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Challenges in Managing Mercury in Field Development and Production

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Mercury Isotopic Analysis: Contaminant-Source Fingerprinting in Field and Production Studies

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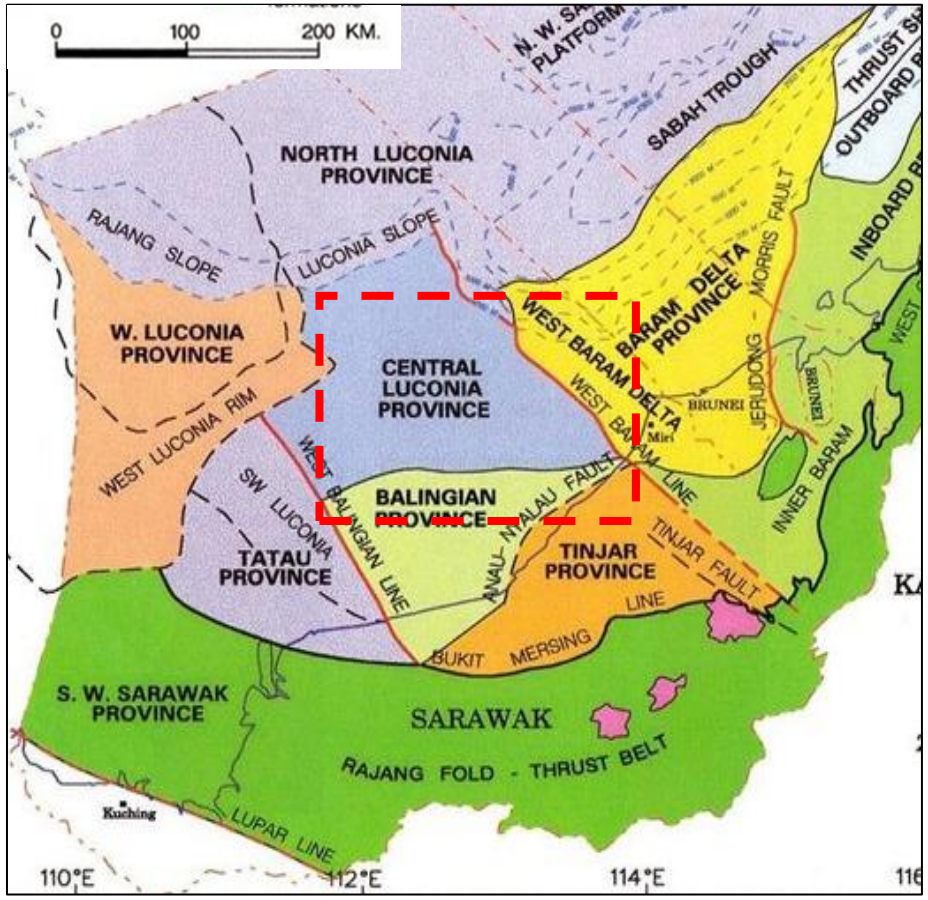
Introduction & Study Area

- Mercury is present in nearly all oil and gas reservoirs, with concentrations ranging from <10 ppb to >1 ppm.

- Production data revealed unexpected mercury encounters during development.

- Concern about mercury occurrences and seeks solutions for better planning and risk management in mercury-affected fields.



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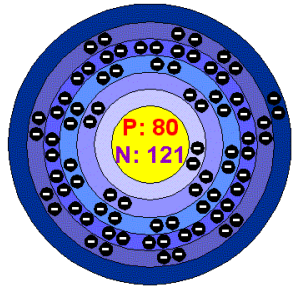
Mercury Isotopes

There are seven stable mercury isotopes (with relative abundance) 196Hg (0.2%), 198Hg (10.0%), 199Hg (16.9%), 200Hg (23.1%), 201Hg (13.2%), 202Hg (29.9%) and 204Hg (6.9%) (Hoefs, 2018).



Mass Dependent fractionation (MDF) – Even Mercury Isotopes

- The primary origin of Mercury, coming from volcanic and elemental mercury (i.e. magmatic rocks, ashes, gases and Hydrothermal sources)

Mass Independent fractionation (MIF) –Odd Mercury Isotopes

- Involves the recycling of mercury via photochemical process mainly in the ocean photic zone and may include bacterial activities which will cause fractionation from the original mercury isotopic signature

Analytical procedures : Fluid samples, cores and outcrops

Sulfinert® Cylinders and valves

Silica layer into the surface of stainless steel, preventing active compounds from reacting with or adsorbing to the steel

Figure Showing sampling location for fluid samples and sulfinate cylinder used (left) and types of samples taken for solids (right).

