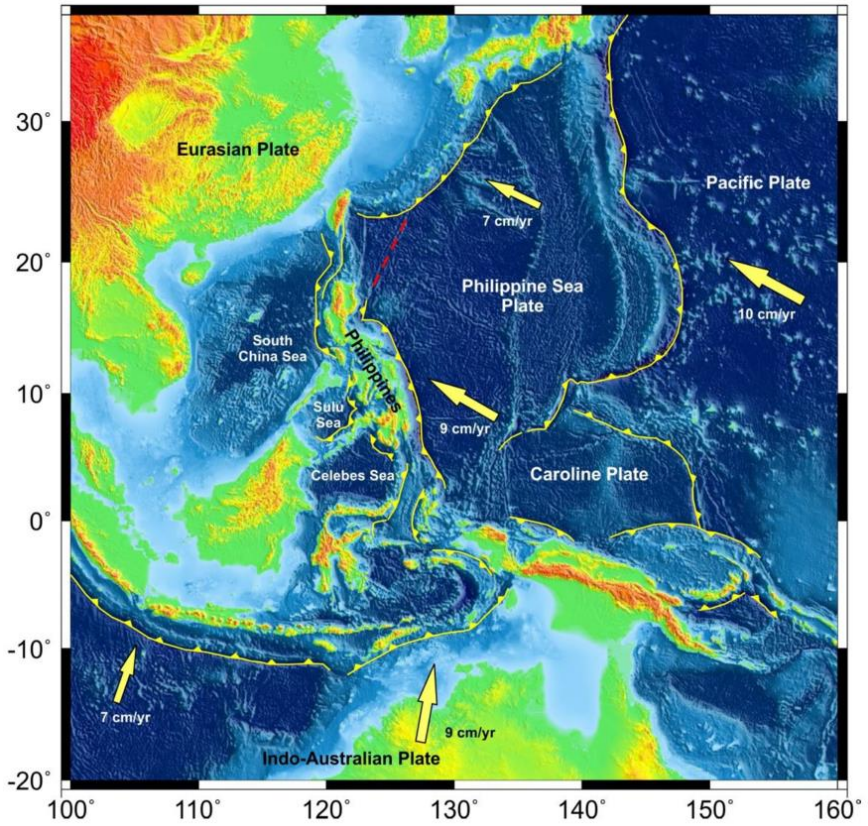
Typical spend on Geo-data services throughout the project-asset lifecycle depending upon scale, complexity and timeline

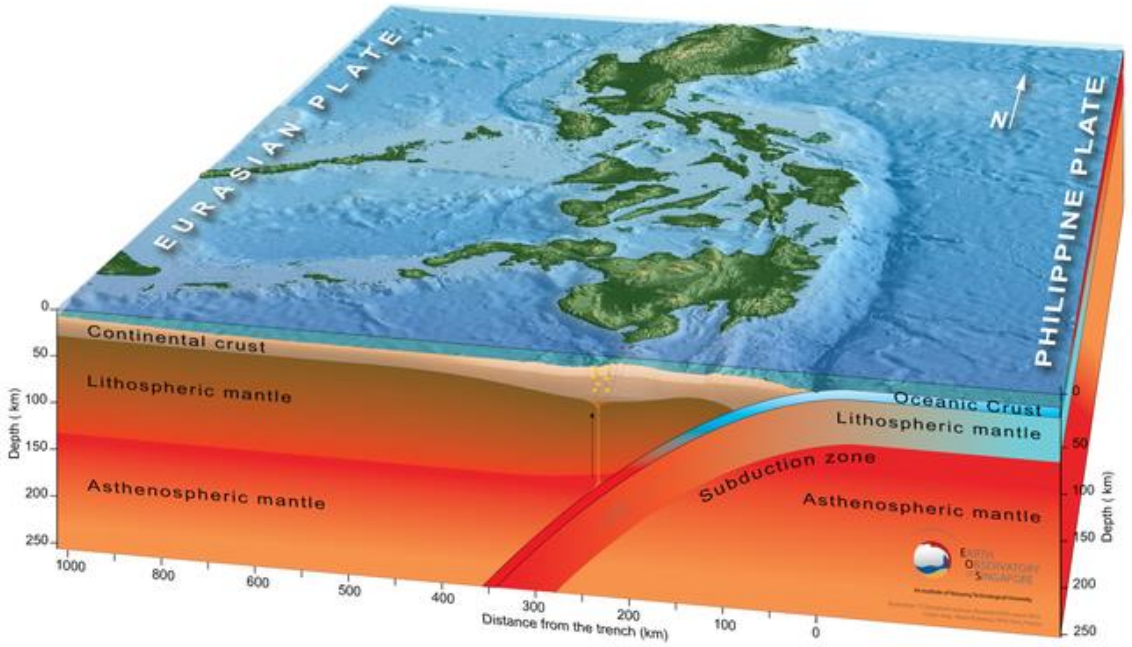
It affects every stage of the life cycle…



Georisk 1 - Earthquakes

- Island arc developed from the collision of tectonic plates.
- Multiple subducting plates





https://earthobservatory.sg/earth-science-education/multimedia/graphics/ubduction-zone-beneath-the-philippines

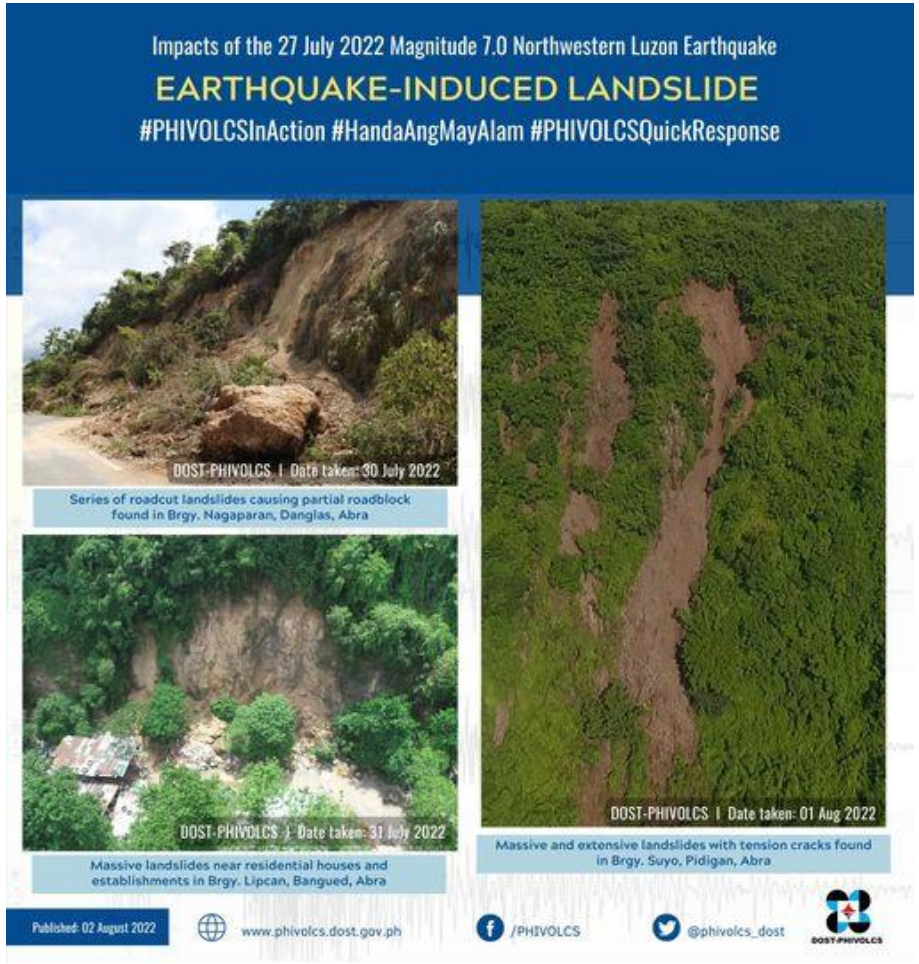
Plate subduction causing earthquakes and volcanoes

