Oil and Gas Seeps from Timor Leste – A Key Factor in Understanding Source Rock Development in the Area

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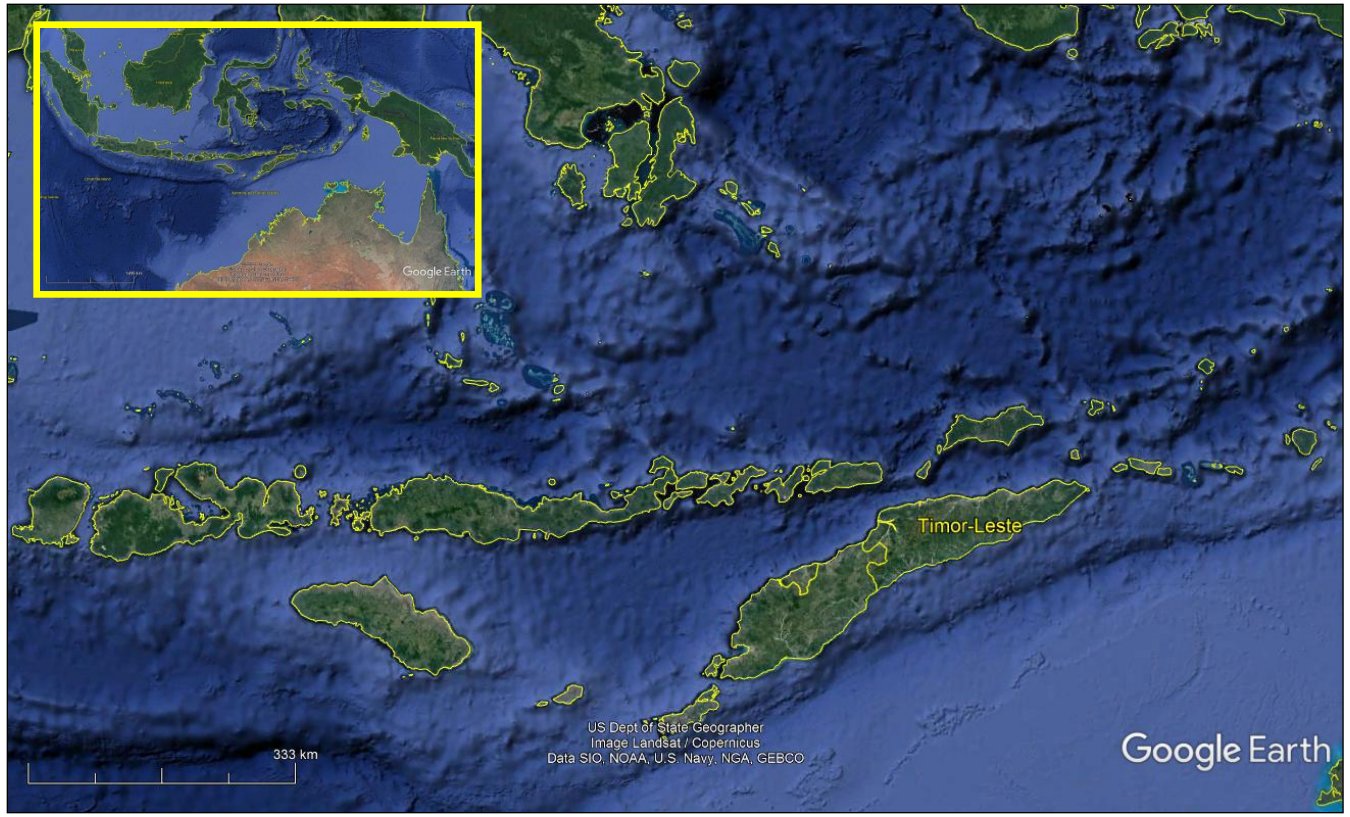
Format of the Presentation

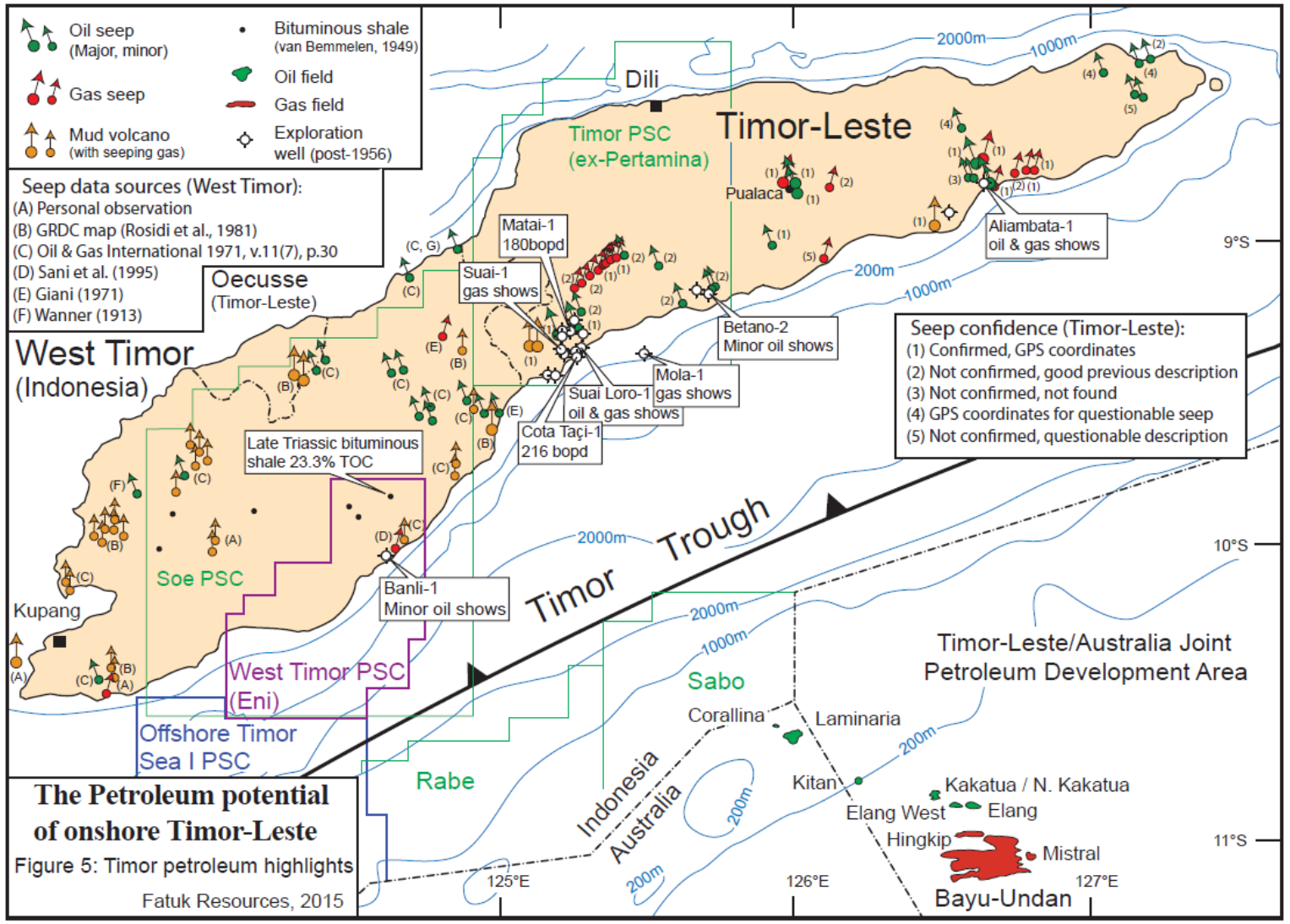
- Background to the study
- Hydrocarbon indications onshore Timor Leste
- Geology of onshore Timor Leste
- Oil compositions and source rock implications
- Gas compositions and implications for origin
- Source rock indications and possible hydrocarbon source rocks
- Conclusions

Background



- Study was initiated in 2018 to try and document and classify hydrocarbon indications onshore Timor Leste
- Work involved:
  - collection of oil and gas seeps for analysis and classification
  - rock samples for source rock potential, maturity and age-dating, (emphasis on Triassic units)
- Involved several field campaigns between November 2018 and June 2019
- Additional samples and information were added from historical Timor Gap EP and Horizon databases where new collection was not possible or better source rocks had been identified previously

Hydrocarbon Indications - Onshore Timor Leste



- Recent database compilation by Timor Gap EP indicate over 200 oil and gas seep records with ~70 of these having accurate GPS locations.
- These include:
  - seeps from wellheads of exploration wells drilled in the late 1950's through to early 1970's
  - gas seeps associated with mud volcanoes
  - long-lived gas seeps often burning when encountered in the field
  - oil and gas seeps which seem to be more seasonal in nature and may be driven by groundwater during the wet season

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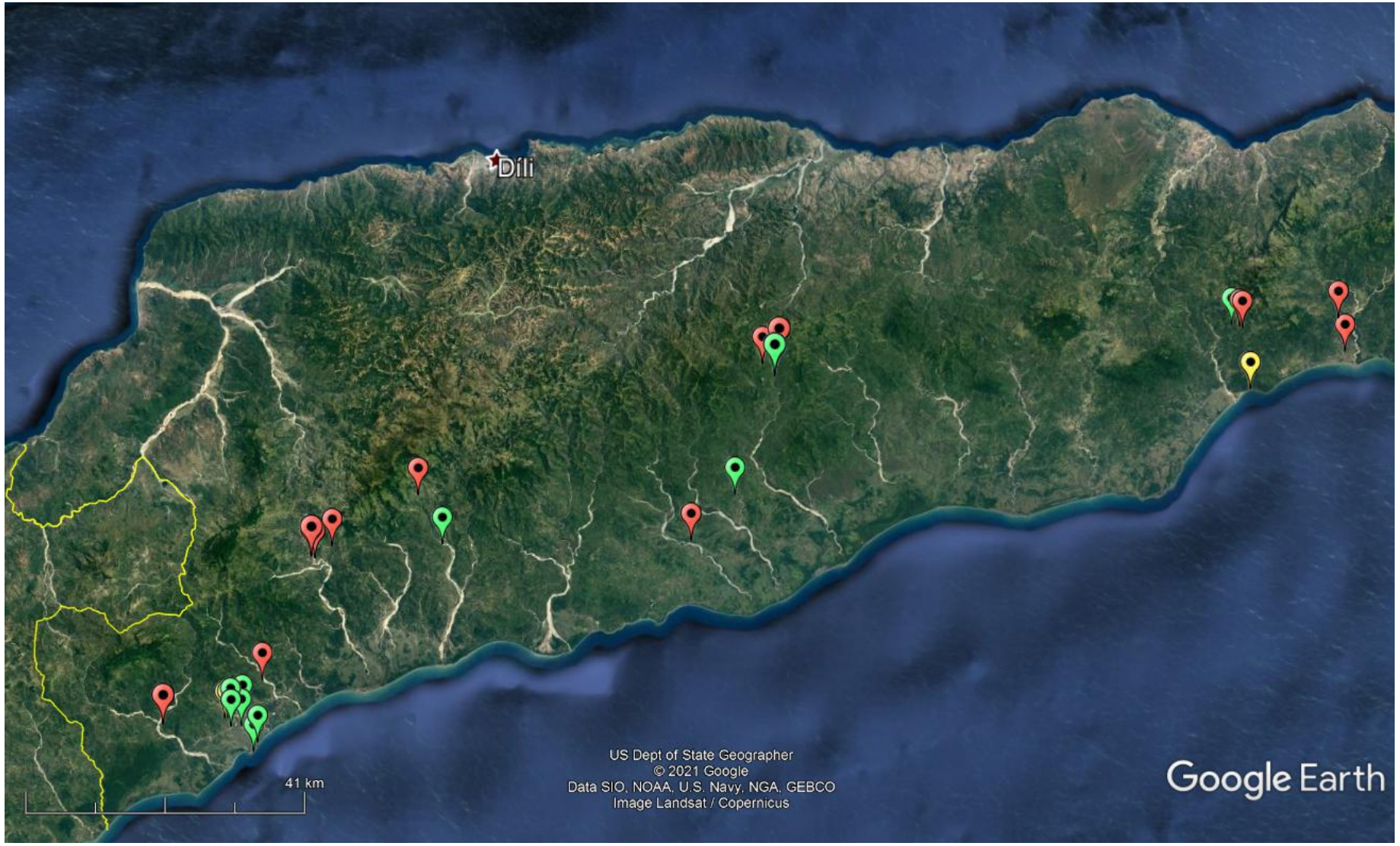
Collected Hydrocarbon Indications - Onshore Timor Leste