Fluid sampling was conducted at the well head and was performed prior to any fluid separation or filtering. Solid samples were obtained from core, ditch cuttings and outcrops. The outcrop samples acted as analogue HC source rocks, volcanics and hydrothermal and the mineral paragenesis associated with primitive rock.

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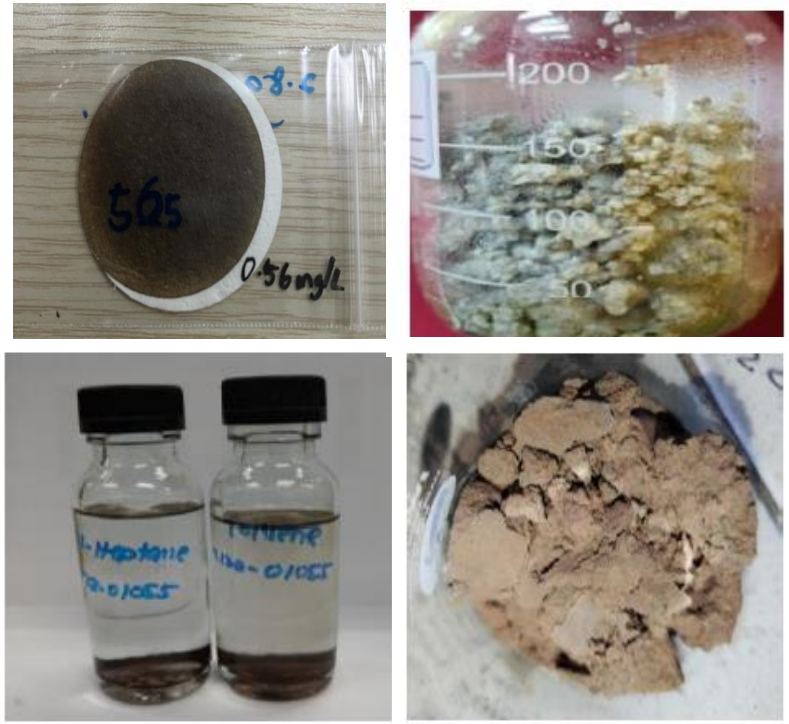
Analytical **procedures** : fluid debris samples from pipelines and Laboratorial apparatuses

Condensate filtrate

Flocs samples from water treatment system



Pigging samples

Single and Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS)