Aurelio, M. A., 2013. Regional Tectonic Setting of the Philippines

Georisk 1 – Earthquakes (Cont'd)

Examples from the 27 July 2022 M 7.0 Northwest Luzon Earthquake

Landslide Trigger



https://edition.cnn.com/2022/07/26/asia/philippines-luzon-earthquake-intl-hnk/index.html

https://global.chinadaily.com.cn/a/202207/27/WS62e0cfb2a310fd2b29e6eb1c.html

Georisk 1 – Earthquakes (Cont'd)

Examples from the 27 July 2022 M 7.0 Northwest Luzon Earthquake

Liquefaction

Ground Rupture

https://global.chinadaily.com.cn/a/202207/27/WS62e0cfb2a310fd2b29e6eb1c.html

Georisk 2 – Volcanoes

Case Area : Manila-N. Mindoro

Potential Hazards for Seabed

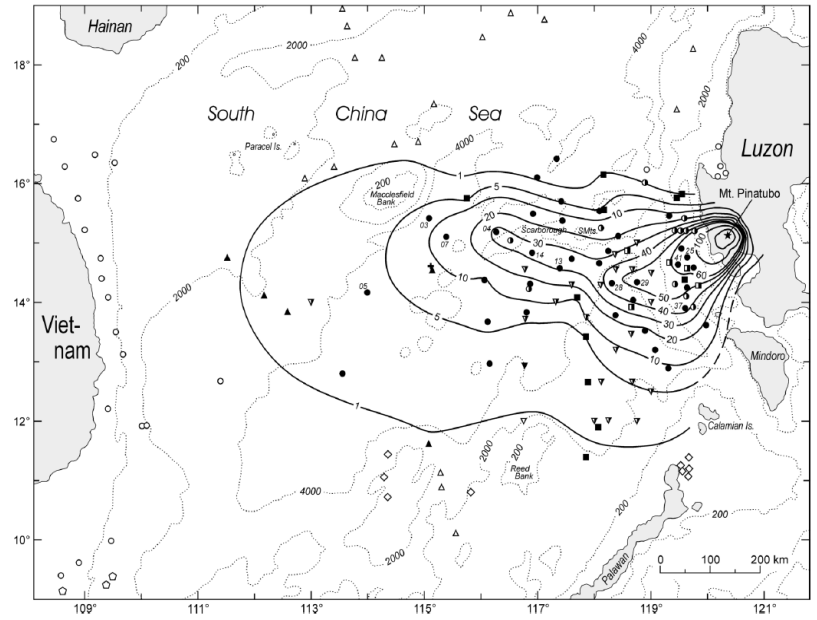
- Volcanic Ash Sediment
- Volcanic induced Earthquake

Mt. Pinatubo

https://www.esquiremag.ph/politics/news/pinatubo-826-earthquakes-a00293-20210128

- The eruption of Mt. Pinatubo in 1991 was considered as the second-largest eruption of the 20th century.

https://volcanoes.usgs.gov/volcanic_ash/pinatubo_1991.html



Ash Distribution of 1991 Pinatubo Eruption

Credit from Wiesner, 2004. Pinatubo Ash Contour Map

Georisk 2 - Volcanoes (Cont'd)

Pumice

Pumice
Extrusive/Cooled quickly

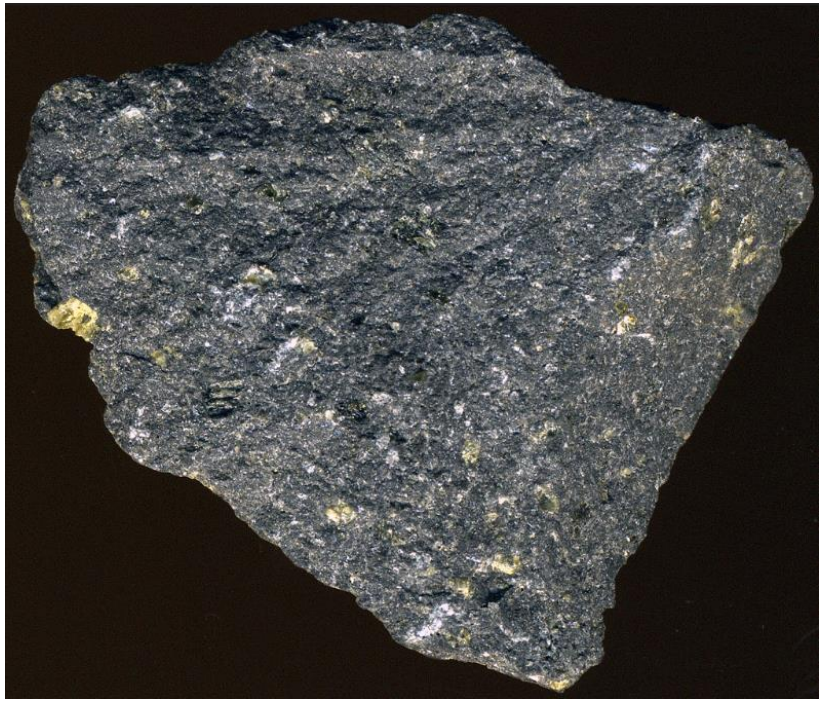
Figure 1. New volcanic deposits observed along the shores of Sitio Maydangeb, Ivana, Batanes Province *(Photo credit to Batanes PDRRMO Dhan Esdicul)*.

