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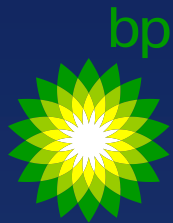
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The Fracts of Life



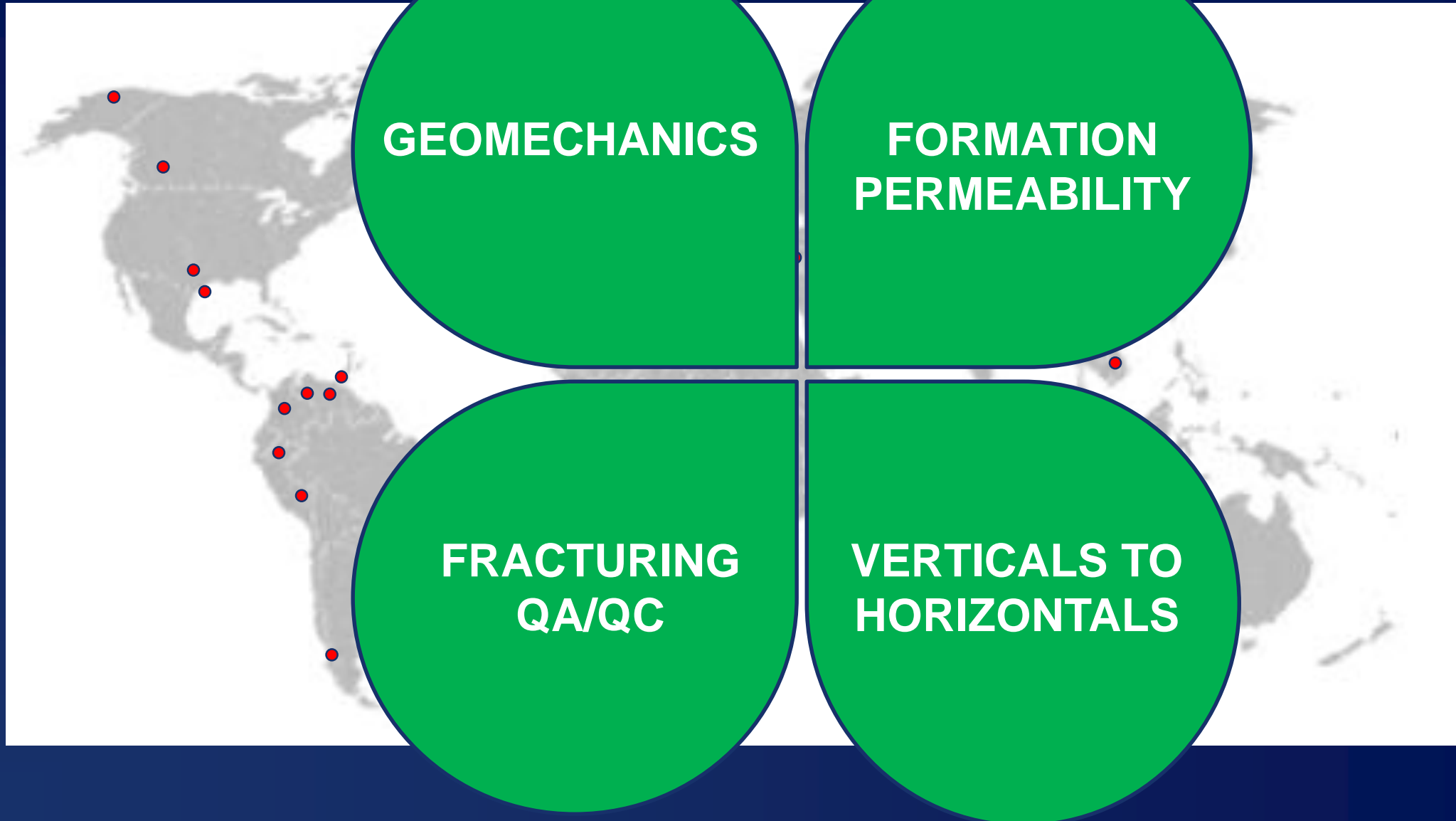
Martin Rylance