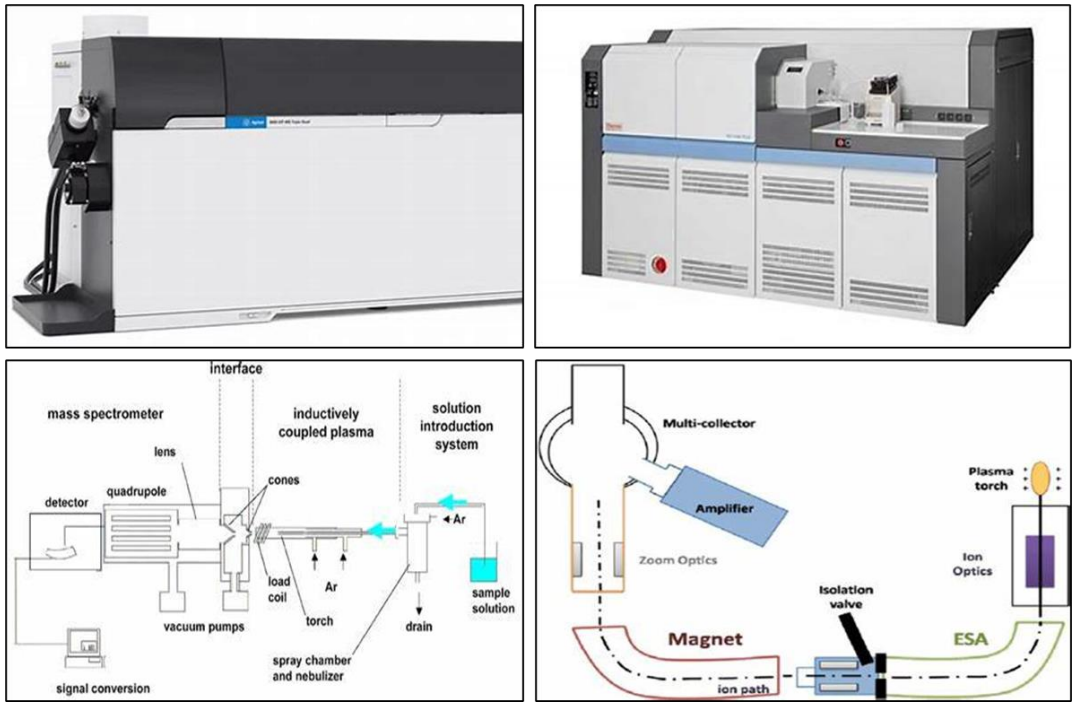
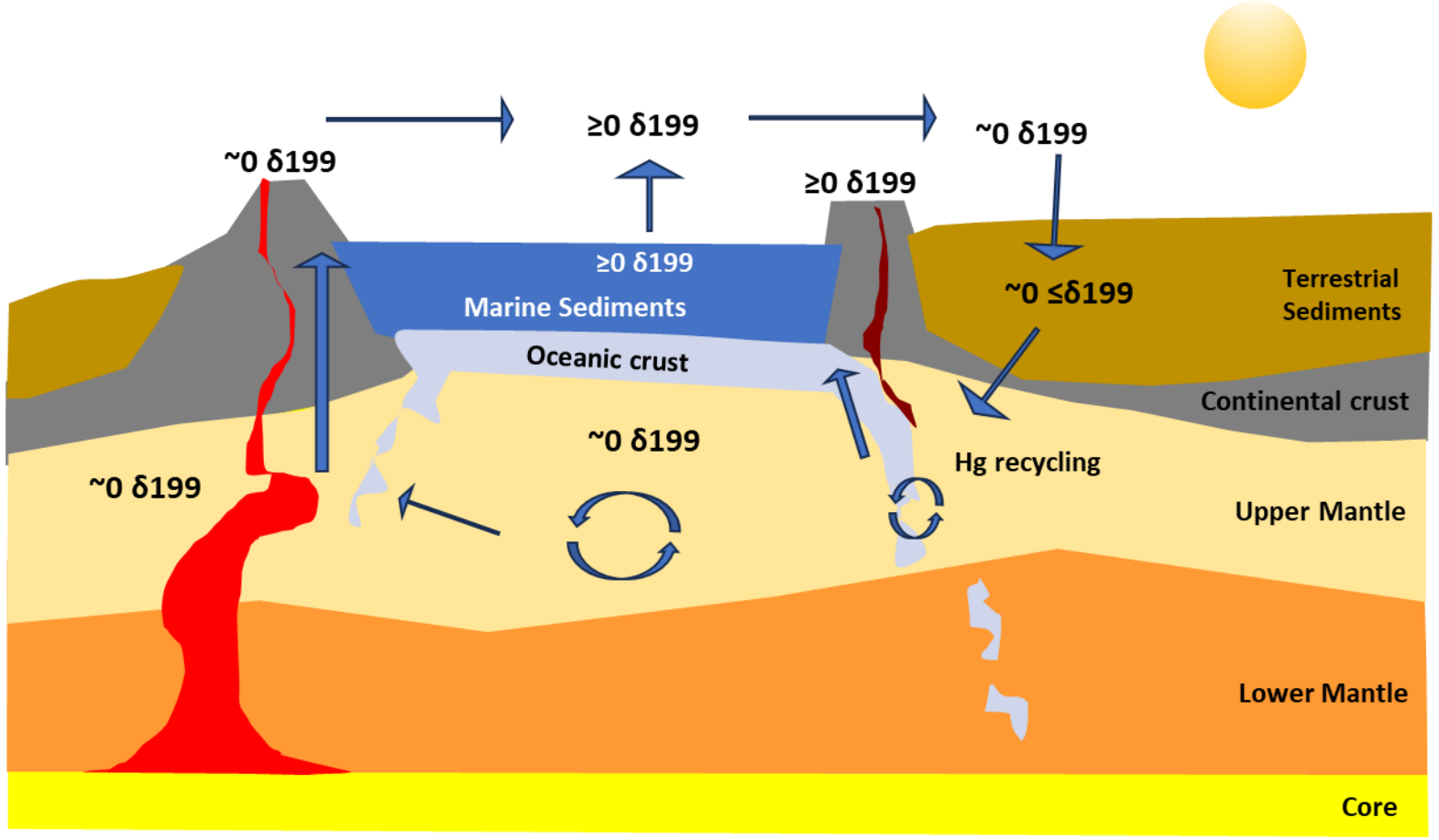