Oil

Gas

Oil and Gas

Indications include:

- Wellhead seeps
- Surface Seeps
- Mud Volcanoes
- Staining in Outcrop

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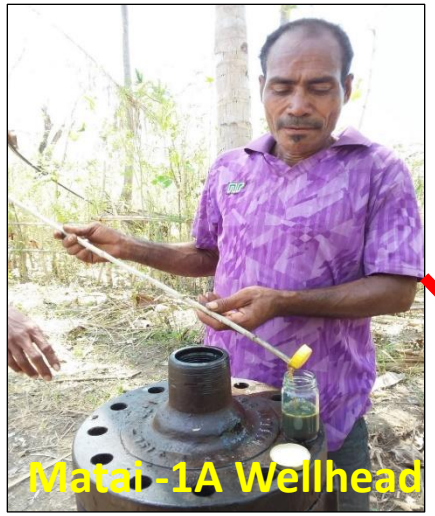
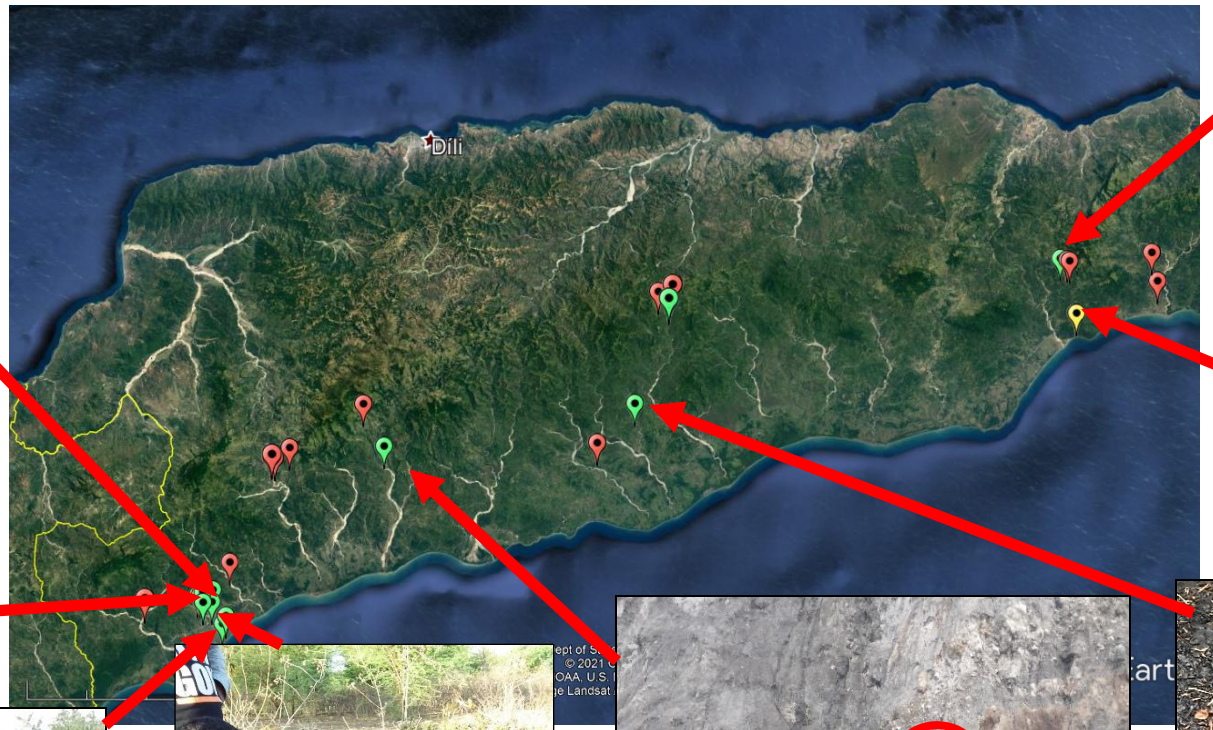
Examples of oil indications


Matai -1A Wellhead


Matai Creek Seep


Cota Taci -1 Wellhead




Suai Loro-1 Wellhead


Oilstain in sandstone blocks at Sap Maras


Iriamo Oil Seep


Aliambata –oil seep from wellhead


Be Manas – Fatu Lulik Oil Seep

Examples of Gas Indications

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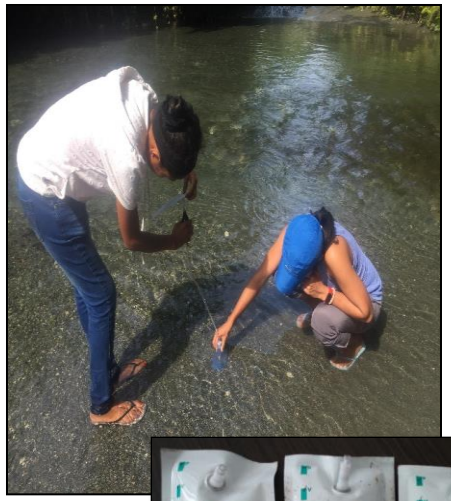
Sampling Techniques

- **Oil seeps**
  - Liquids, varied from light mobile to heavy viscous - collected in glass bottles, salt added to stop any further bacterial action.
  - Rock/Soils – collected in cloth bags and solvent extracted prior to analysis
- **Gas Seeps**
  - Water-based gas seeps – collected with funnel, pump connected to Isotech gas bag
  - Others – inverted canister filled with gas and sample then pumped into the Isotech gas bag







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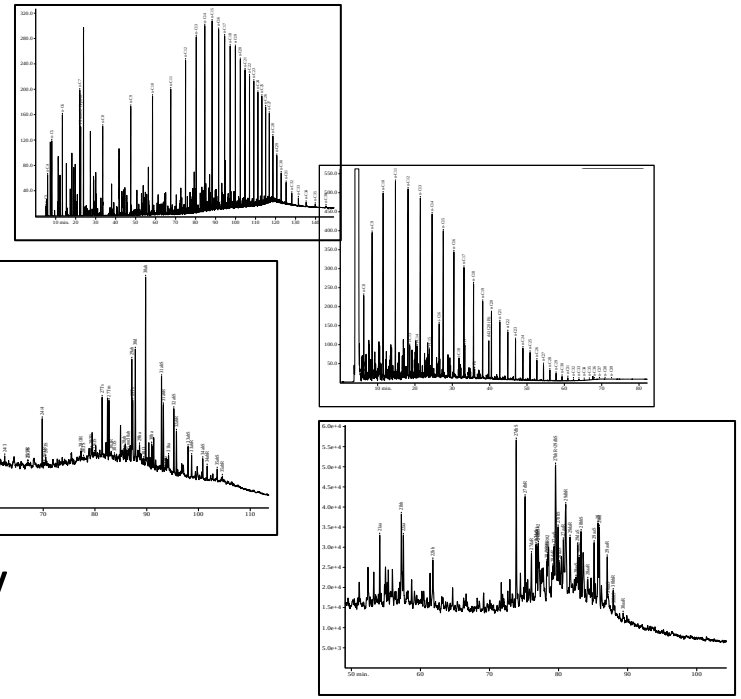
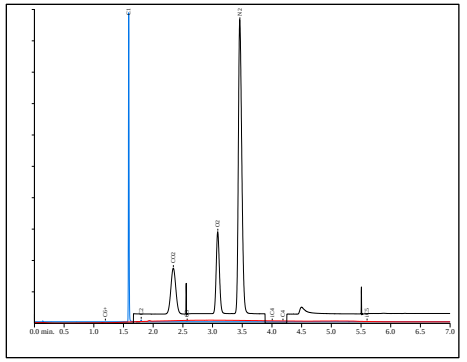
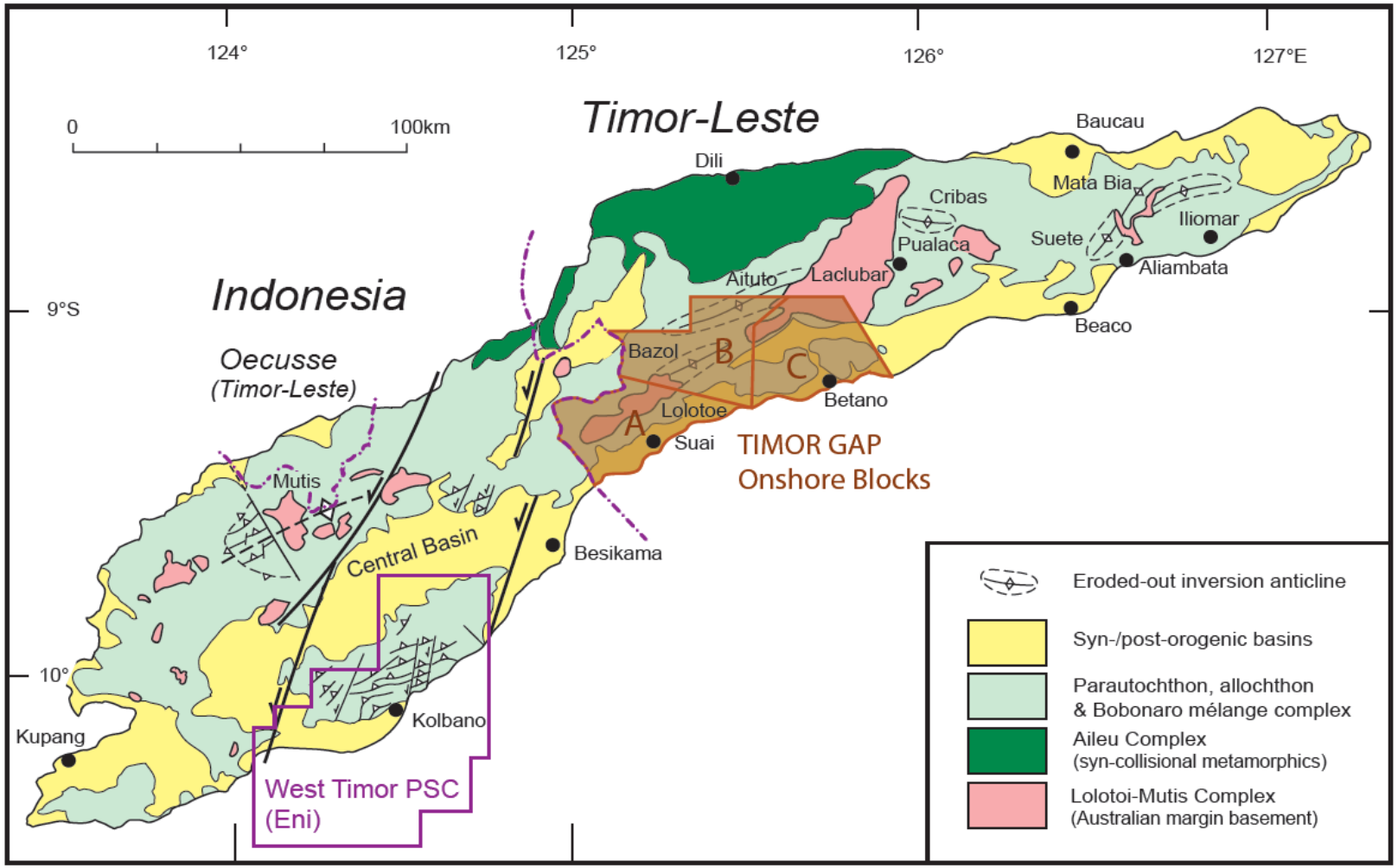
Analysis Techniques

- **Oils**
  - Separation from water where necessary (extraction)
  - API Gravity (if sufficient oil)
  - Sulphur Content
  - Whole oil gas chromatography (if possible)
  - Fractionation
  - Alkane fraction gas chromatography
  - Combined alkane and aromatic fraction gas chromatography
  - Carbon isotopes of alkanes and aromatics
- **Gases**
  - C_1-C_5 hydrocarbon composition
  - CO_2, N_2 and O_2+Ar content
  - Carbon isotope analysis – C_1, C_2, C_3, $\underline{i}$-C_4, $\underline{n}$-C_4
  - Deuterium isotope analysis – methane
  - Carbon isotope analysis of CO_2





Geology of Timor Leste



The geology of Timor Leste comprises four main components:

- In-place Australian Continental Crust
- Australian Continental margin basement and overlying passive margin sediments (para-autochthon) thrust back towards Australia during arc-continent collision
- Forearc remnants thrust back towards Australia (allochthon)
- Plio-Pleistocene syn- and post orogenic basins mostly along the southern coast of Timor Leste

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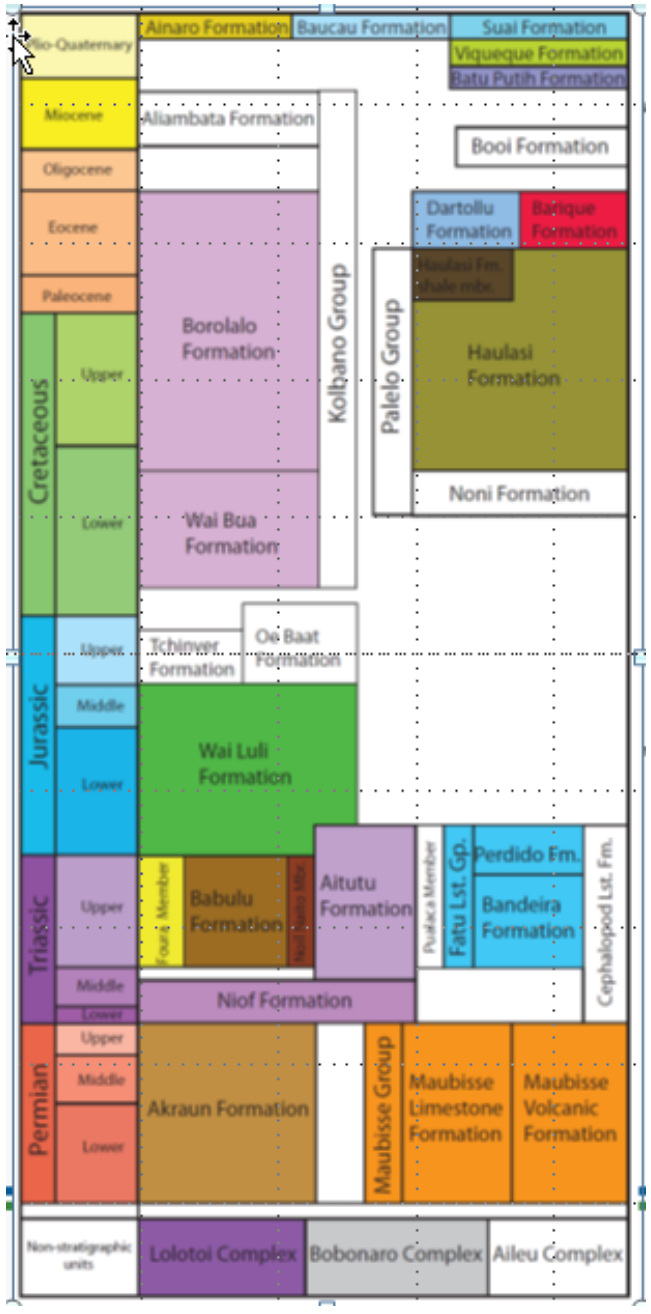
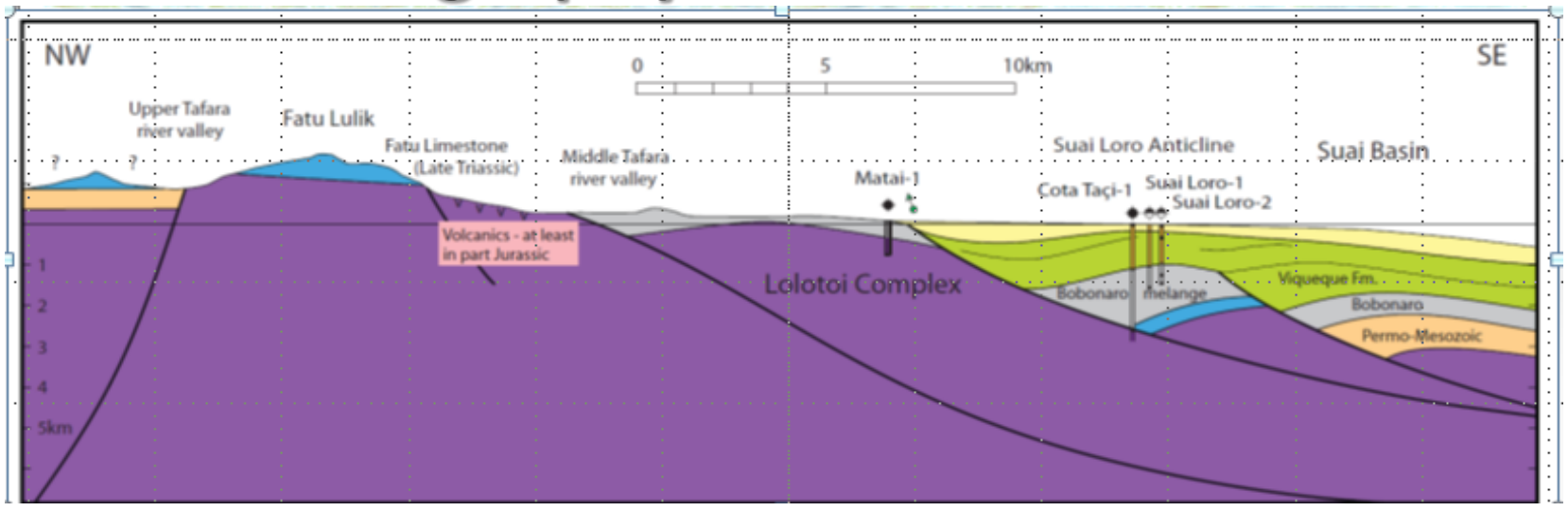
Stratigraphy





- Stratigraphic units of the distal margin of the Australian Continent (Permian, Triassic and Jurassic) are of key interest as source and reservoir units.
- Melange, syn- and post-orogenic units comprise overburden and may also provide good seals, with some reservoir potential
- Still a significant amount of work to do to understand the age relationships and regional distribution of the various Mesozoic and Paleozoic lithostratigraphic units on Timor Leste
- Current work concentrated on the Triassic to help understand source distribution and reservoir potential

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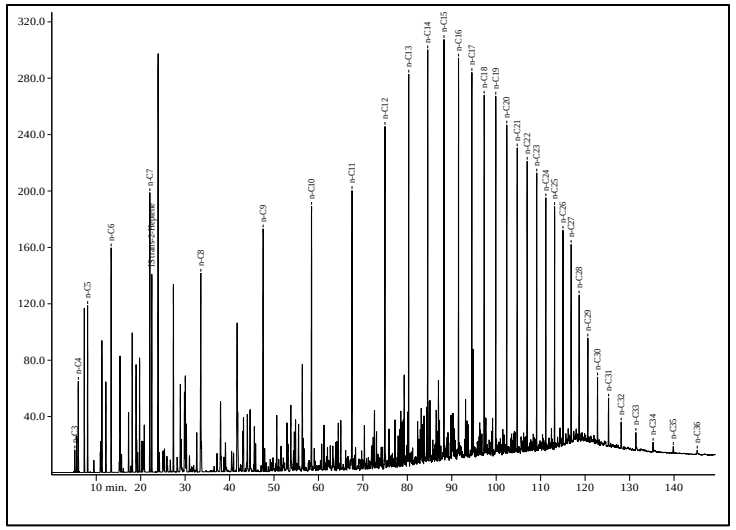
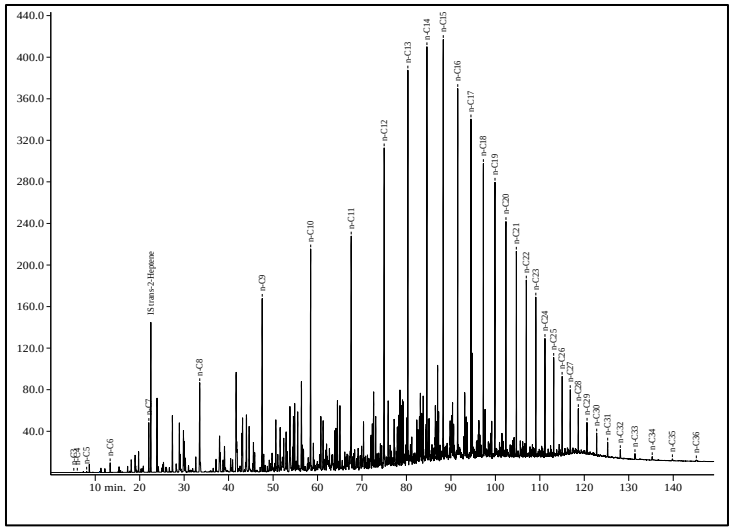
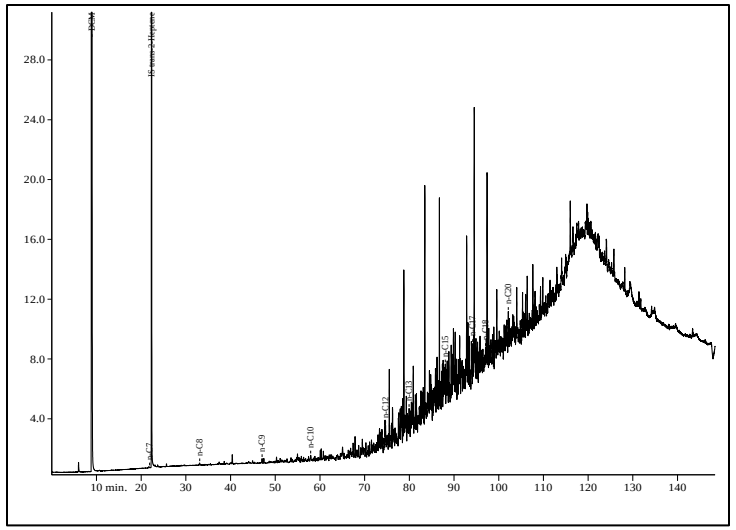
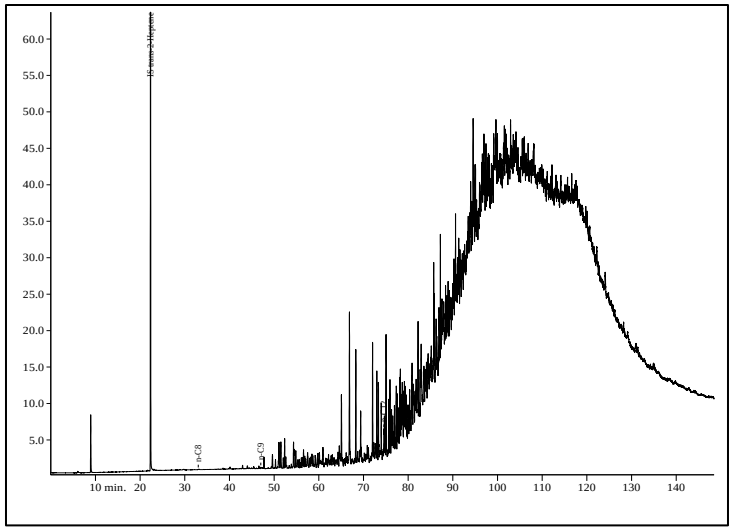
Oil Compositions – Whole Oils









- Seeps range from light (44.7°API) to heavy (23.1°) oils
- Range from non-degraded to heavily biodegraded
- Lighter non-degraded oils show evidence of water washing
- Wellhead seeps are generally less degraded than natural seeps suggesting that this is a surface phenomenon
- Overall alkane distributions and low pristane/phytane ratios suggest a marine source type