Pumice from Japan submarine volcano reached Northern Philippines (2021)

Figure 3. Satellite imagery of the volcanic eruption plume of Fukutoku-Okanoba Volcano. (Source: NASA Earth Observatory)

- Crushable – strength degradation with cyclic loading
- Maybe hard as the volcanic rock and cause of foundation damage

Georisk 2 - Volcanoes (Cont'd)



Basalt
Extrusive/Cooled quickly

Granite
Intrusive/Cooled slowly

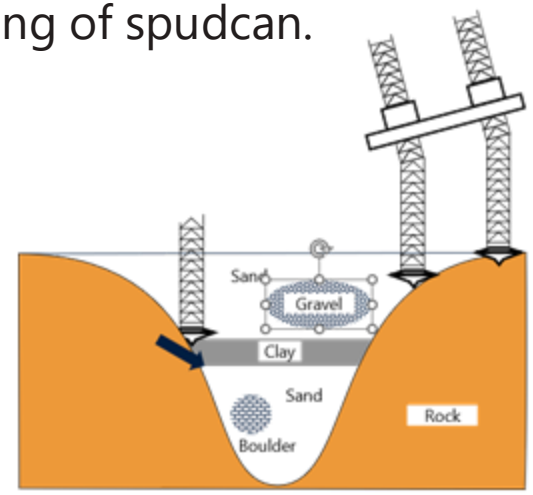
Volcanic Rock

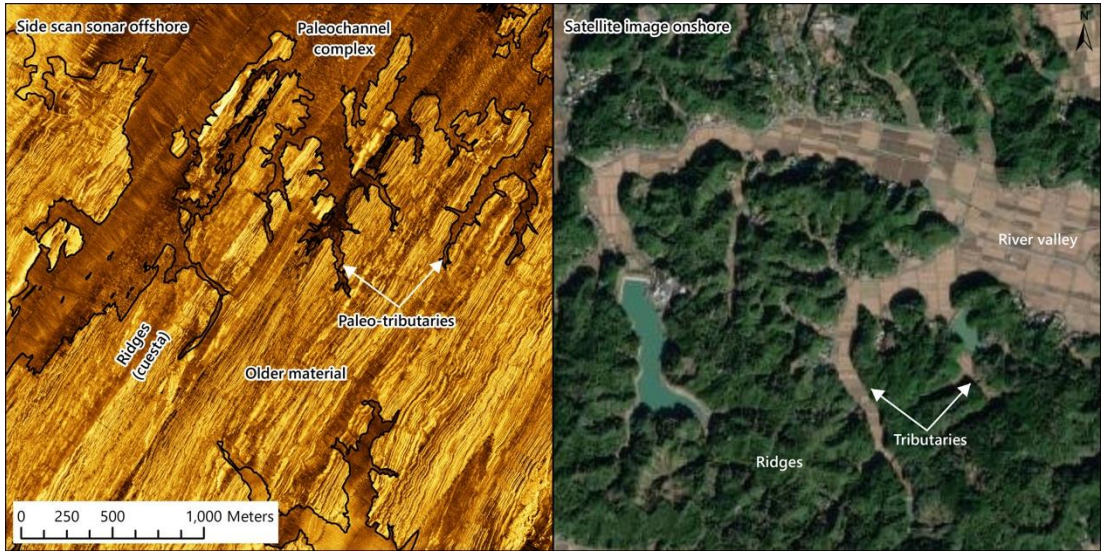
- Extremely hard (UCS over 100MPa)
- At seabed, potentially outcropping and very thick
- Isolated Boulders in sediment that cause of damage in pile tip and "extrusion buckling" for further driving.

https://www.flickr.com/photos/jsjgeology/16540711697

Georisk 3 – Paleochannels

- A paleochannel is an ancient river valley that is under present sea level and filled with variable, loose or unconsolidated sediments. These may be present in many nearshore areas around Philippines.
- A paleochannel may have very steep slopes resulting in a high risk of jack-up rig punch-through or slipping of spudcan.





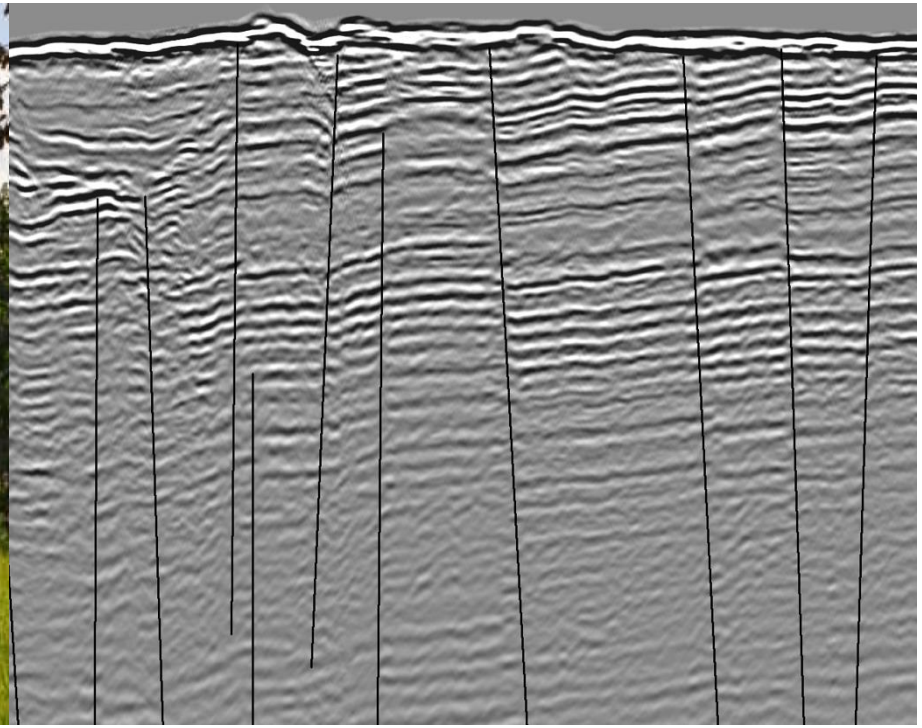
Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Georisk 4 - Faulting