Figure: Single and Multi-Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS), and schematic (Left) (Gilstrap Jr RA (2009) and MC-ICP-MS (NEPTUNE PLUS, ThermoScientific) and schematic (right) (Farhat and Ahmed, 2016)

Schematic of Mercury cycle Isotopes in the Subsurface



Conceptual model modified from Yin et al 2022 to demonstrate the deep cycling of Mercury isotopes within the subsurface

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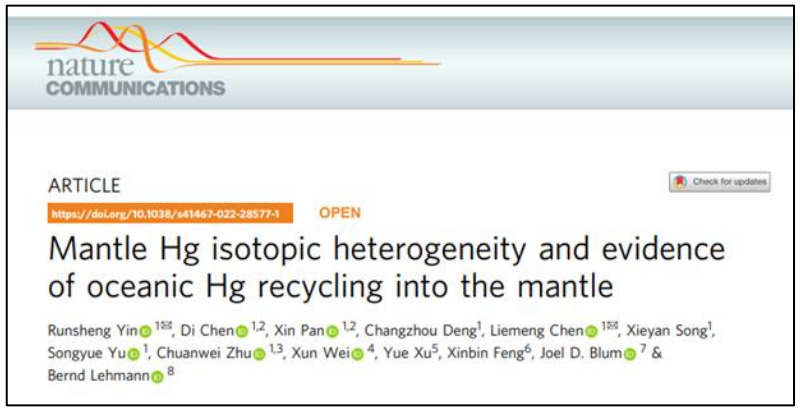
Isotopic Zoning developed by Yin et al 2022



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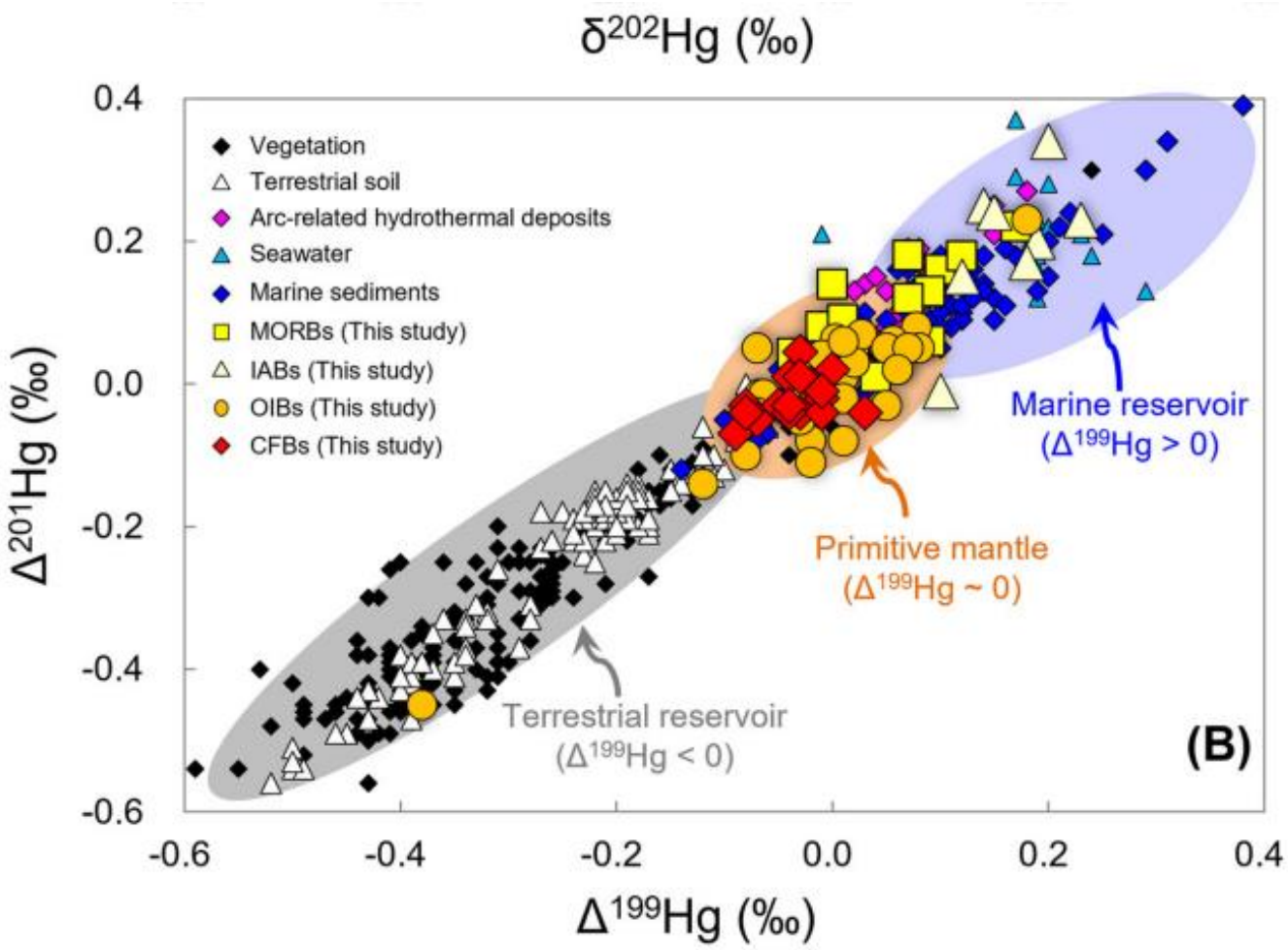
Mantle Hg isotopic heterogeneity and evidence of oceanic Hg recycling into the mantle