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THE “FRACTS” OF LIFE

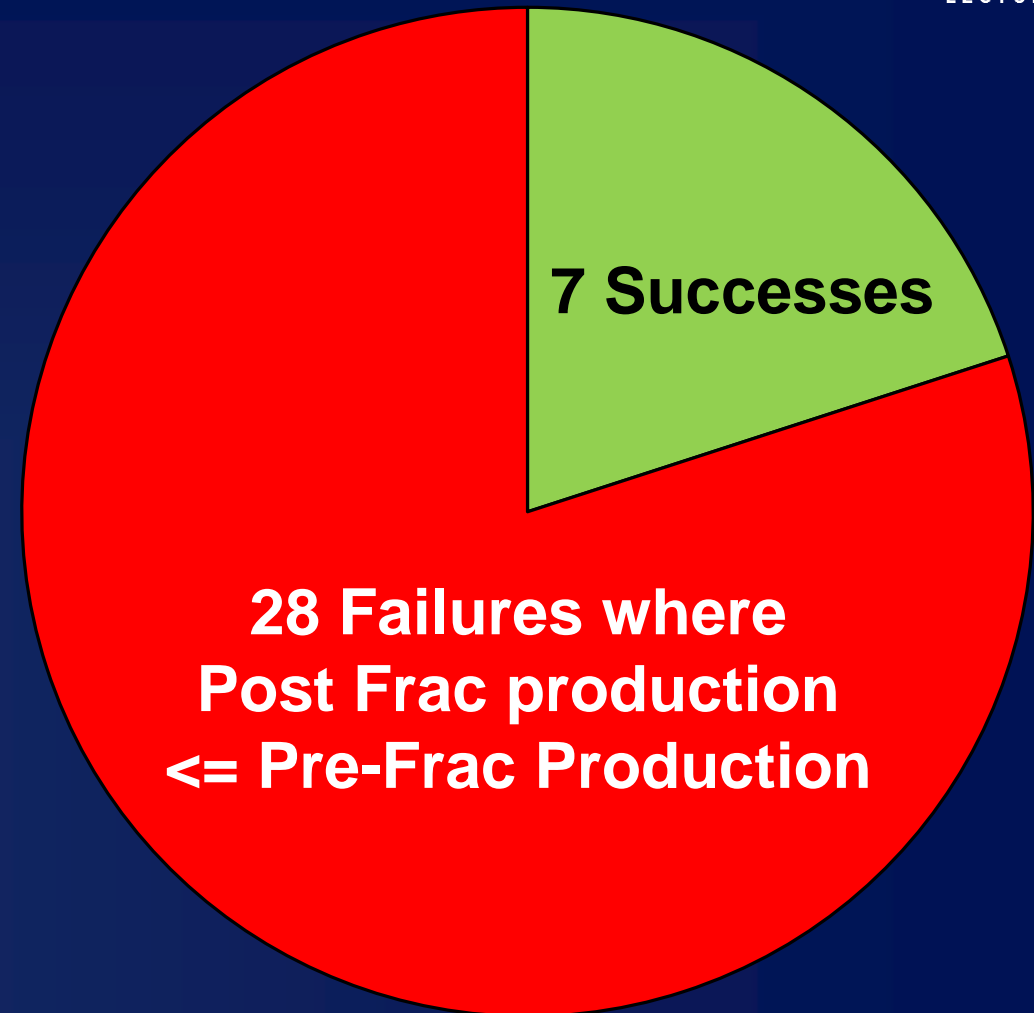
Key Aspects



THE “FRACTS” OF LIFE Geo-Mechanics “Issue”

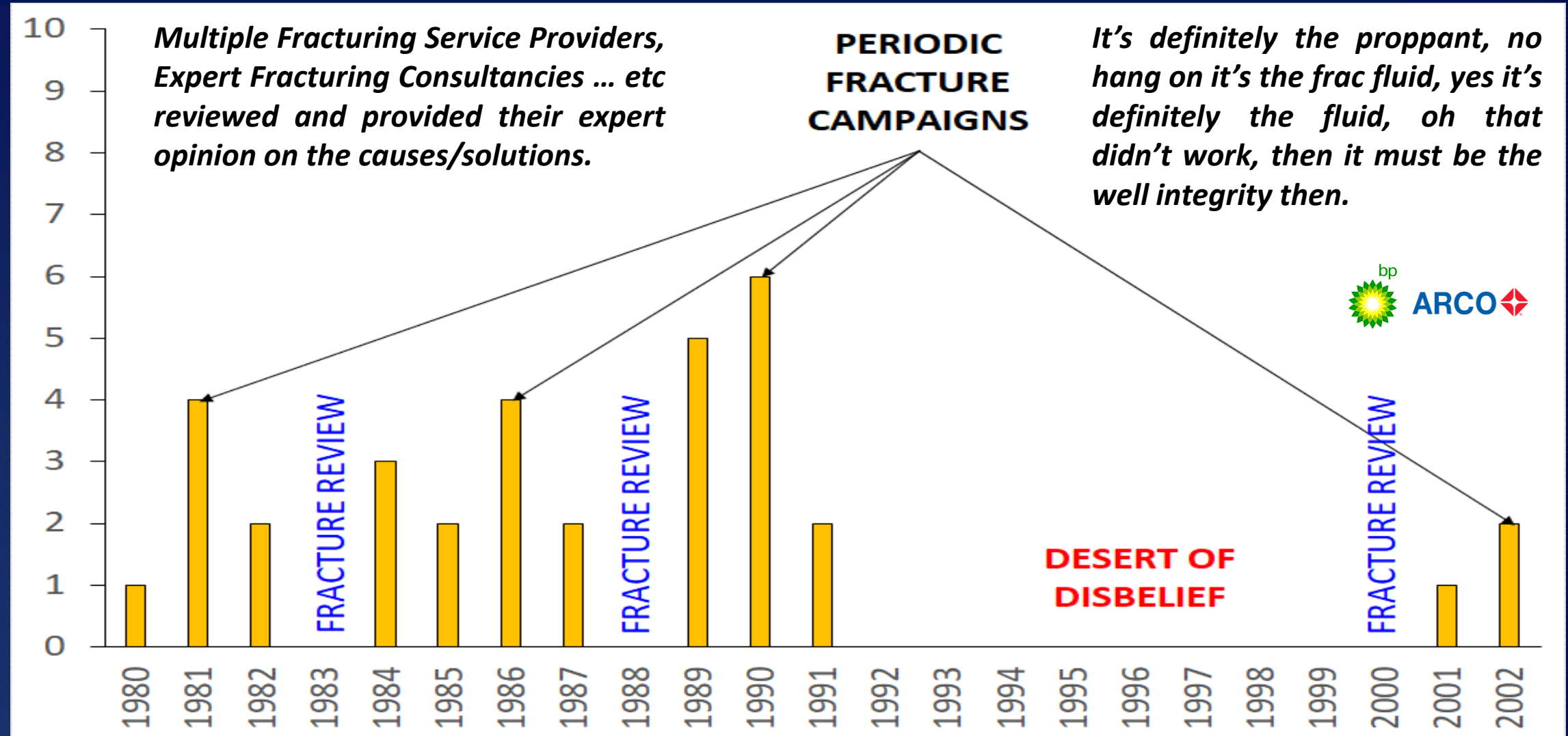