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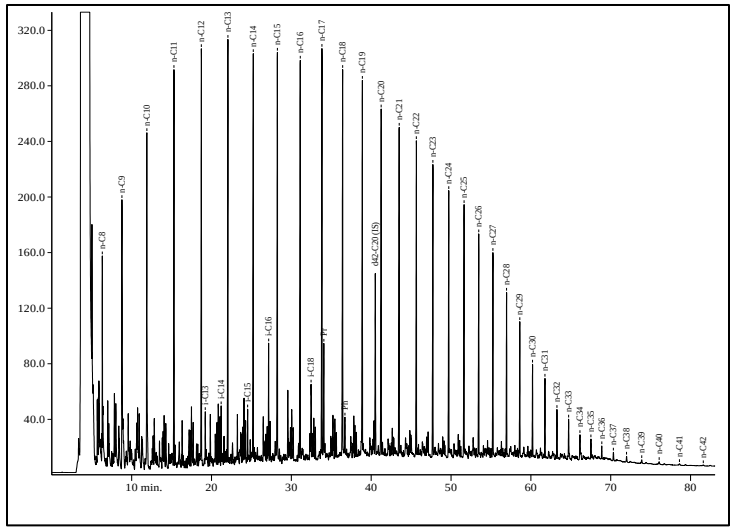
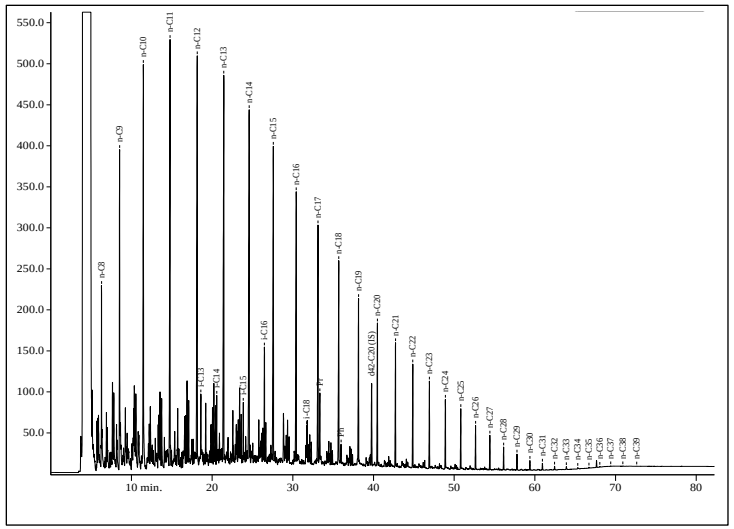
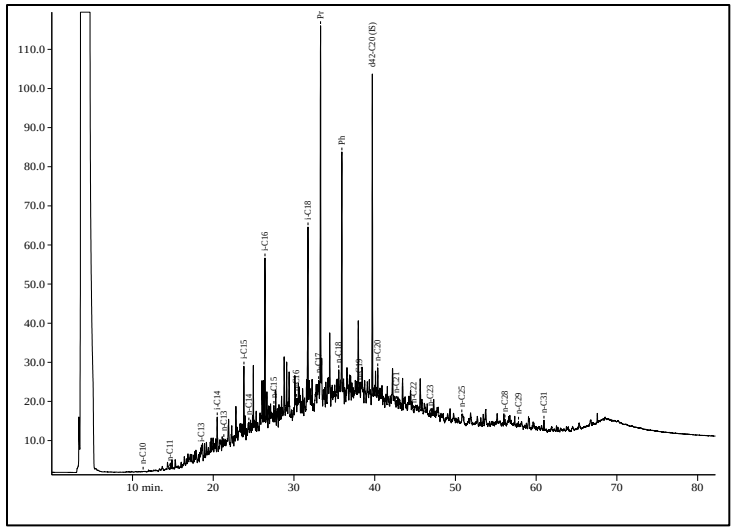
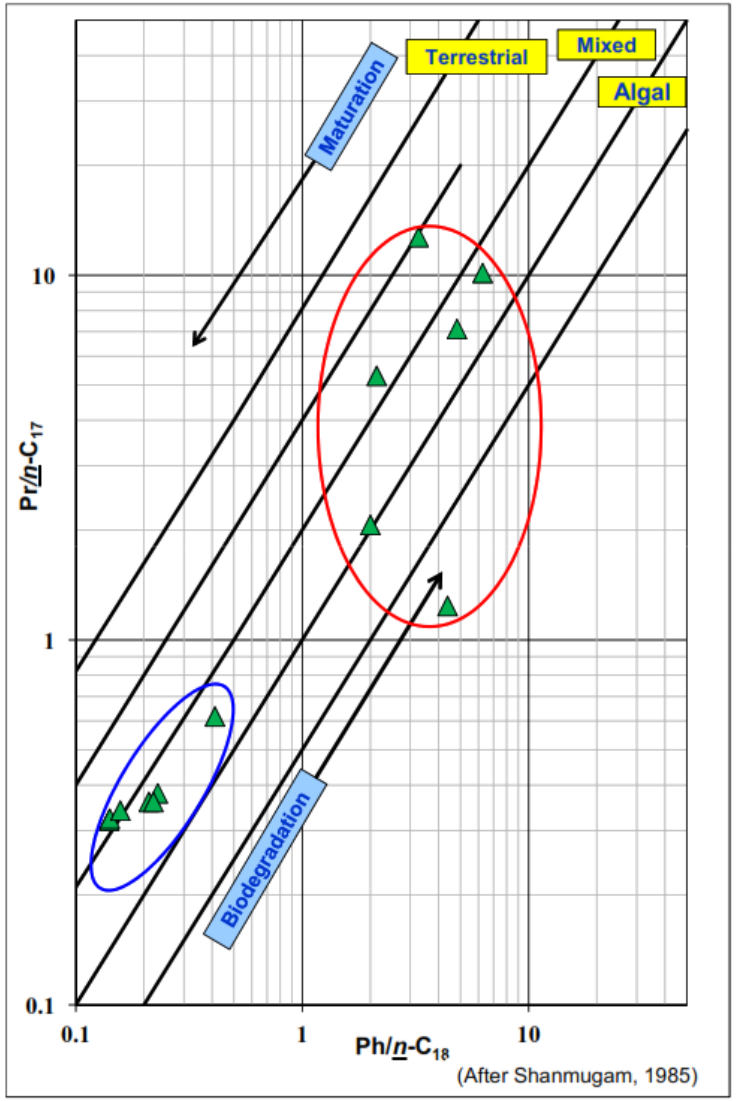
Oil Compositions - Alkanes







- Alkane profiles typical of marine oils (low waxes, low pristane/phytane ratios)
- Unaltered oils (blue circle) - very similar marine source for each
- Biodegraded oils show much wider spread of values due to effects of partial to severe biodegradation



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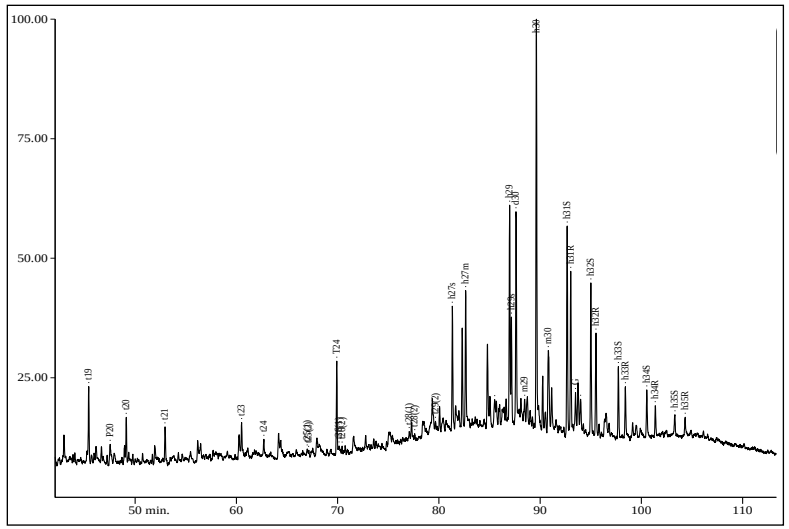
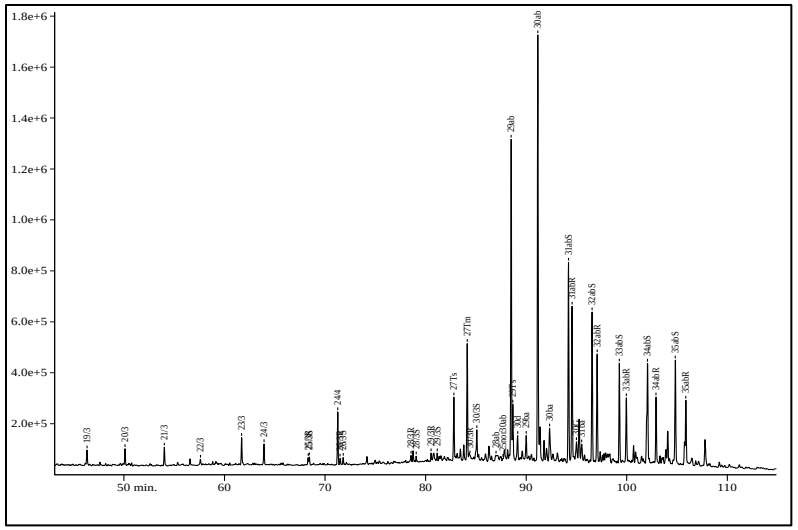
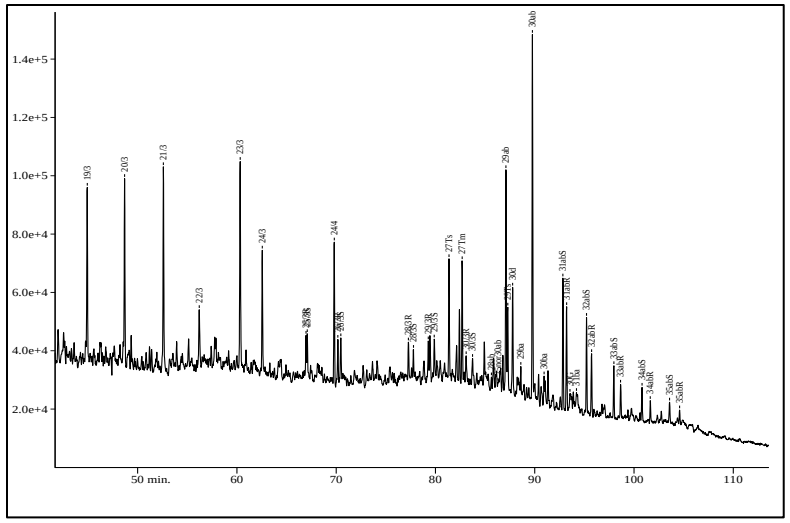
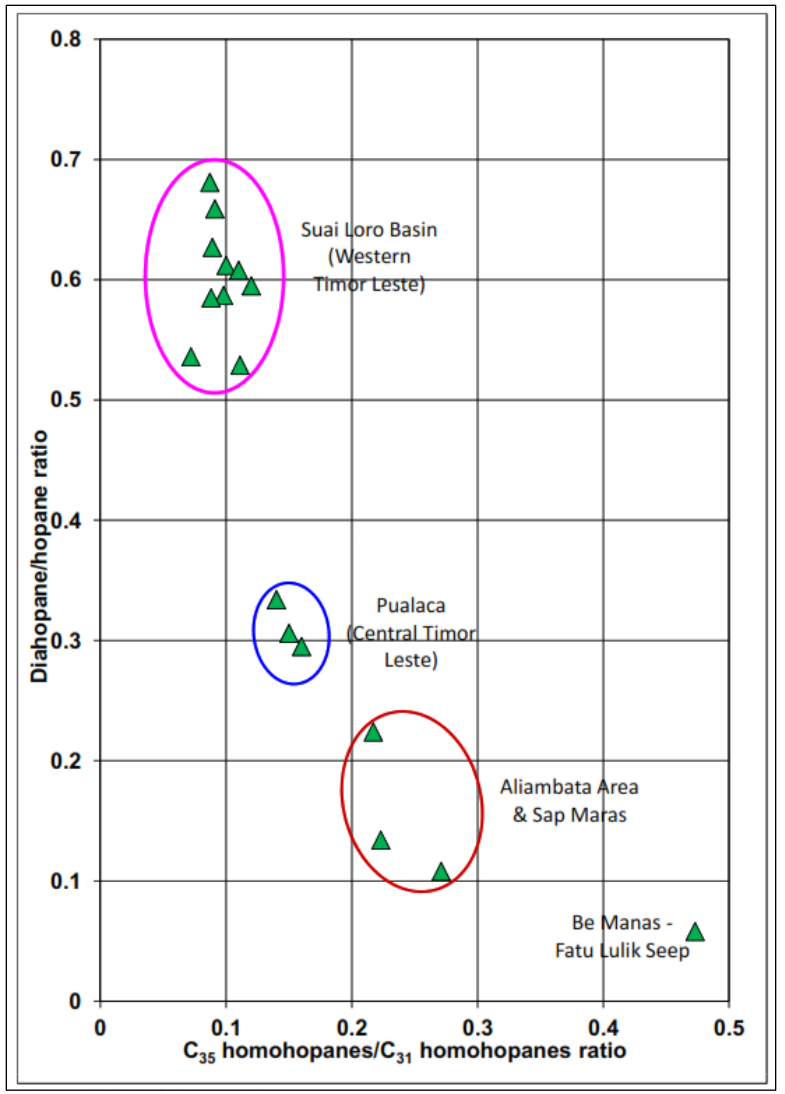
Oil Compositions - Terpanes