Fault Scarp

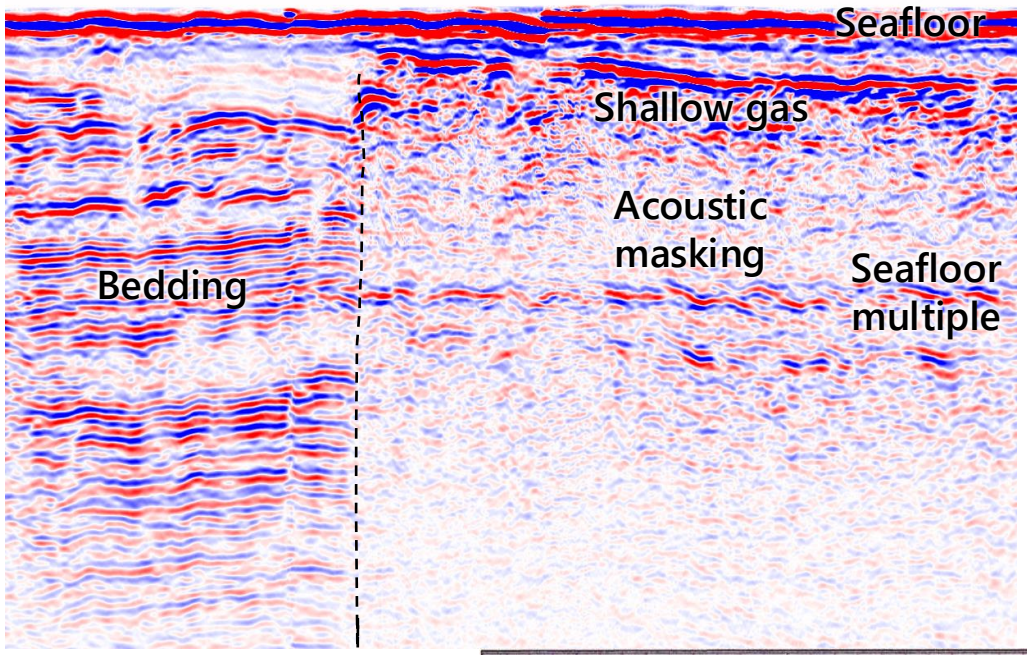
https://www.phivolcs.dost.gov.ph/index.php/earthquake/earthquake-hazards?cookie_40d1b2d83998fabacb726e5bc3d22129=accepted

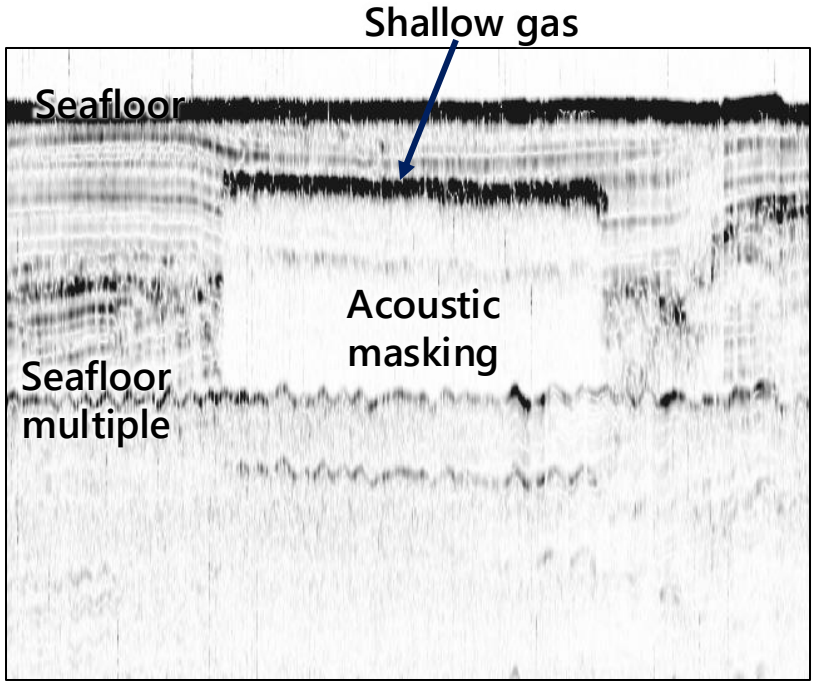
Marine Faults



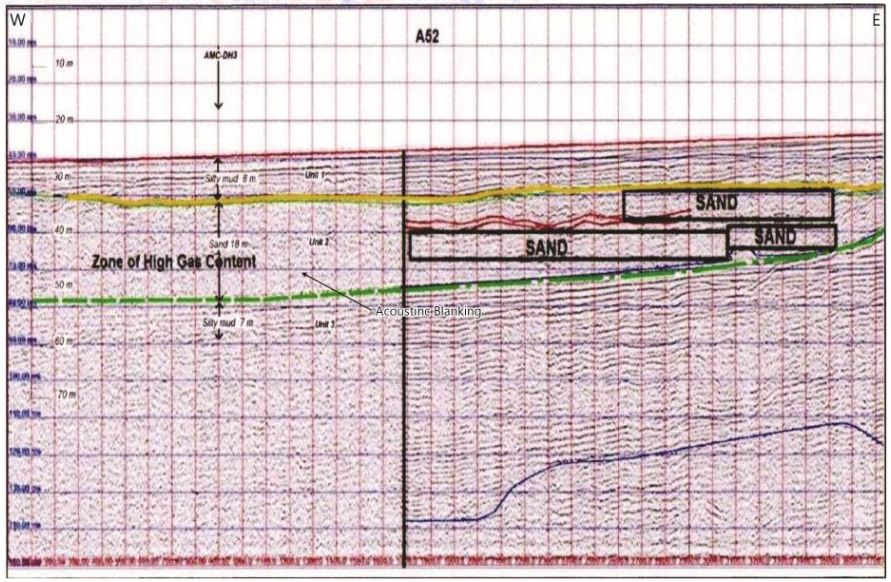
Cause offset to foundations or cables

Georisk 5 - Shallow Gas





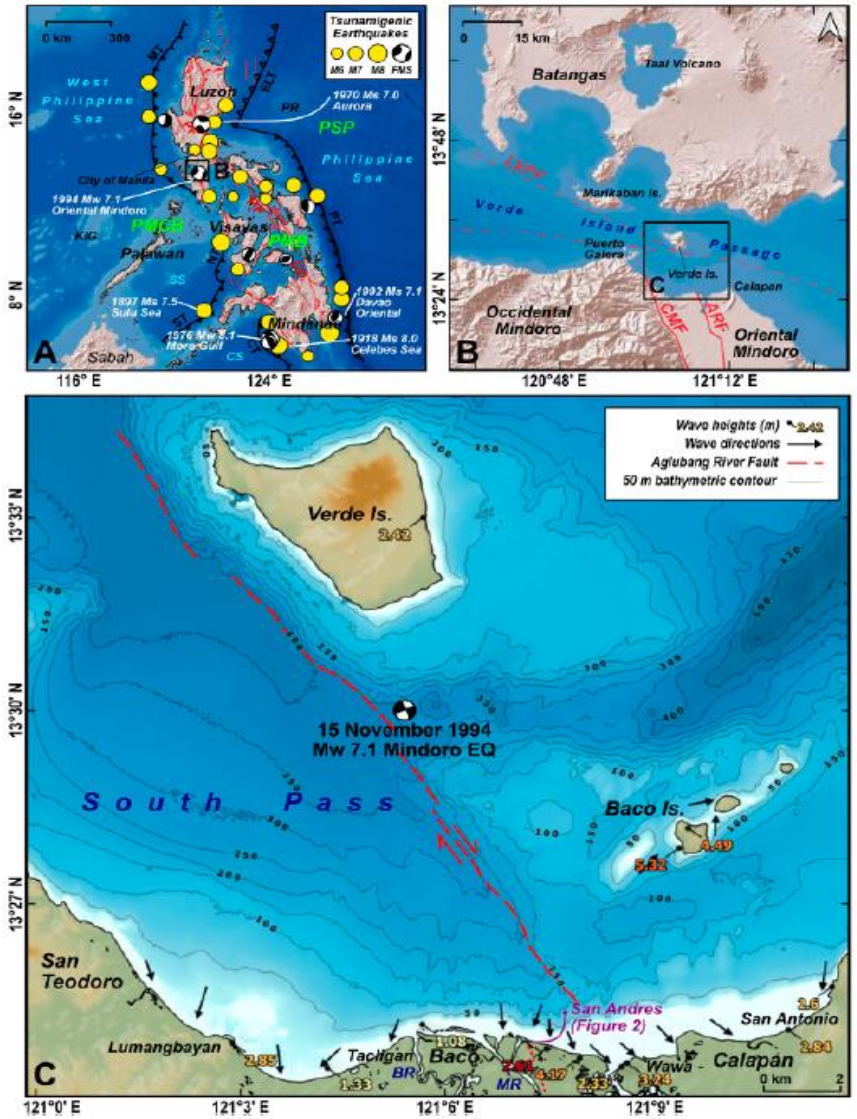
Manila Bay Area seismic section showing high has content zone