Non-Operated JV in South-East Asia

- Multi-layered sands (1,000 – 14,000 ft)
- Produced 13.1 Tcf and 0.4 Bbls liquids
- Deep tight-sand opportunity 0.75 Tcf
- Application of hydraulic Frac technique
- Some 30 years of attempted fracturing
- **Spectacularly** unsuccessful campaign



THE “FRACTS” OF LIFE

Geo-Mechanics “Issue”



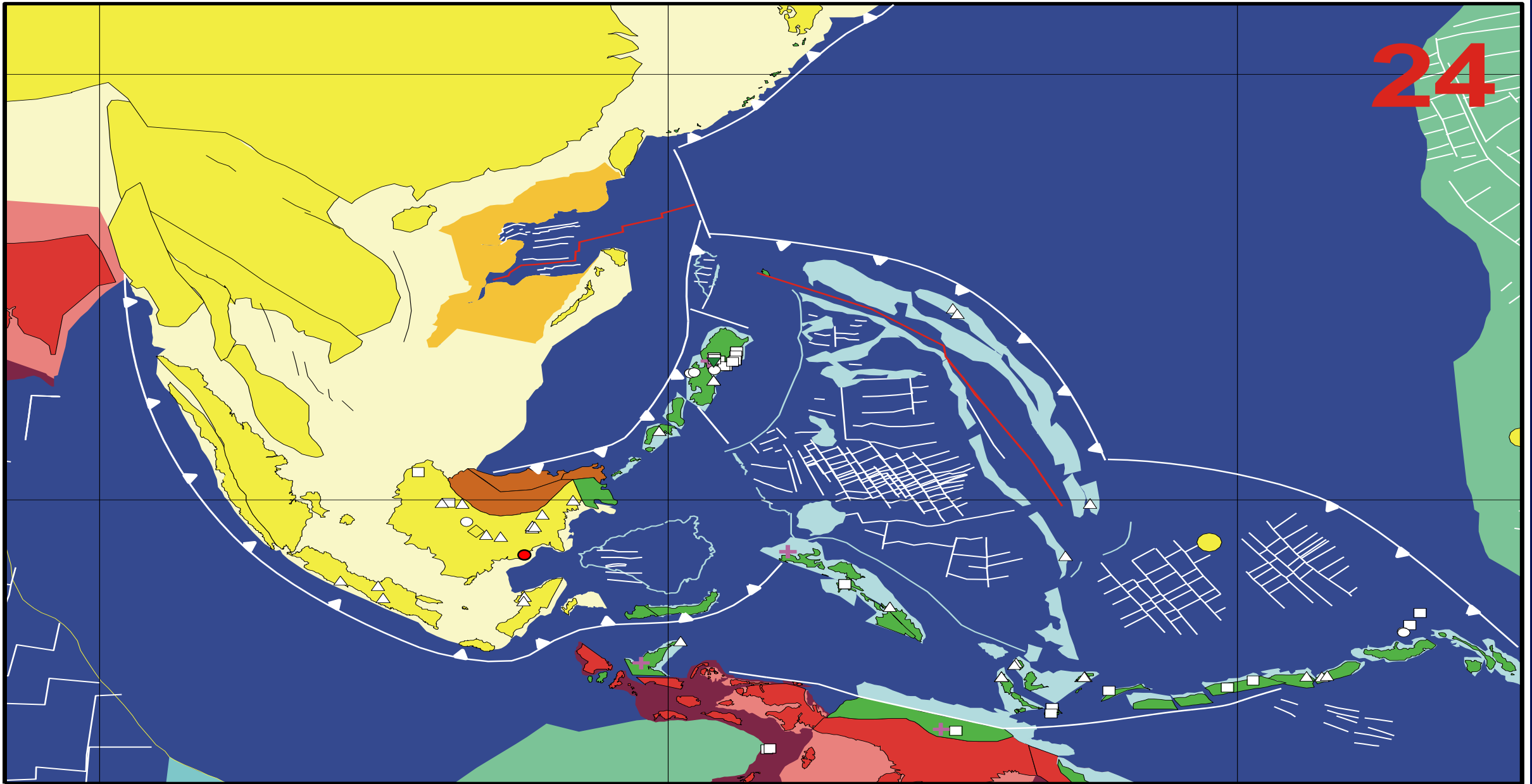
THE “FRACTS” OF LIFE Geo-Mechanics “Issue”