- While oils show generally very similar terpane distributions they can be subdivided based on:
  - diahopanes/hopanes
  - tricyclic/pentacyclic terpanes
  - extended homohopane patterns
- Source facies and maturity effects



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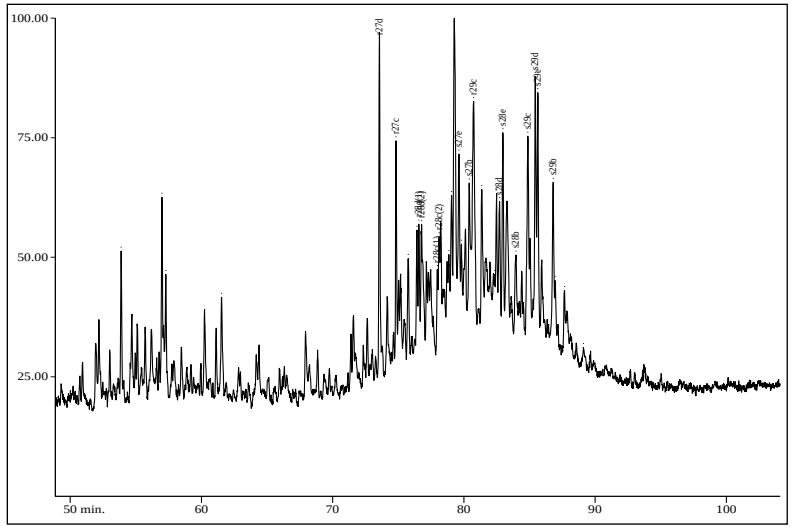
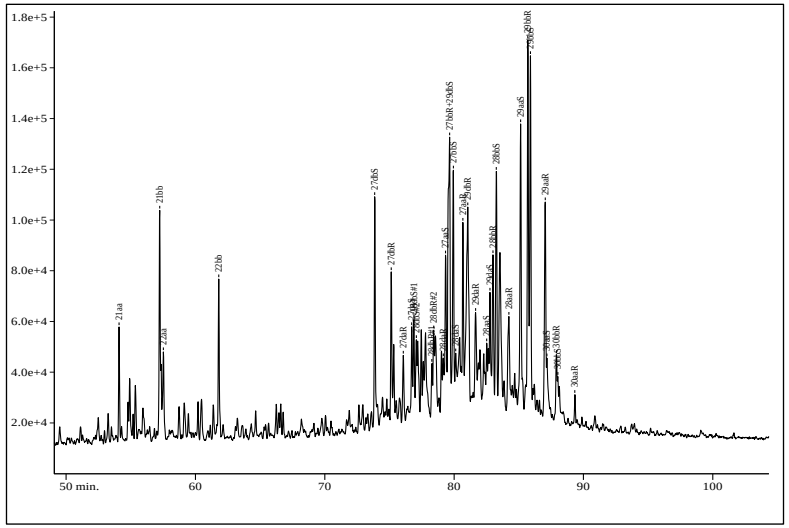
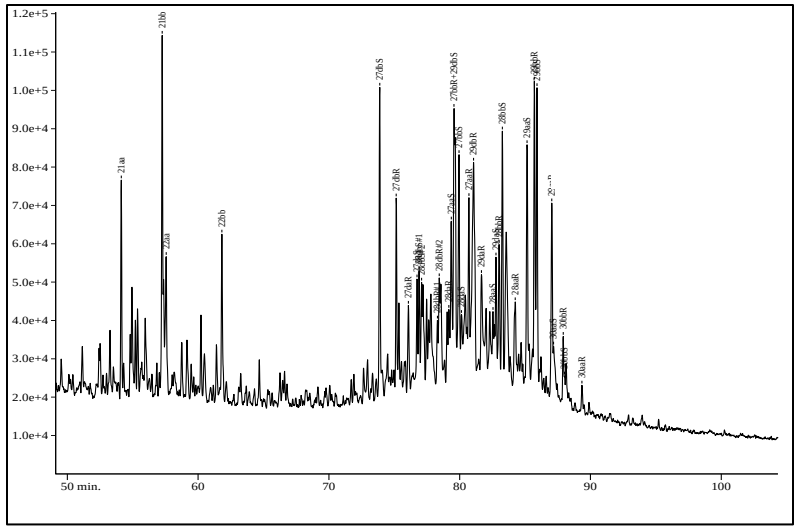
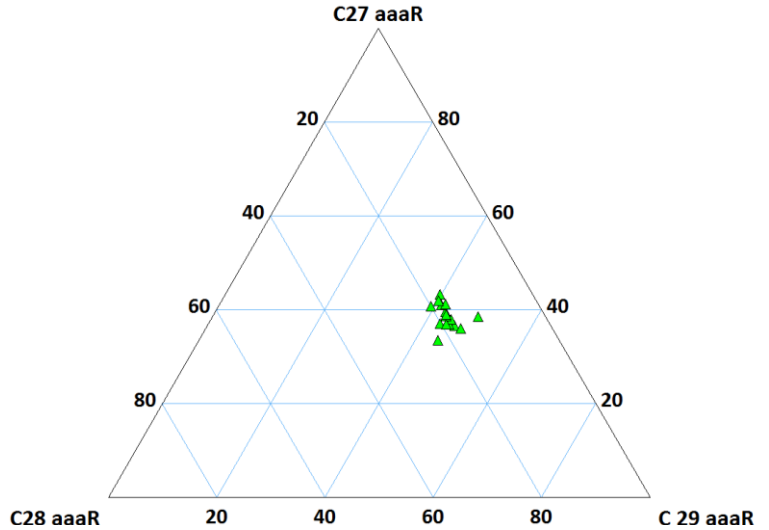
Oil Composition - Steranes

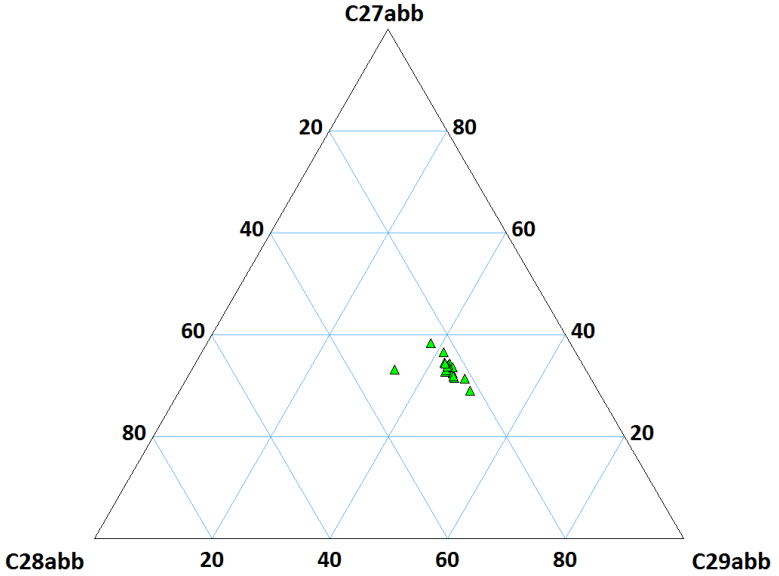






- Oils exhibit very similar sterane carbon number compositions indicating marine algal source rocks
- Main differences:
  - Relative amounts of regular steranes and rearranged steranes
  - Relative amounts of C_{21}-C_{22} steranes to C_{27}-C_{29} steranes
  - C_{30} hopane/C_{29} steranes ratio





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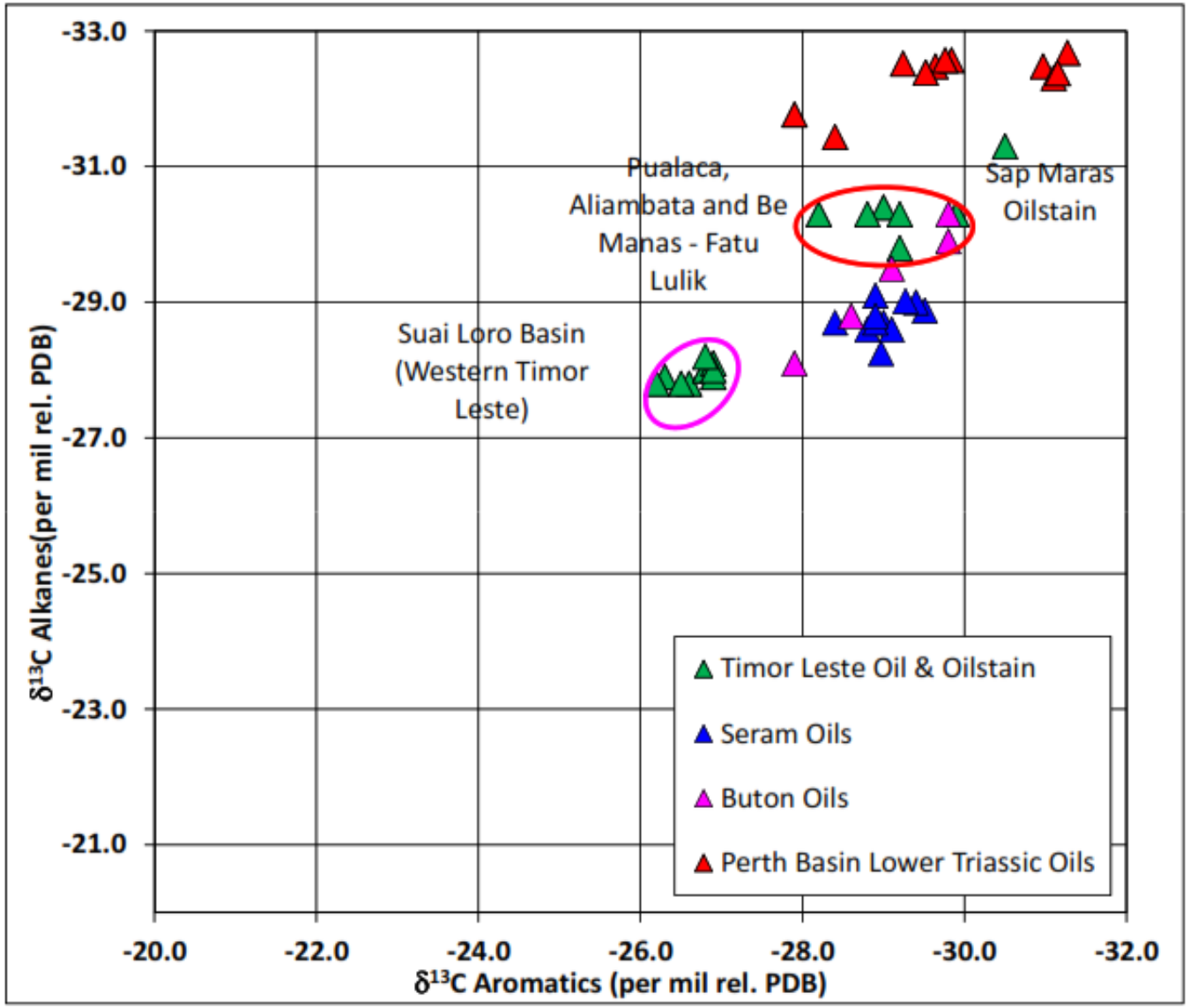
Oil Composition - Carbon Isotopes



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- Despite marine nature of all oils and similarity of organic matter types the oils can be sub-divided into two distinct oils groups:
  - Group A: Suai Basin
  - Group B: Central & Eastern Timor Leste
- Oilstain at Sap Maras is isotopically lighter than Group B
- Late Triassic-sourced oils from Buton and Seram shown for comparison'
- Early Triassic-sourced oils from Perth Basin isotopically-lighter than all these oils

Oil Groups and Source Facies Interpretation

Oils sourced from marine algae
Pr/Ph ratios (0.9-3.0)
Isoprenoid/*n*-alkane
Low wax content
$C_{27/28/29}$ Sterane Distributions (34-43/17-20/40-49)

Analysed Timor Leste Oils

Diahopane/hopane ratios
Terpanes - $C_{24}T/C_{30}P$ - cyclic
Reg/Rearr. steranes
C_{30} hopane/C_{29} steranes
C_{35}/C_{31} ext. homohopanes
Alkane CI values

Group A	0.53 – 0.66 0.04 – 0.19 High 0.95 – 1.52 0.07 – 0.12 -27.8 – -28.1
Group B	0.13 – 0.33 0.23 – 0.46 Mod-Low 0.55 – 0.84 0.14 – 0.27 -30.3 – -31.3
Group C	0.06 0.05 Low 8.2 0.47 -29.8

B1	0.30 – 0.33 0.34 – 0.46 0.54 – 0.63 0.14 – 0.16 -30.3 – -30.4
B2	0.11 – 0.22 0.23 0.82 – 0.84 0.22 – 0.27 -30.3
B3	0.13 0.05 0.55 0.22 -31.3

Group A: Suai Basin Oils - Marine source rock with significant argillaceous component deposited in normal salinity waters in a more oxidising environment than Group B oils.