Runsheng Yin[1✉], Di Chen[1,2], Xin Pan[1,2], Changzhou Deng[1], Liemeng Chen[1✉], Xieyan Song[1], Songyue Yu[1], Chuanwei Zhu[1,3], Xun Wei[4], Yue Xu[5], Xinbin Feng[6], Joel D. Blum[7] & Bernd Lehmann[8]

- Data plotting around 0 is to elemental.
- Data plotting negatively, is predominantly going to be terrestrial.
- Data plotting positively, is predominantly going to be marine.



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Application zoning with global mercury source signatures for Fluids in Sarawak basin cycle

- Zoning and isotopic range template was overlain onto Washburn et al 2018 study to test if the zoning and range can be applied to other works.
- 41 data points from 5 fields were plotted. Applied zoning and isotopic range adapted from Yin et al 2022.

Marine zone range

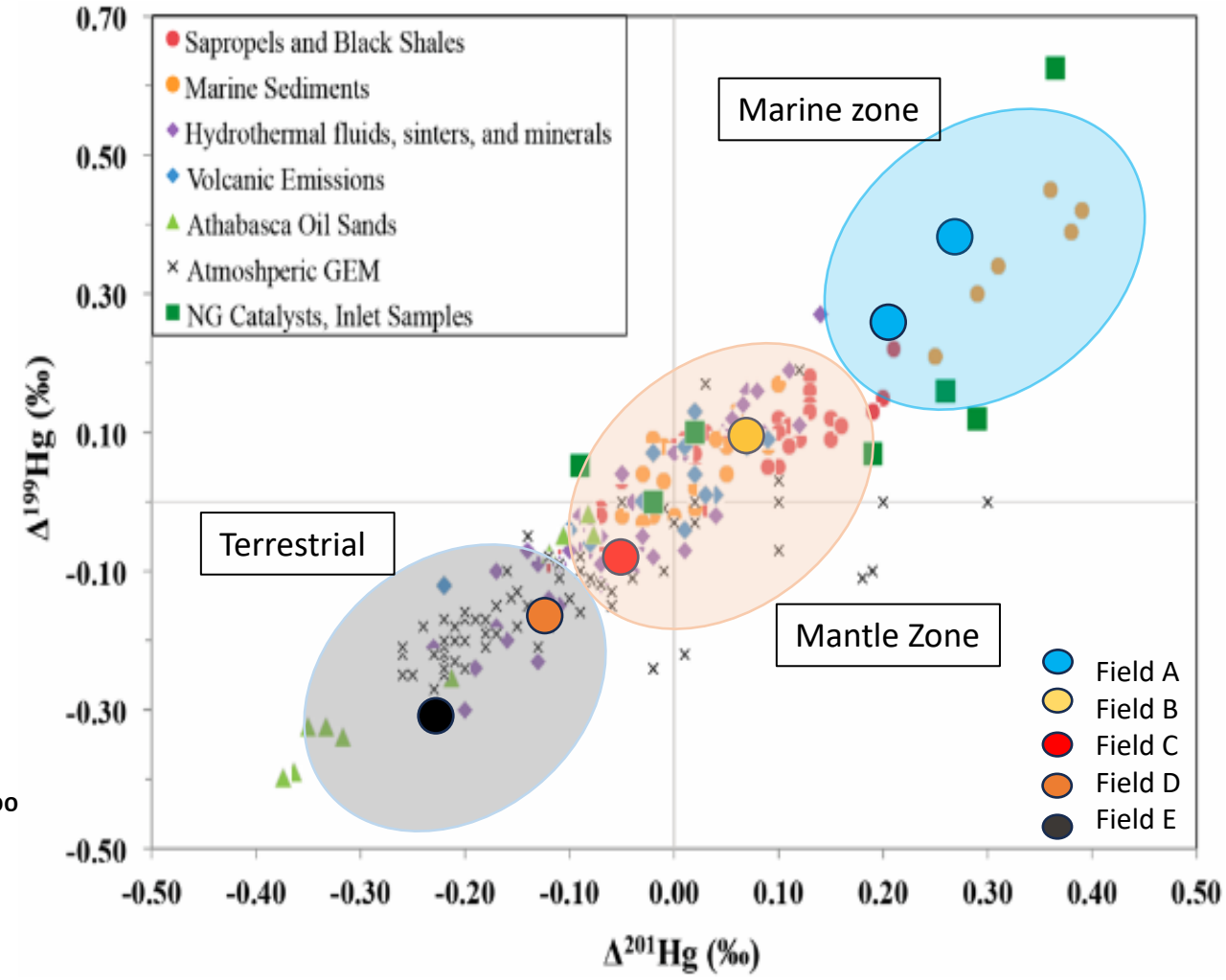
δ199 0.2‰ – δ201 0.18‰ Upwards

Mantle primitive range

δ199 -0.05‰ – δ201 -0.05‰ to δ199 -0.2‰ – δ201 0.2‰

Terrestrial range

δ199 -0.05‰ – δ201 -0.05‰ and below



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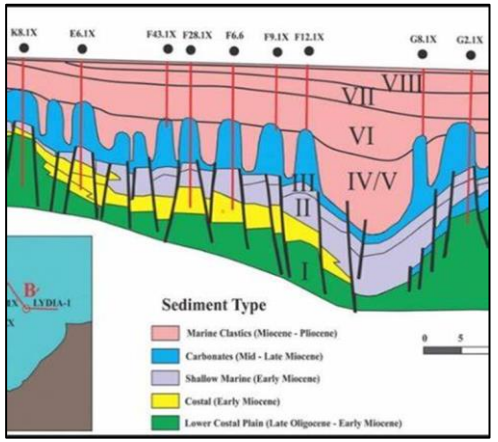
Hg isotope type, origin, migration and geological control

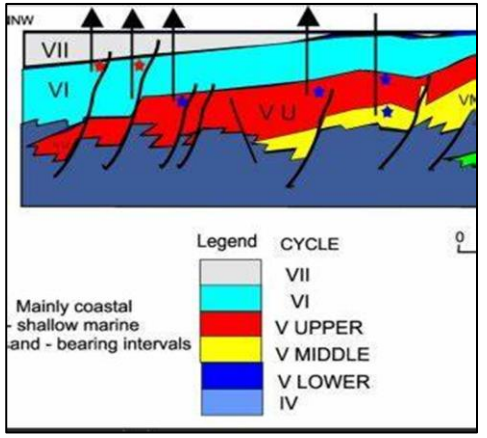
	REGION				
FIELD		C.LUCONIA	W.B.D	TINJAR	ROCK TYPE
	Field A fluid/debris	Mantle/terrestrial			Carbonates
	Field B fluid/debris	Terrestrial			
	Field C fluids		Marine		Clastic
	Baronia fluids		Marine		
	SK coal			Terrestrial*	End members
	Niah limestone			Mantle*	
		Deep-seated fault	Shallow-growth fault	No fault	
	FAULT				