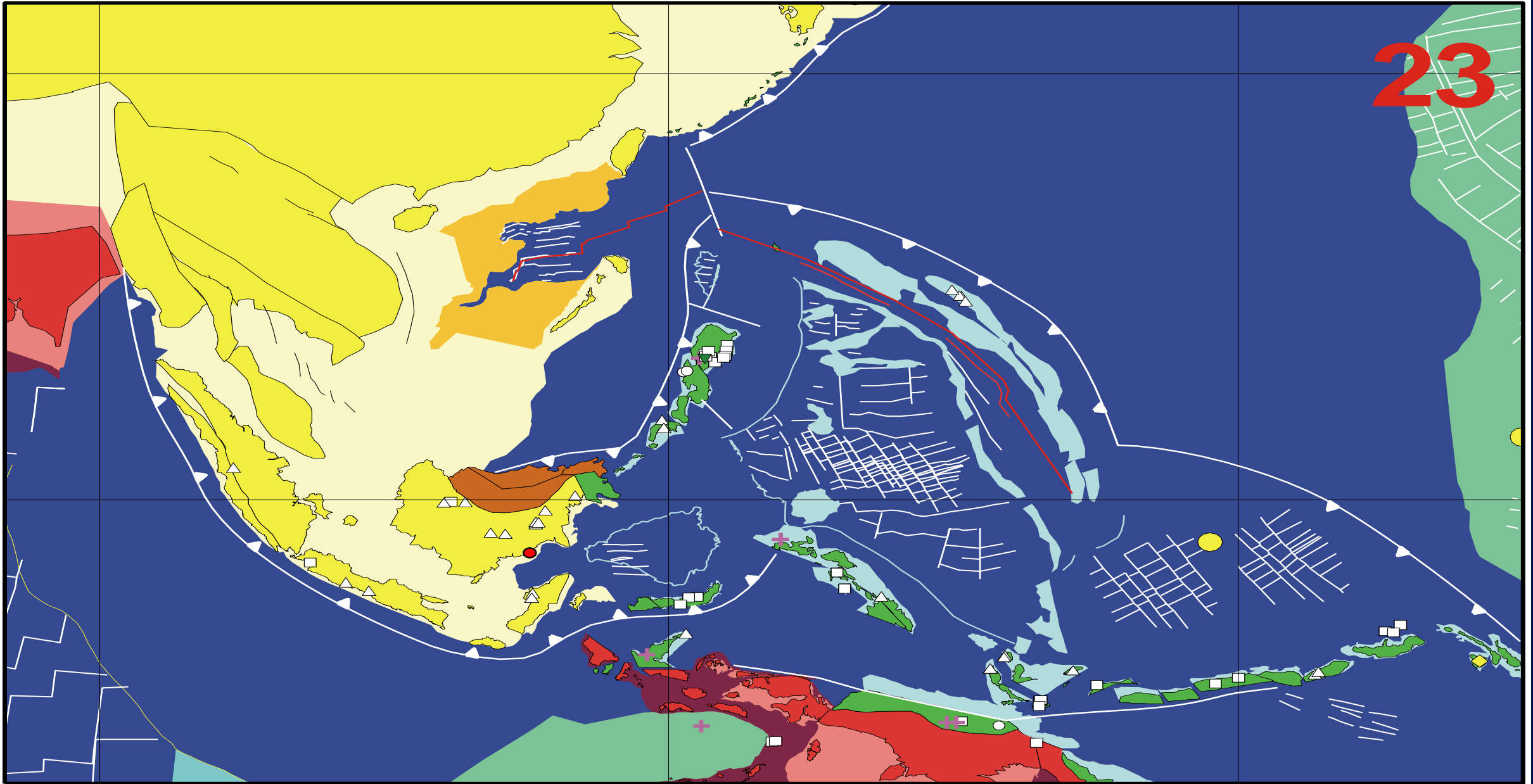
Independent Frac Reviews Indicated:

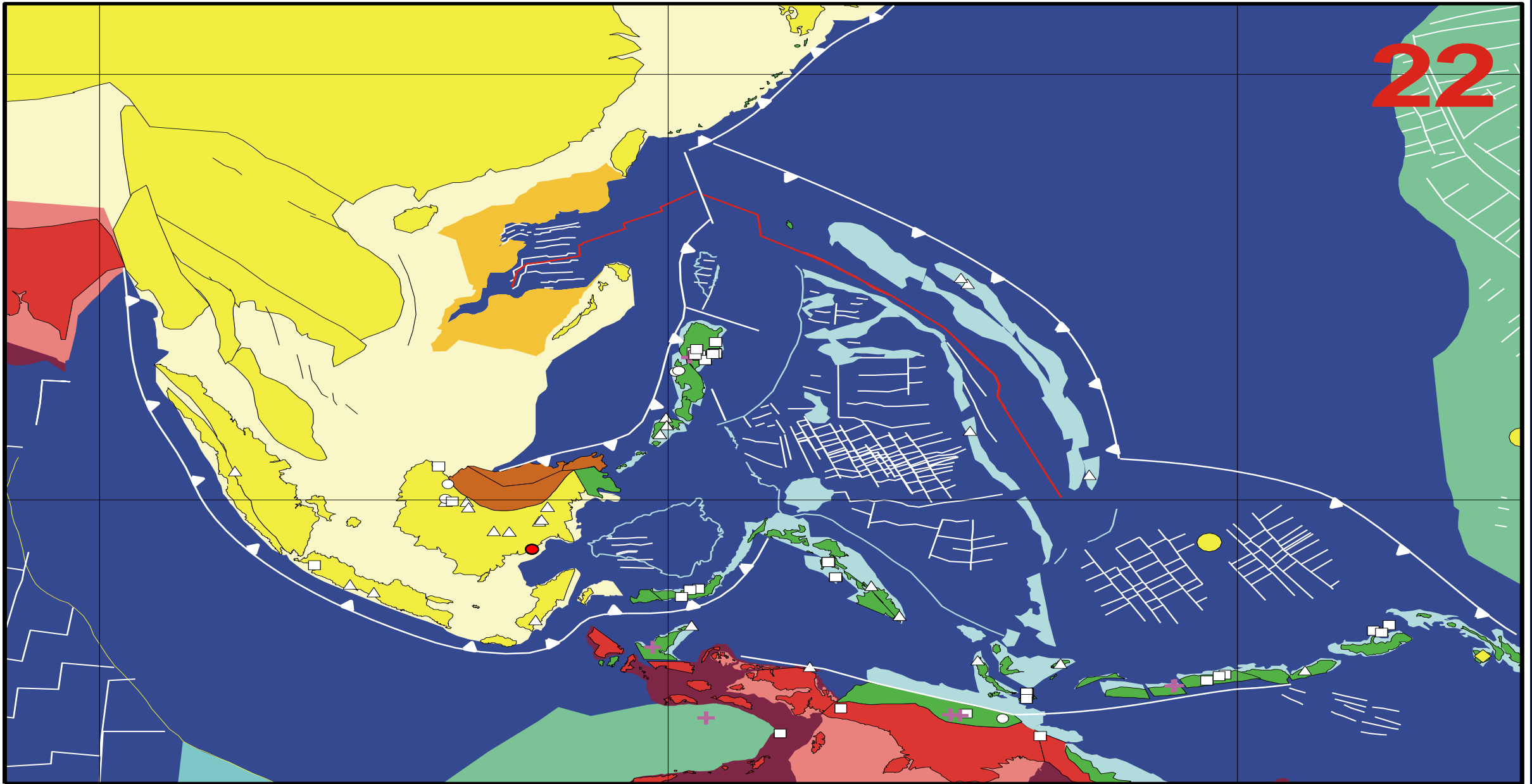
- Poor fracturing fluid QA/QC (55 lb/Tg)
- Poor proppant quality/excessive crush
- Poor well design and casing integrity