Group B oils: - Calcareous marine source rock deposited in a more reducing environment than source of Group A oils. Distinctions between sub-groups probably represent stratigraphic variations in water chemistries during deposition of source unit

Group C: Be Manas – Fatu Lulik oil - Marine calcareous source rock, high bacterial input, deposited in a more saline and strongly reducing environment than the Group B oils.

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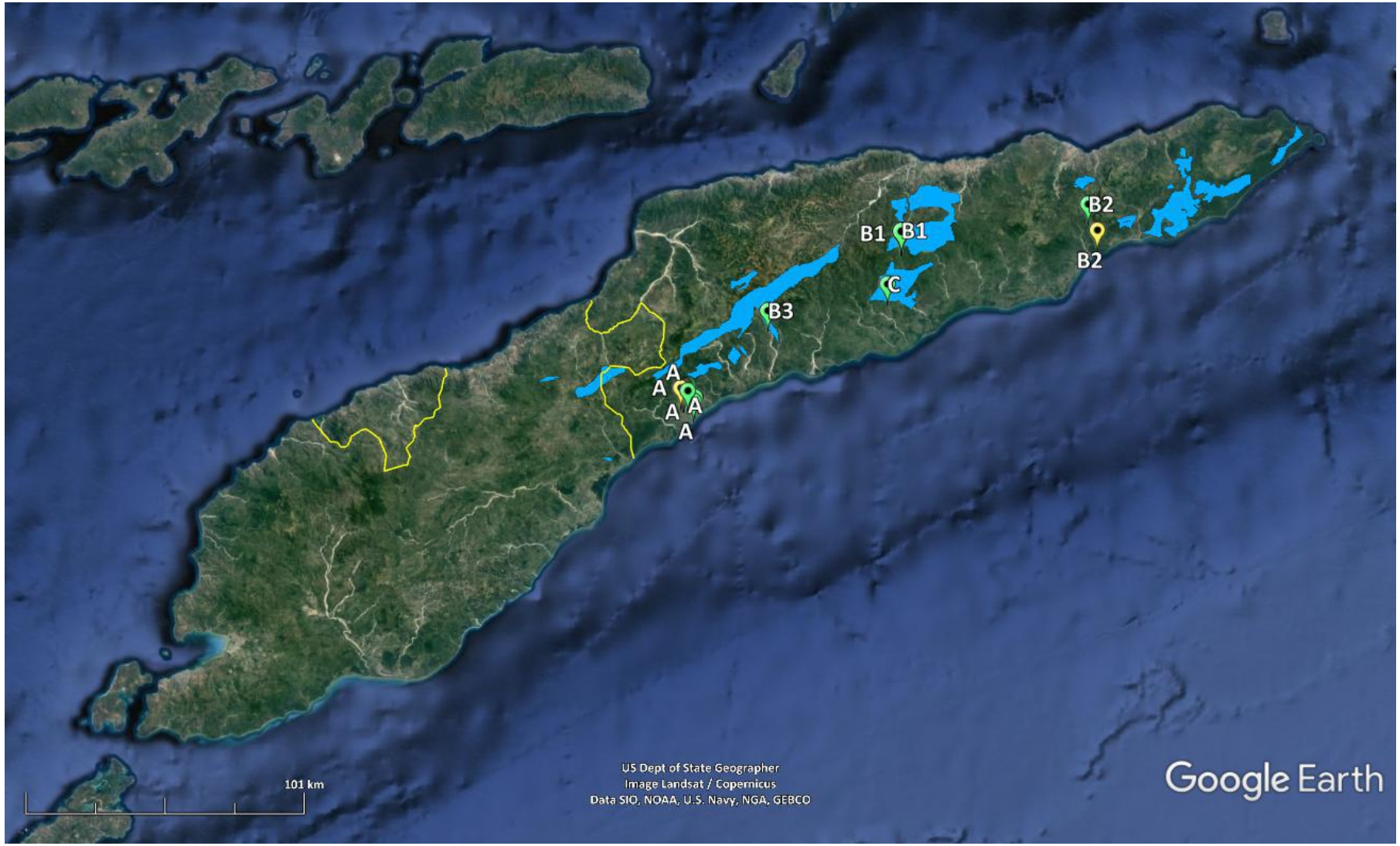
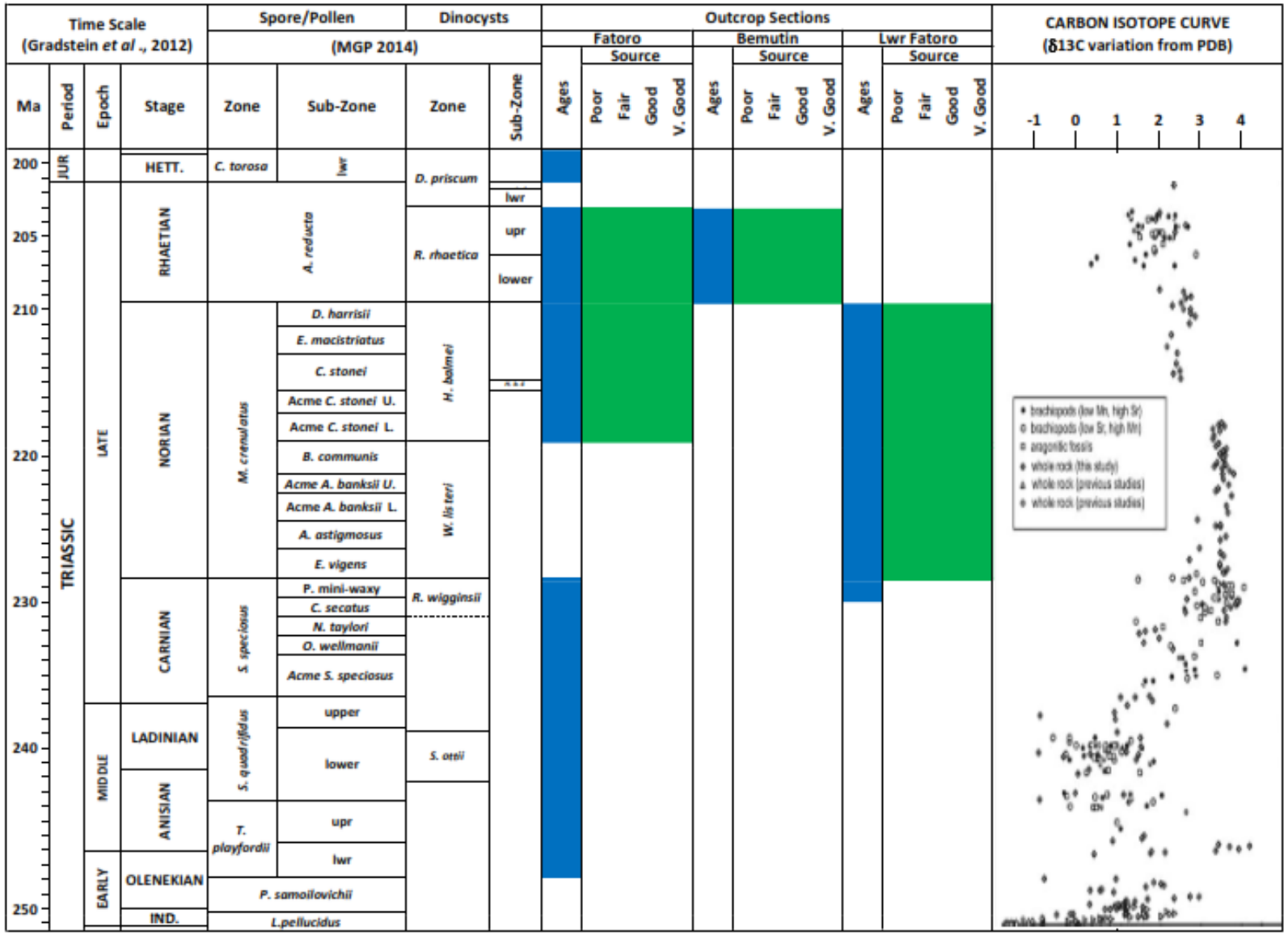
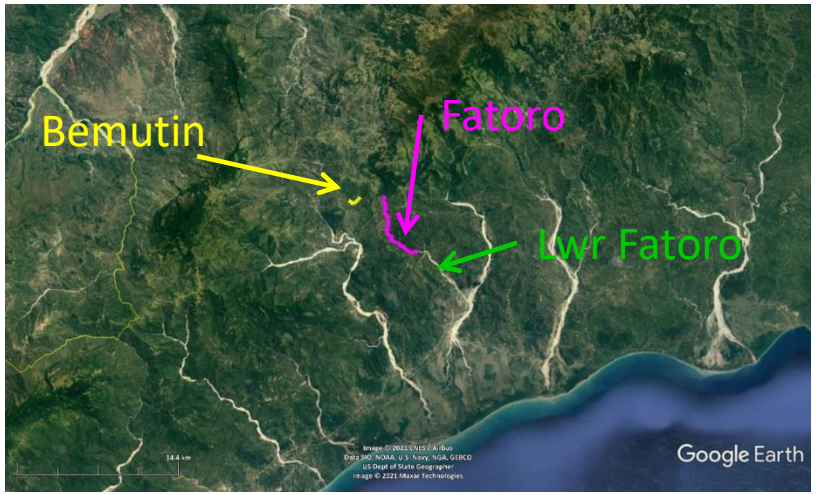
Regional Distribution of Oils Groups



- Group A oils are confined to Suai Basin and have not been detected outside this area
- Group B oils are scattered throughout Central and East Timor Leste and tend to be close to areas of outcropping Middle-Late Triassic Aitutu Formation
- The Group C oil at Be Manas Fatu Lulik is similar to Group B oils and may represent a facies variation within the same source horizon

Observed Source Rocks





- Very good oil source rocks identified to date at outcrop restricted to Late Triassic (Norian – Rhaetian)
- No Early Triassic source rocks identified but few outcrops examined
- Oil isotopic variations may reflect carbon isotopic variations of seawater during Triassic (Tanner, 2010)
  - Basal Triassic: strong –ve excursion
  - Early Triassic: instability
  - Middle-Late Triassic: rising values/stability
  - Latest Triassic: moderate –ve excursion