- Fluids from WBD are isotopically more enriched and have a marine origin
- Mantle source in carbonate – deep-seated fault –upwelling from deep mantle
- Terrestrial/mantle source in carbonates– with clastic influence (higher silica)

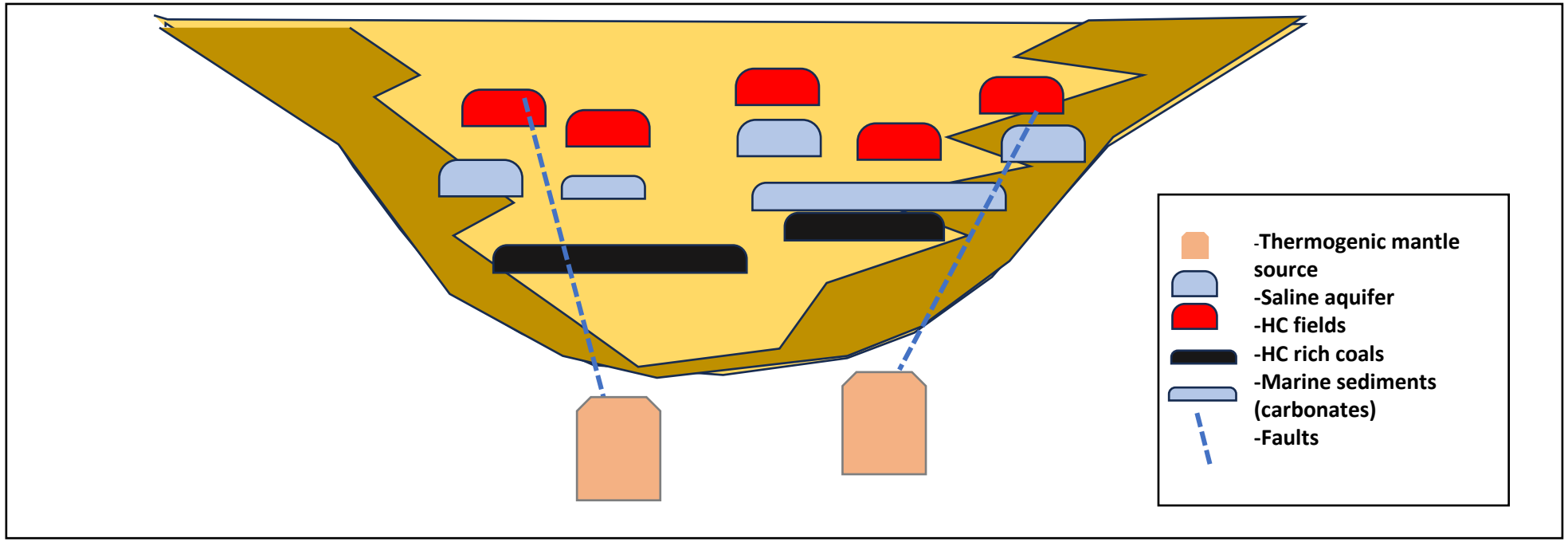
Central Luconia wells deep-seated horst-graben faults



West Baram Delta shallow growth faults



Hypothetical Contaminant Sources – Mercury Migration



- Mercury from thermogenic sources with isotopic values around 0 are propagating along faults from deeper sources and filling HC reservoirs, leading to high concentrations of mercury within the HC from MDF sources.

- The HC carbonate reservoirs influence the Hg concentrations due to their marine origin. Therefore, producing enrichment of heavier Hg via MIF sources.

Conclusion

- Hg source origin identification has been established to assess mercury origin in field development and can potentially show migration patterns of mercury in the subsurface.
- Regional geology analysis suggests that there is structurally driven migration of mercury along deep-rooted faults up to the Miocene carbonate reservoirs which is supported by mercury findings.
- Further studies are recommended to strengthen the isotope-mercury fingerprinting.