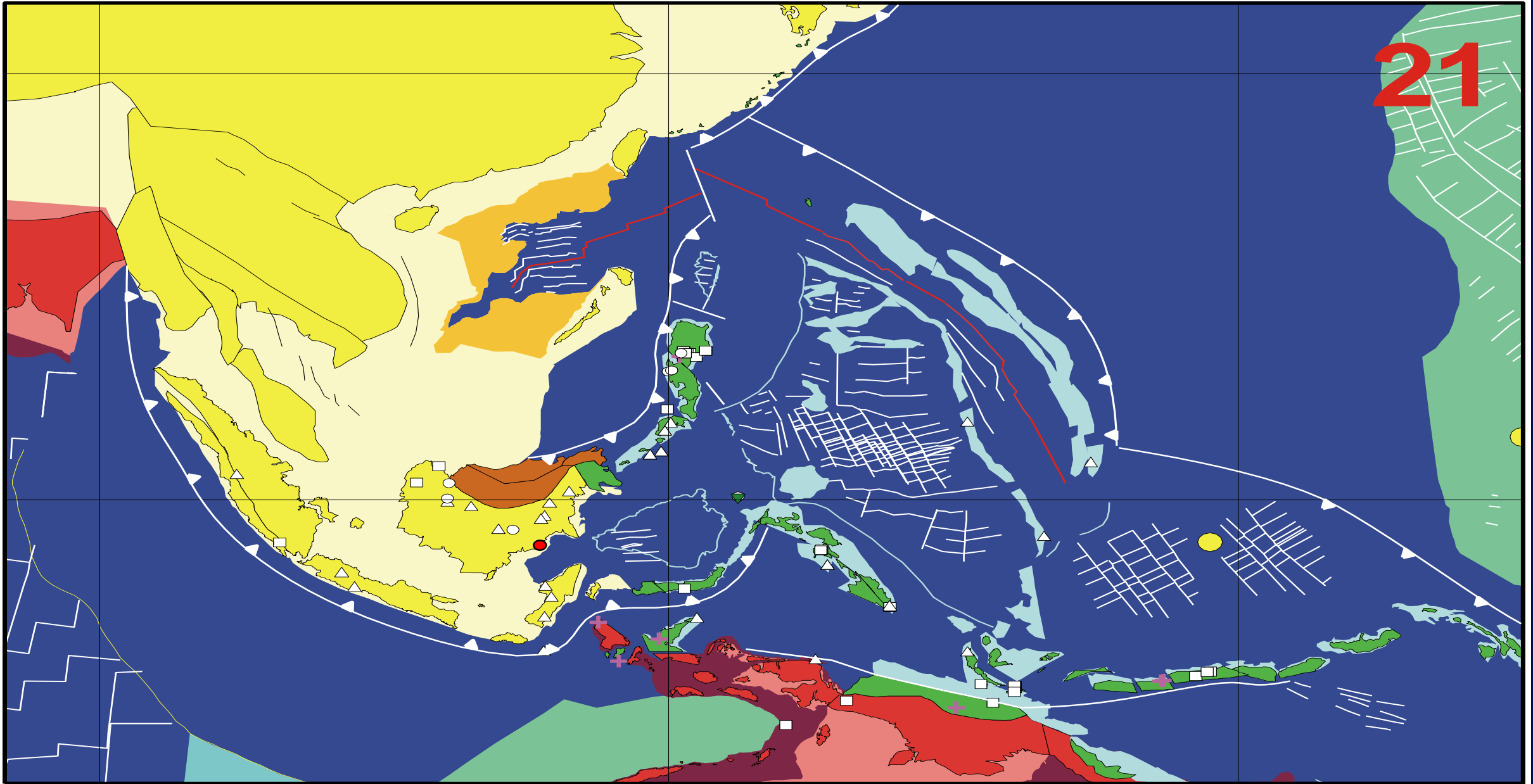
However, each subsequent Campaign would deliver an equivalent cycle of Review, Absolute Certainty of the Root-Cause, Execution, Failure, Pause and then “rinse and repeat”.