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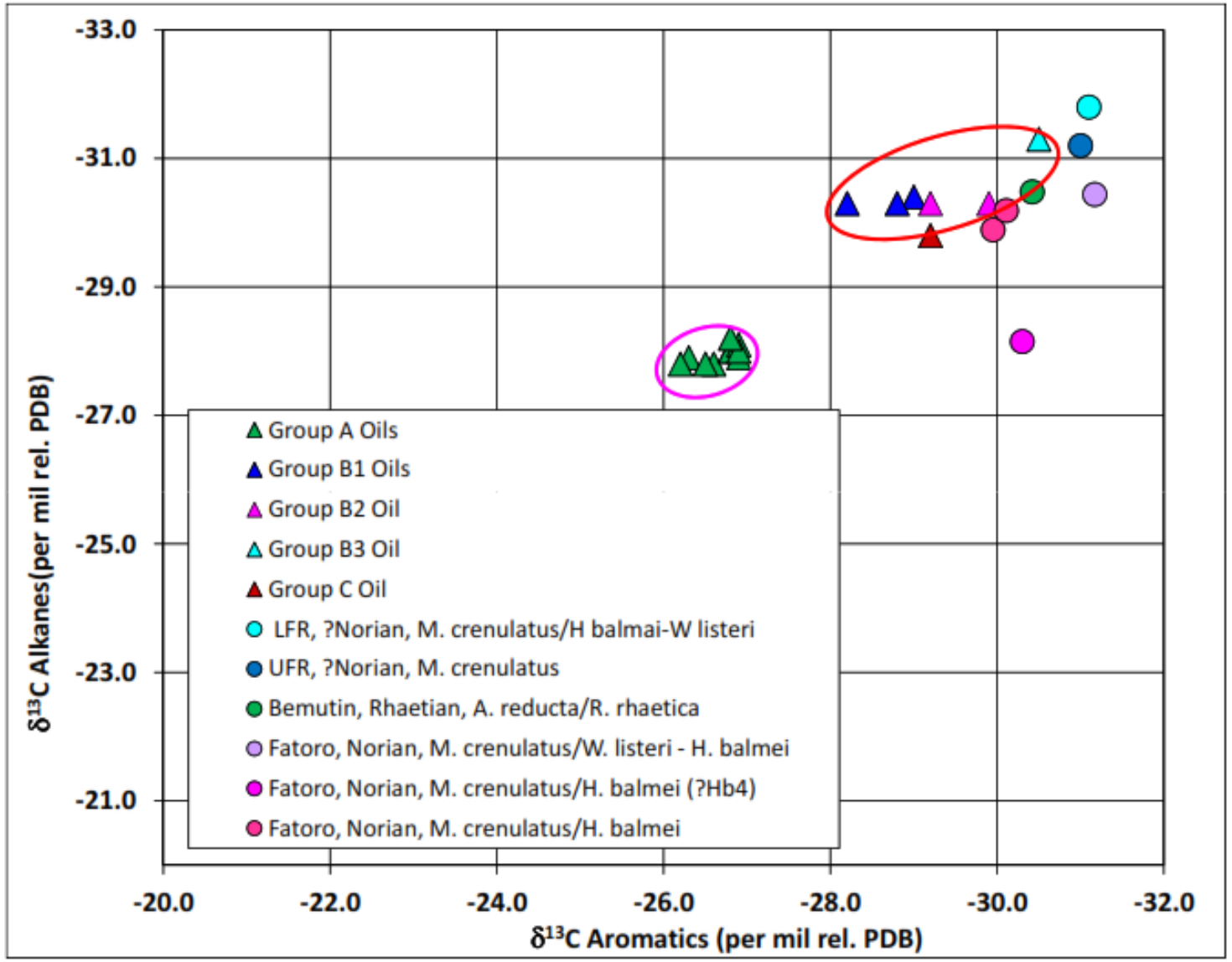
Oil-Source Correlation



- Late Triassic (Norian and Rhaetian) outcrop samples show a good match with Group B and C oils based on carbon isotope values
- High extended homohopane content observed in Group C oil has also been observed in the Norian age, M. crenulatus/H. balmei (?Hb4) source rock from Fatoro
- There is sufficient variation with biomarker compositions of Norian and Rhaetian source rocks to suggest that the Group B sub-groups relate to stratigraphic and facies variations within the Rhaetian and Norian source rocks
- Source of the Group A oils has not been identified at outcrop but may occur within the earlier part of the Norian or within one of the positive isotope excursions during the Early Triassic.

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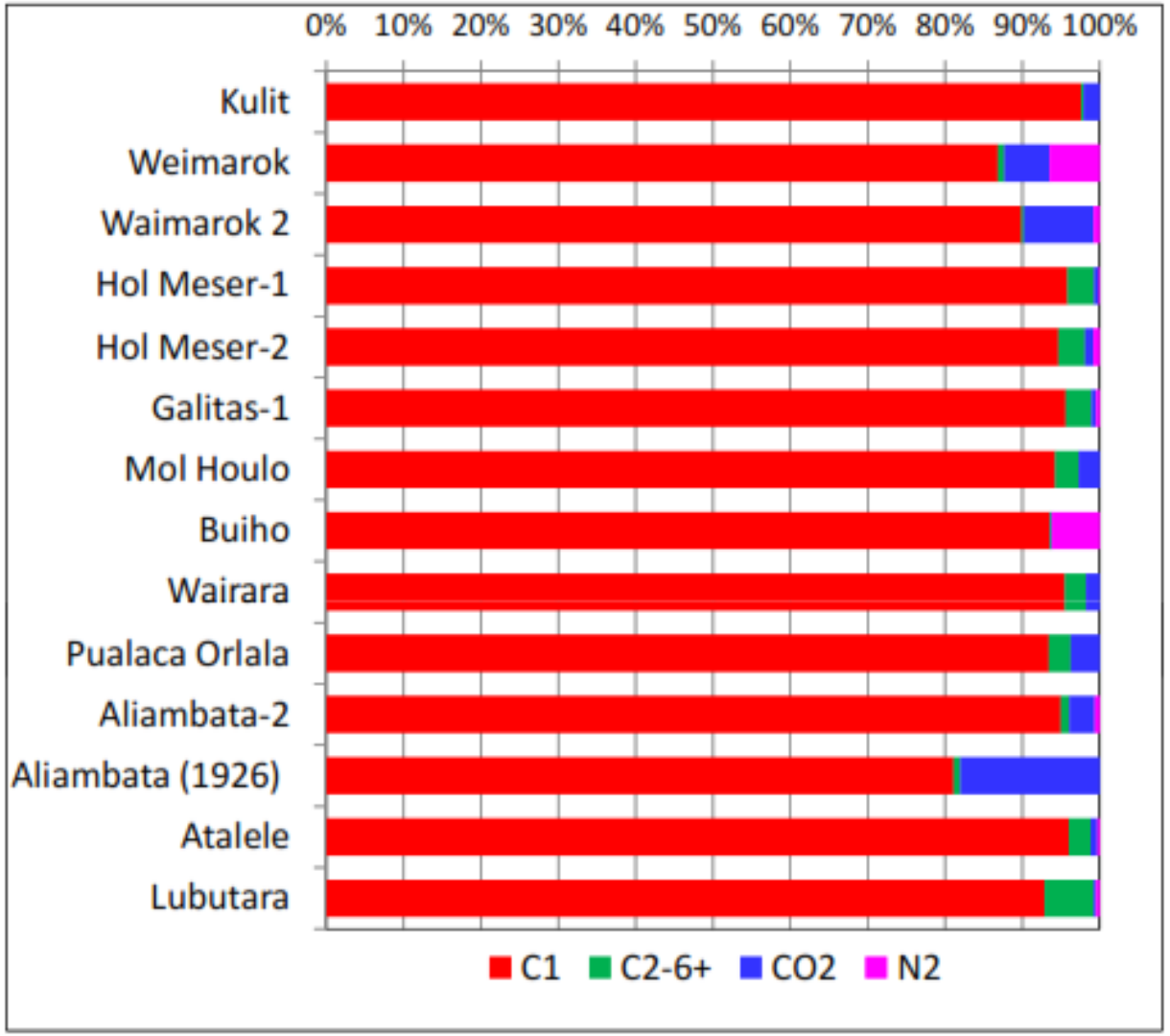
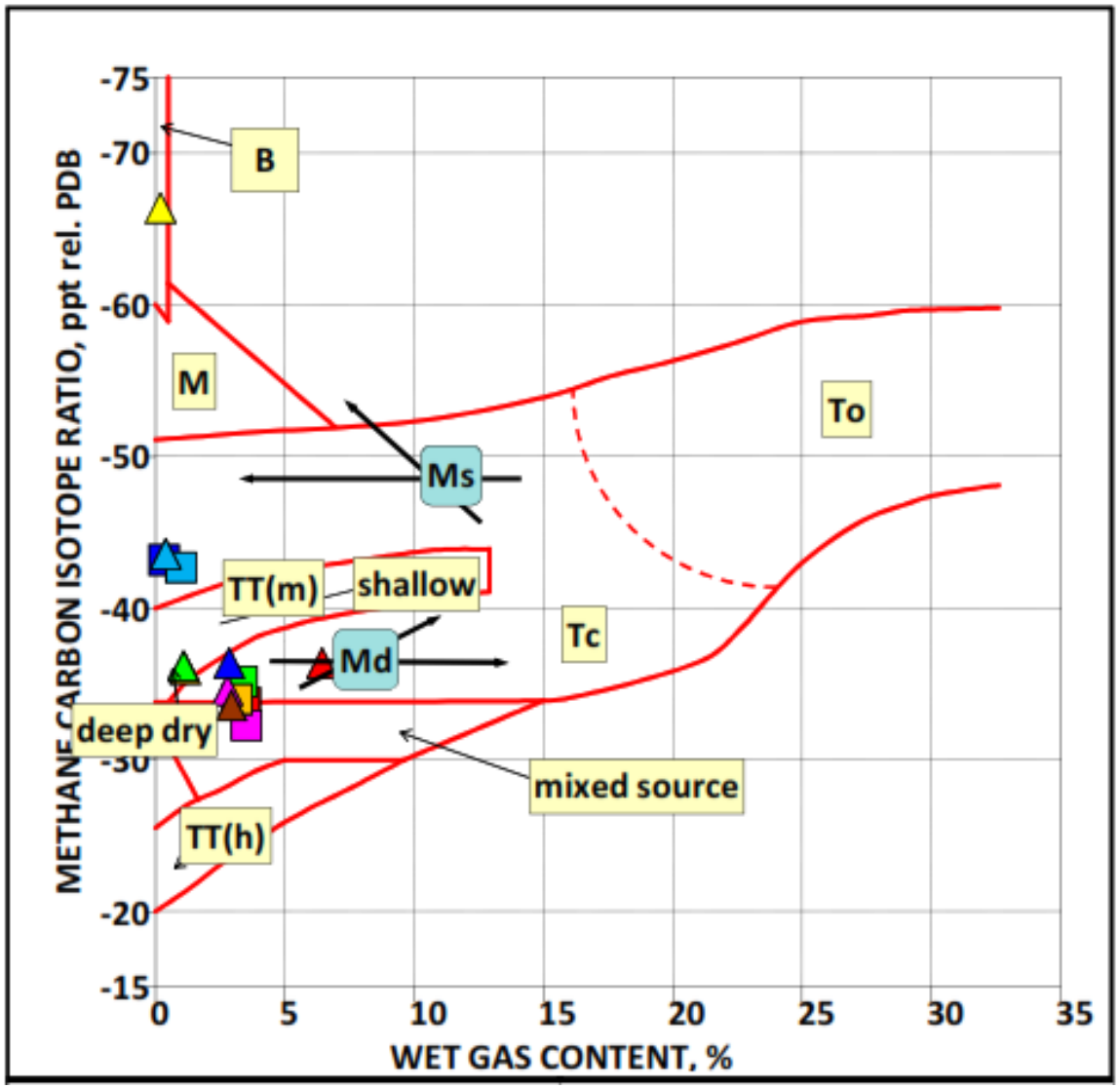
Gas Compositions



- Four gas samples had no hydrocarbons due to sampling issues. Not discussed further
- Gases:
  - Methane (81-98%)
  - CO_2 (0.1-18%),
  - Nitrogen (0-6.5%) and
  - Wet Gas (C_2-C_{6+}) (0.2 – 6.4%)

Gas Origin – CI Methane vs Wet Gas Content



COMMENTS	After Schoell, 1983	KEY	
B = biogenic gas, To = oil-associated,		Kulit	Weimarok
Tc = condensate associated		Waimaruk-2	Hol Meser-1
TT(m) = non-associated dry gases		Hol Meser-2	Galitas-1
from sapropel		Mol Houlu	Buiho
TT(h) = non-associated dry gases		Wairara	Pualaca Orlala
from humic organic matter		Aliambata-2	Aliambata(1926)
M = mixed gas (d - deep, s - shallow)		Atelele	Lubutara

- Gases plot in three main groups:
  - Mature dry (-ish) gas
  - Less mature but drier gas
  - Isotopically light gas (?biogenic)