Avalar Mining Corp. 2021.

Georisk 6 - Tsunamis

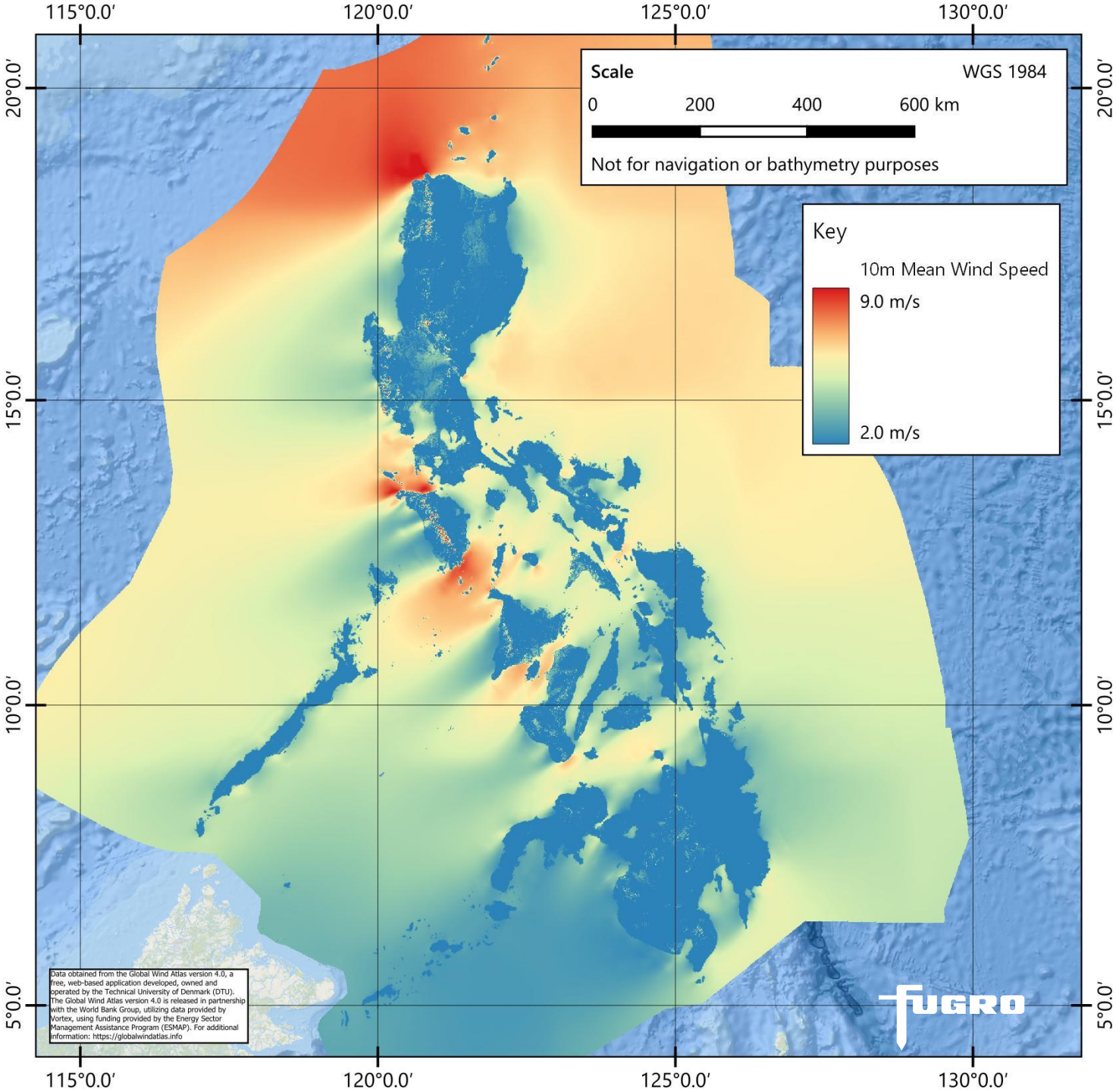
15 November 1994 Mindoro Earthquake Tsunami



https://en.wikipedia.org/wiki/1994_Mindoro_earthquake#/media/File:Tsunami_damage_mindoro.jpg