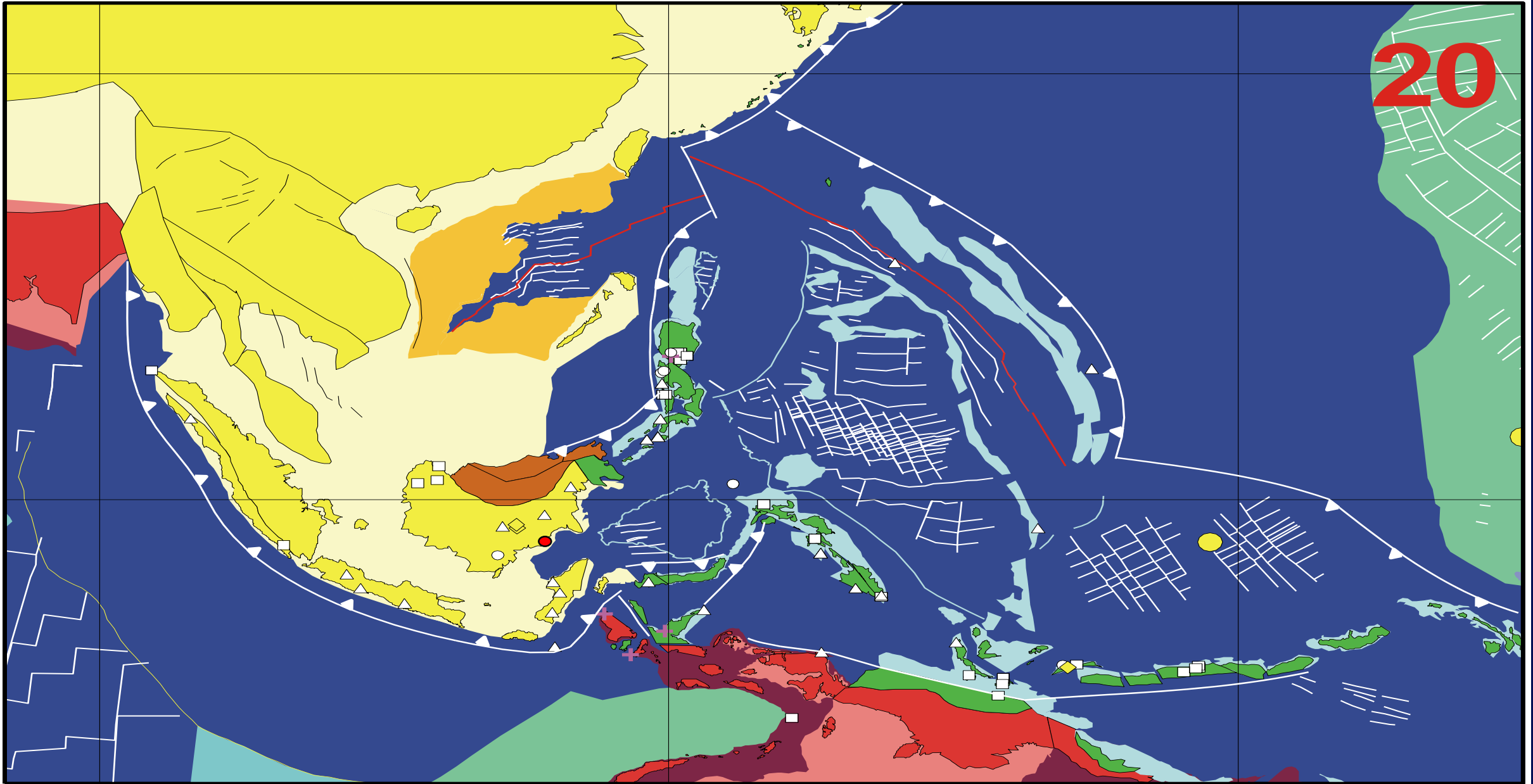