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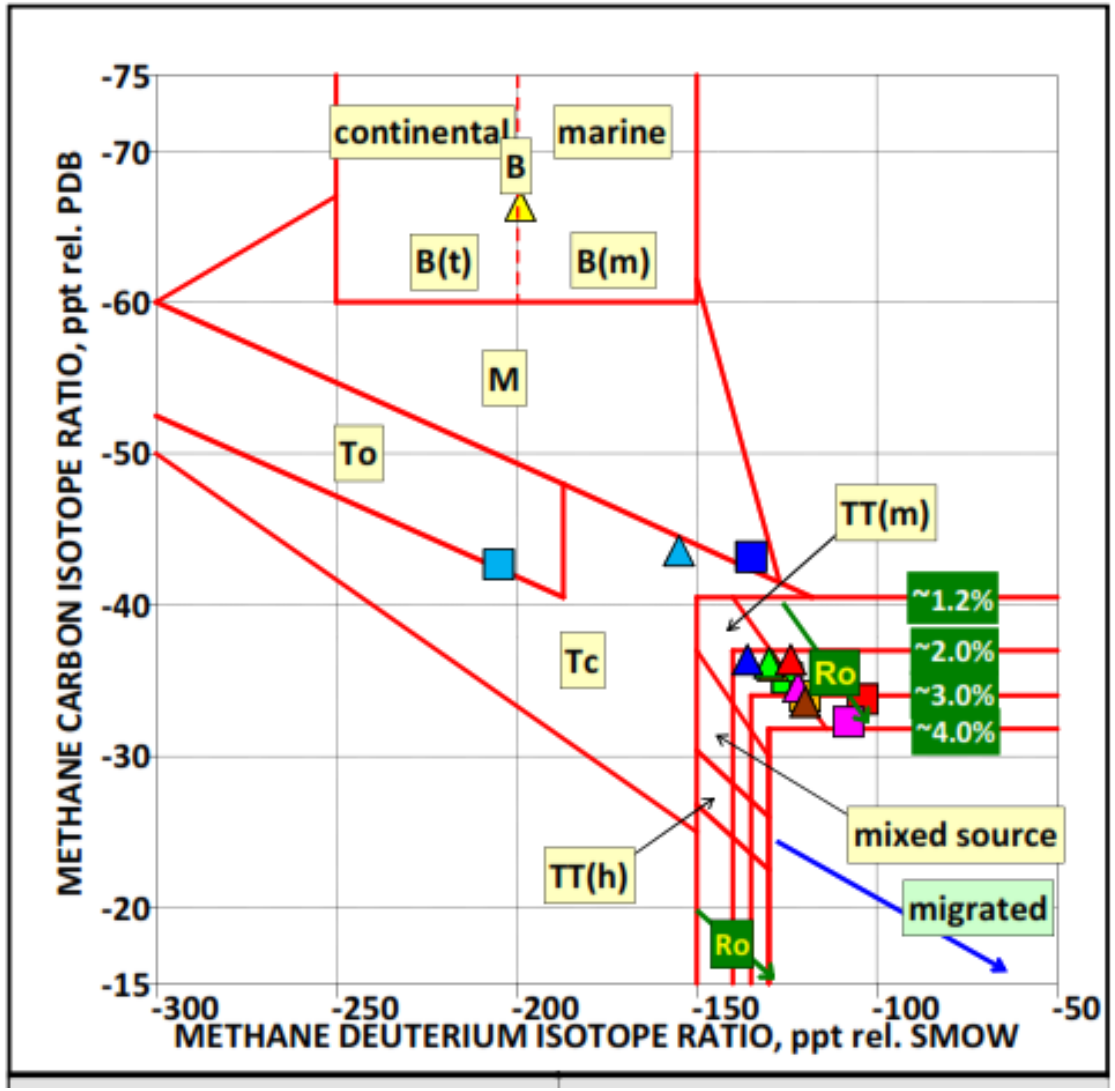
Gas Origin – CI Methane vs DI Methane



COMMENTS	KEY	
B = biogenic gas (m - marine, t - terrestrial environments)	Kulit	Weimarok
To = oil-associated, Tc = Condensate associated	Waimaruk-2	Hol Meser-1
TT(m) = nonassociated dry gases from sapropel	Hol Meser-2	Galitas-1
TT(h) = nonassociated dry gases from humic organic matter	Mol Houlu	Buiho
M = mixed gas	Wairara	Pualaca Orlala
	Aliambata-2	Aliambata (1926)
	Atalele	Lubutara

- Gases plot in three main groups:
  - Mature dry (-ish) gas from postmature oil source
  - Early gas window (but dry) gas
  - Isotopically light gas (?biogenic)

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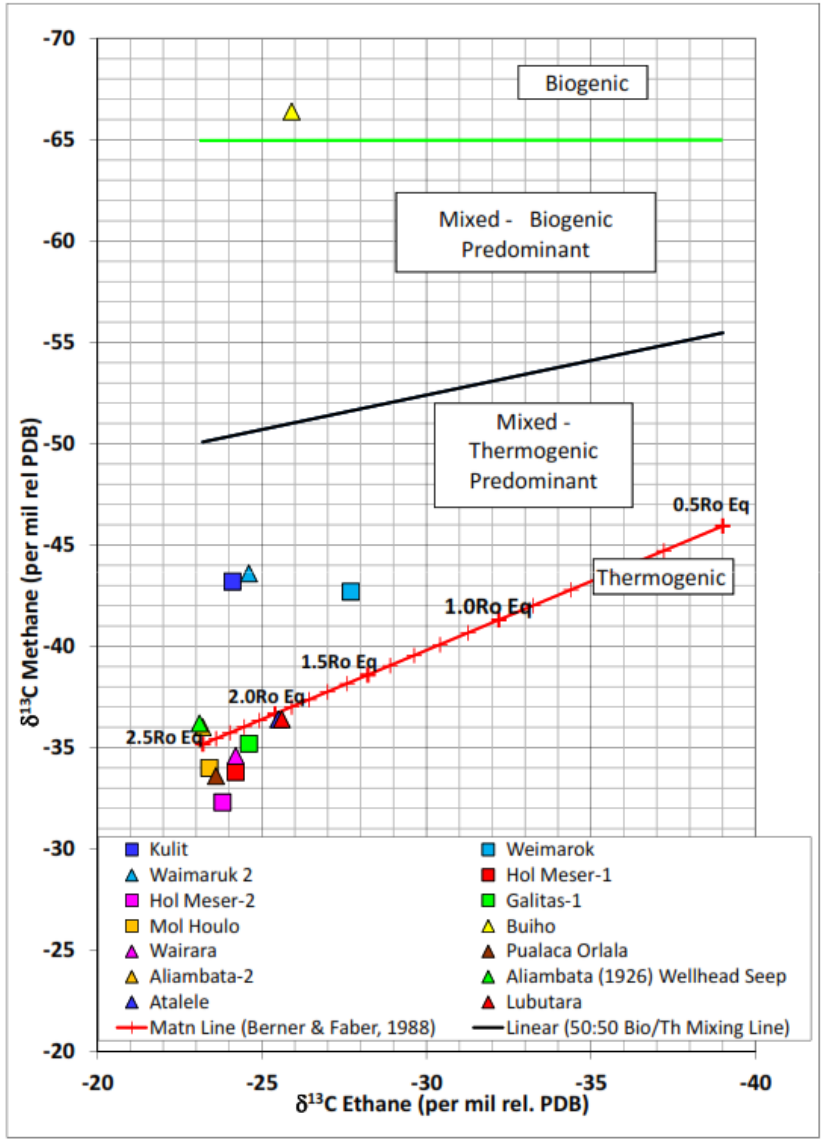
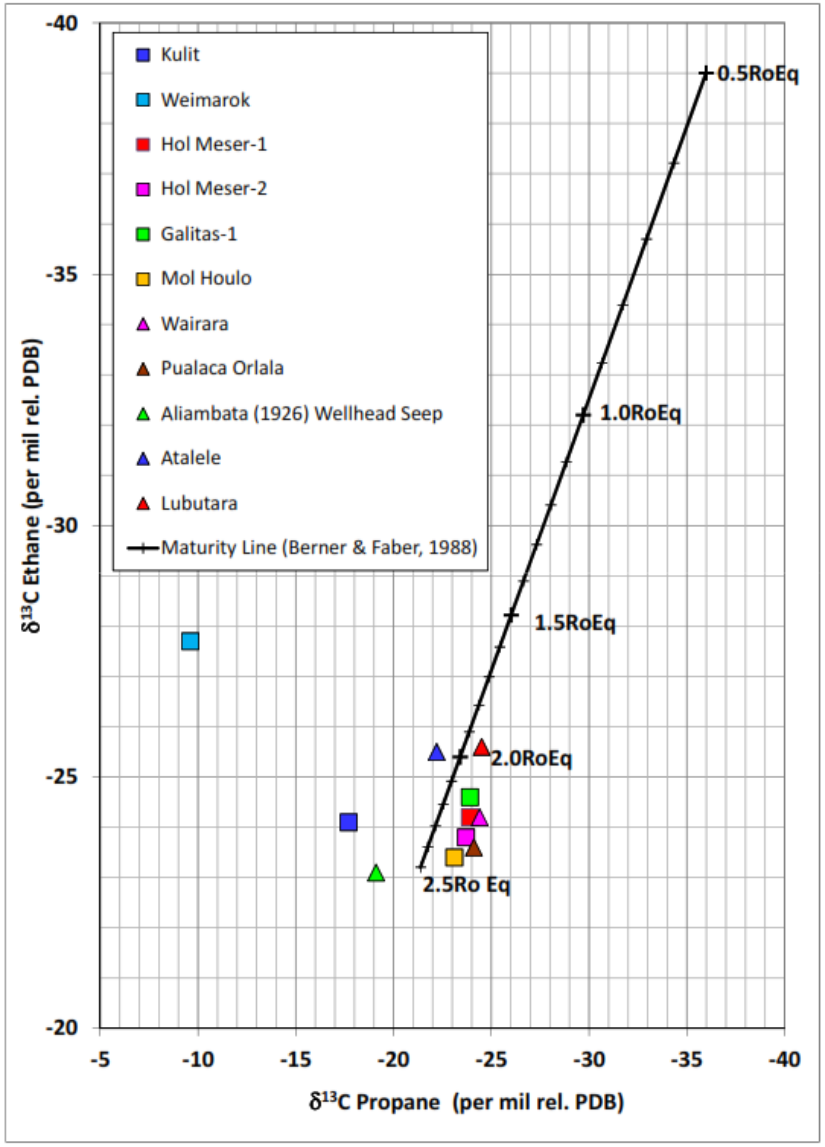
Gas Origin – CI for methane, ethane and propane



Carbon isotope plots confirm the presence of:

- Main group of gases generated from a highly mature (1.8-2.5%Ro) sapropelic source (Type I). Lower wet gas content observed where CO_2-enriched
- A family of dry gases in the Suai Basin (Type II). These:
  - Contain isotopically heavy propane (-19 to -7 per mil)
  - Are enriched in carbon dioxide (2-9%)
  - Exhibit isotopically-heavy carbon dioxide (-4 to +22 per mil)

  These gases are thought to be associated with mud volcanoes and may result from anaerobic biodegradation of migrating or reservoired petroleum and secondary methanogenesis
- Isotopically light gas (possibly biogenic) identified at Buiho (Type III)
- Isotopically-heavy carbon dioxide is common in the seep gases



Regional Distribution of Gas Types

- Type I (mature dryish gases) show a very similar distribution to the Group B oils and are probably associated with Triassic or Permian source rocks
- Type II - (mud-volcano associated gases derived from anaerobic biodegradation of petroleum, and secondary methanogenesis) are restricted to Suai Basin
- Type III (? biogenic gas) – unusual to find biogenic gas in this geological setting

Conclusions

- Hydrocarbon indications are common onshore Timor Leste and their analysis confirms the presence of at least two, and possibly three, active petroleum systems:
  - Late Triassic (Norian – Rhaetian) calcareous shales and limestones have generated the Type B oils identified in central and eastern Timor Leste. The oil sub-groups identified are though to represent stratigraphic/facies variations within this source sequence
  - A source has not been identified for the Type A oils within the Suai Basin. Based on the heavier carbon isotope values an older Middle-Late Triassic or possibly early Triassic sequence is proposed
  - Mature dry gases identified in central and eastern Timor Leste show a similar distribution to the Type B oils but are more likely to be sourced from older (Early Triassic or Permian) rocks due to the high maturity levels indicated
  - Dry gases in the Suai Loro Basin exhibit unusual compositions and are believed to be associated with mud volcanoes in the area and result from anaerobic degradation/secondary methanogenesis of petroleum
- More work was/is planned to
  a) build the hydrocarbon database
  b) collect more and better source rock samples and tie down the ages of these sections using palynology

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