Georisk 7: Metocean

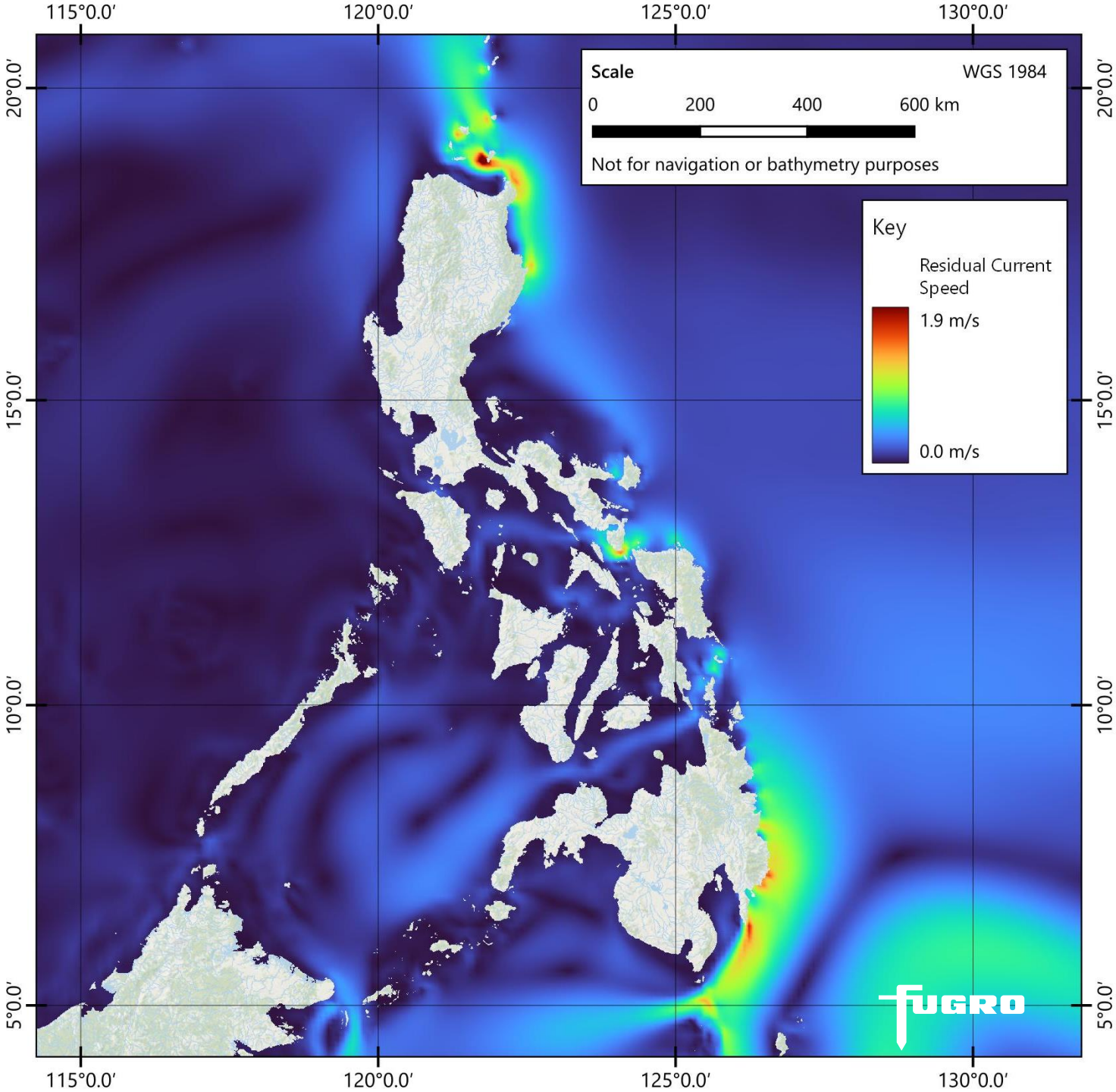
Mean wind speed at 10 m height



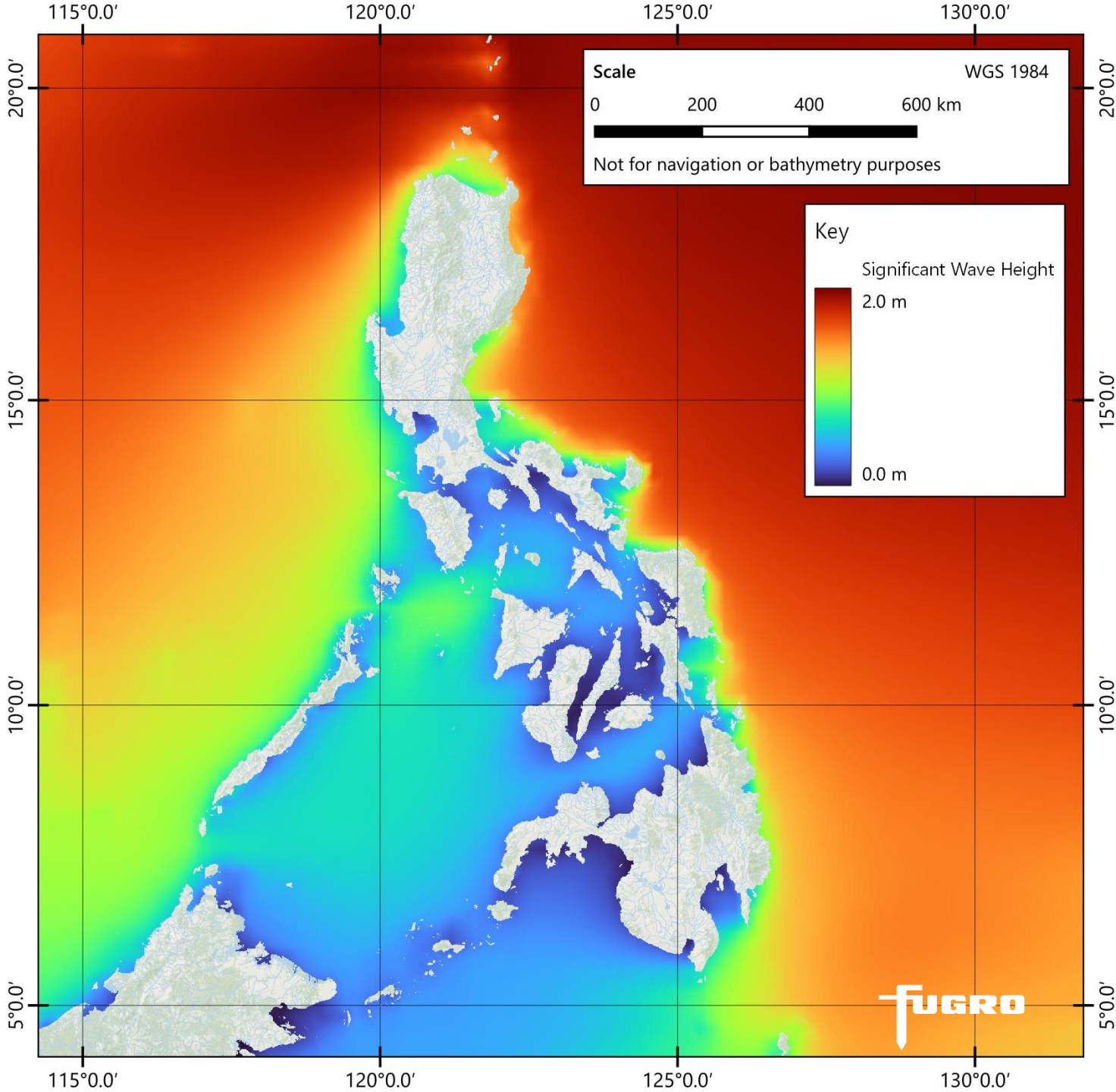
Georisk 7: Metocean

Residual (non-tidal) current speeds

- Mean from 1993-2020 hindcast data



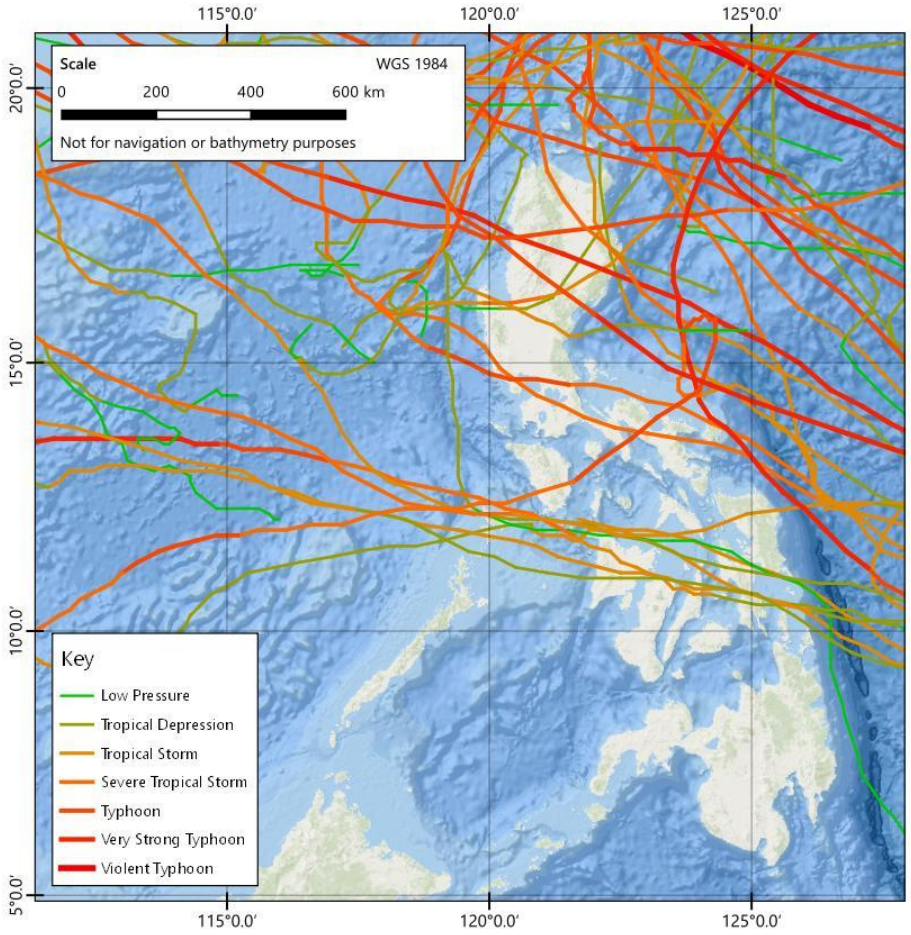
Georisk 7: Metocean



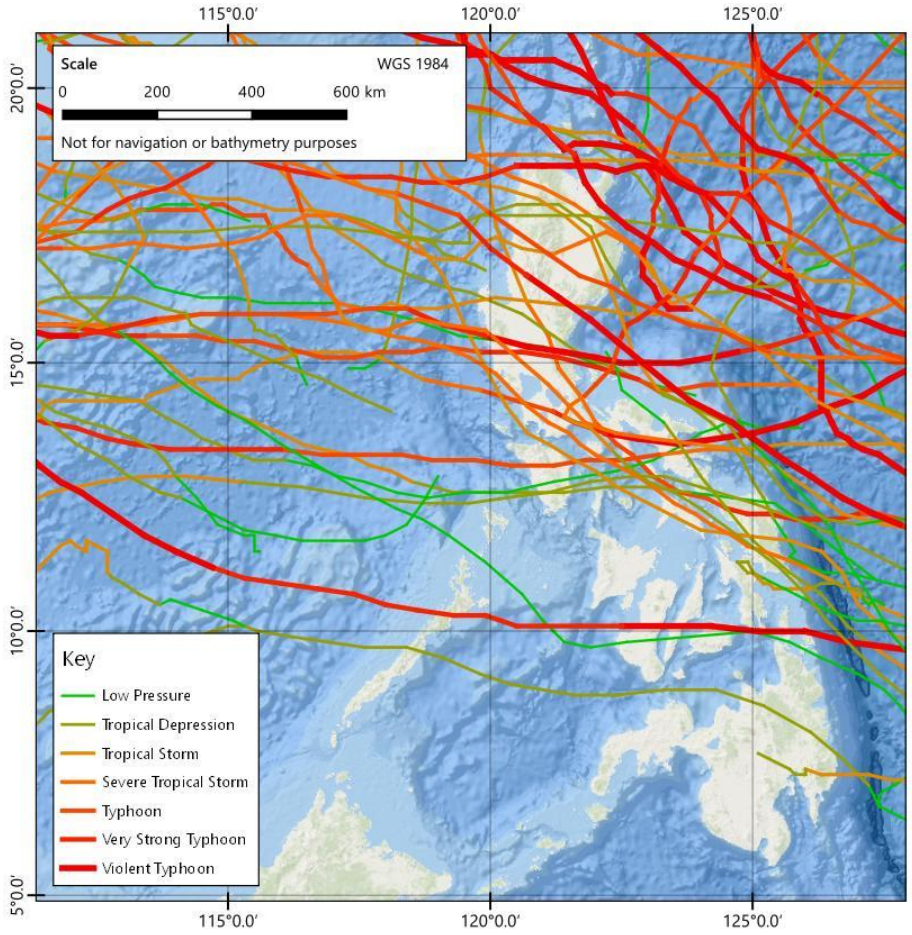
Significant Wave Height

- Mean of hindcast data 1993-2020

Georisk 7: Metocean



Storm Tracks – 2000 to 2004



Storm Tracks – 2020 to 2024

Overview of Geo-risks and Associated Hazards

- **Earthquake**
  - Landslide trigger
  - Liquefaction – Loss of foundation support
  - Cyclic loading
  - Tsunami (Infrastructure damage)
- **Faulting**
  - Displacement during earthquake
  - Can cause stratigraphy to vary over a short distance
  - Pathway for fluid/gas migration
- **Shallow Gas**
  - Overpressure
  - Change in geotechnical properties
  - Flammable
- **Variable Seabed Geomorphology**
  - Sand waves
  - Scour and seabed mobility
- **Volcanoes**
  - Eruptions
  - Volcanic rock
  - Pumice vessel hazards
- **Stratigraphy**
  - Paleochannels
  - Punch through hazards
  - Thick quaternary deposits
  - Muddy delta deposits
  - Weak marine rock
  - Excessive leg penetrations
  - Shallow bedrock
  - Basement granites
  - Heavily faulted bedrocks
- **Other risks**
  - Typhoons
  - UXO
  - Fishing Activity
  - Reefs and wrecks
  - Existing O&G/Telecoms infrastructure

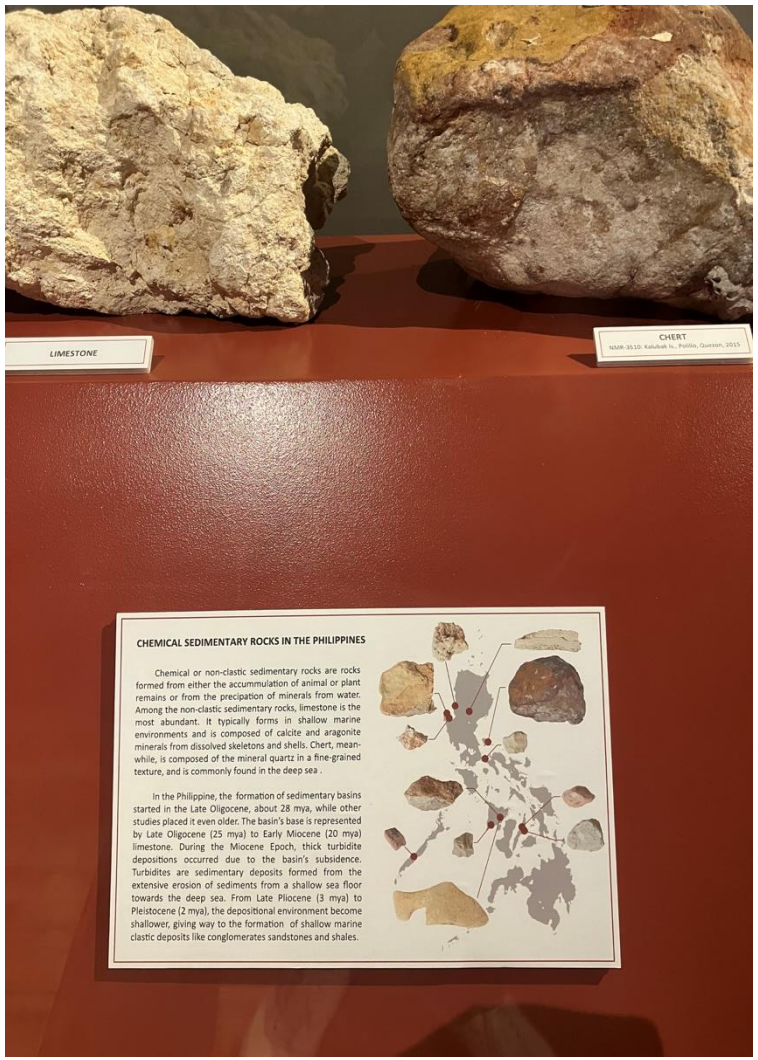
Observations for Philippines

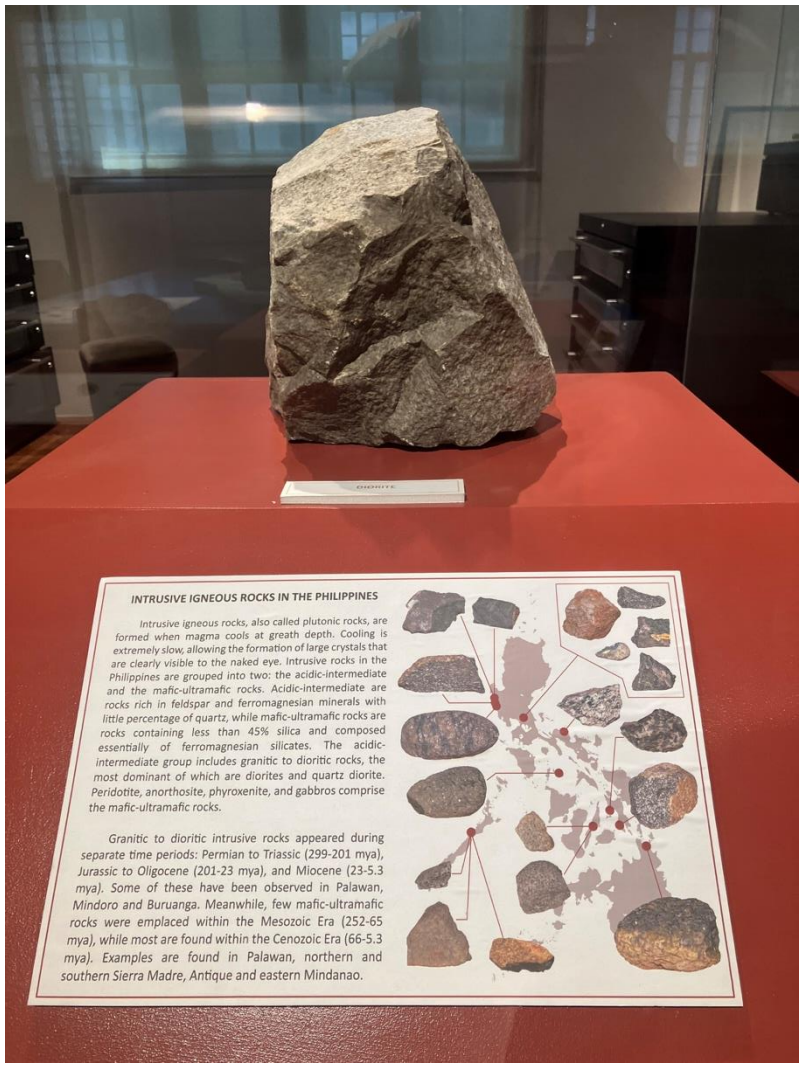
- The Philippines has unique geological features – complex plate interactions, plate tectonic induced earthquakes and volcanic activities.
- Volcanic activities provide various volcanic materials – volcanic rocks and ashes. These are categorised as problematic soils and pay particular attention for cyclic response.
- Nearshore conditions are also unique – paleochannels and wave cut platform are typical features and pay particular attention for foundation design and construction.
- Regional seismicity presents a risk for fault displacement and liquefaction.
- Variability of stratigraphy both vertically and laterally – ranging from volcanic & plutonic igneous basement to highly variable soil profiles due to subaerial exposure linked with sea-level fluctuations.
- Bedforms in Guimaras Strait – indicate significant seafloor sediment mobility and potentially strong scour – possibility for undercutting of foundation.
- Evidence of shallow gas offshore Cavite – potentially compromised foundation support.
- Significant risk of UXO given history of military activity – dearth of relevant data means uncertainty.
- Reefs and wrecks present affecting site accessibility
- Active typhoon season between June and November with an average of up to 10 making landfall annually.

National Museum of Natural History

National Museum of Natural History – National Museum

National Museum of Natural History





Thanks!

FUGRO

Unlocking **Insights**
from **Geo-data**