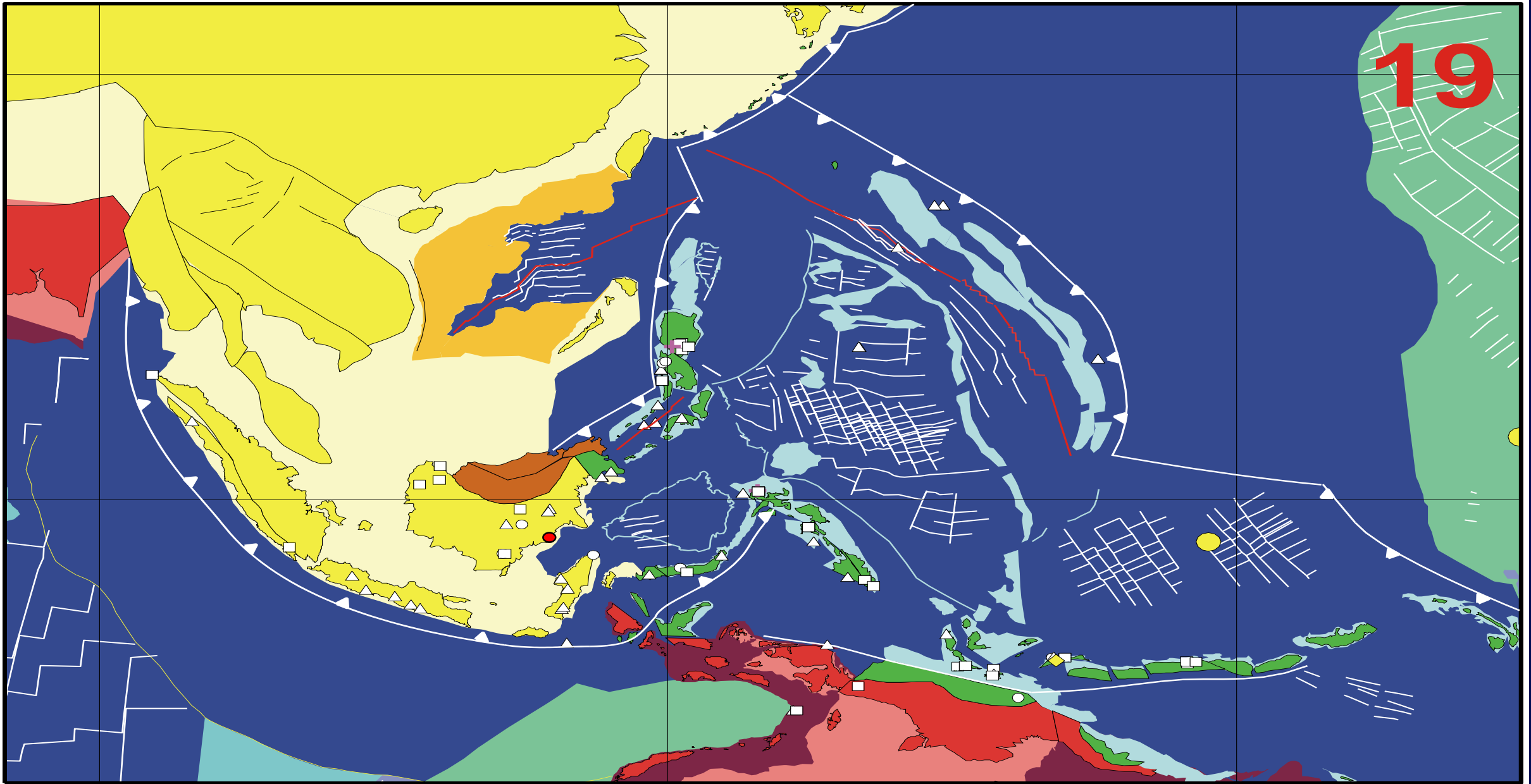




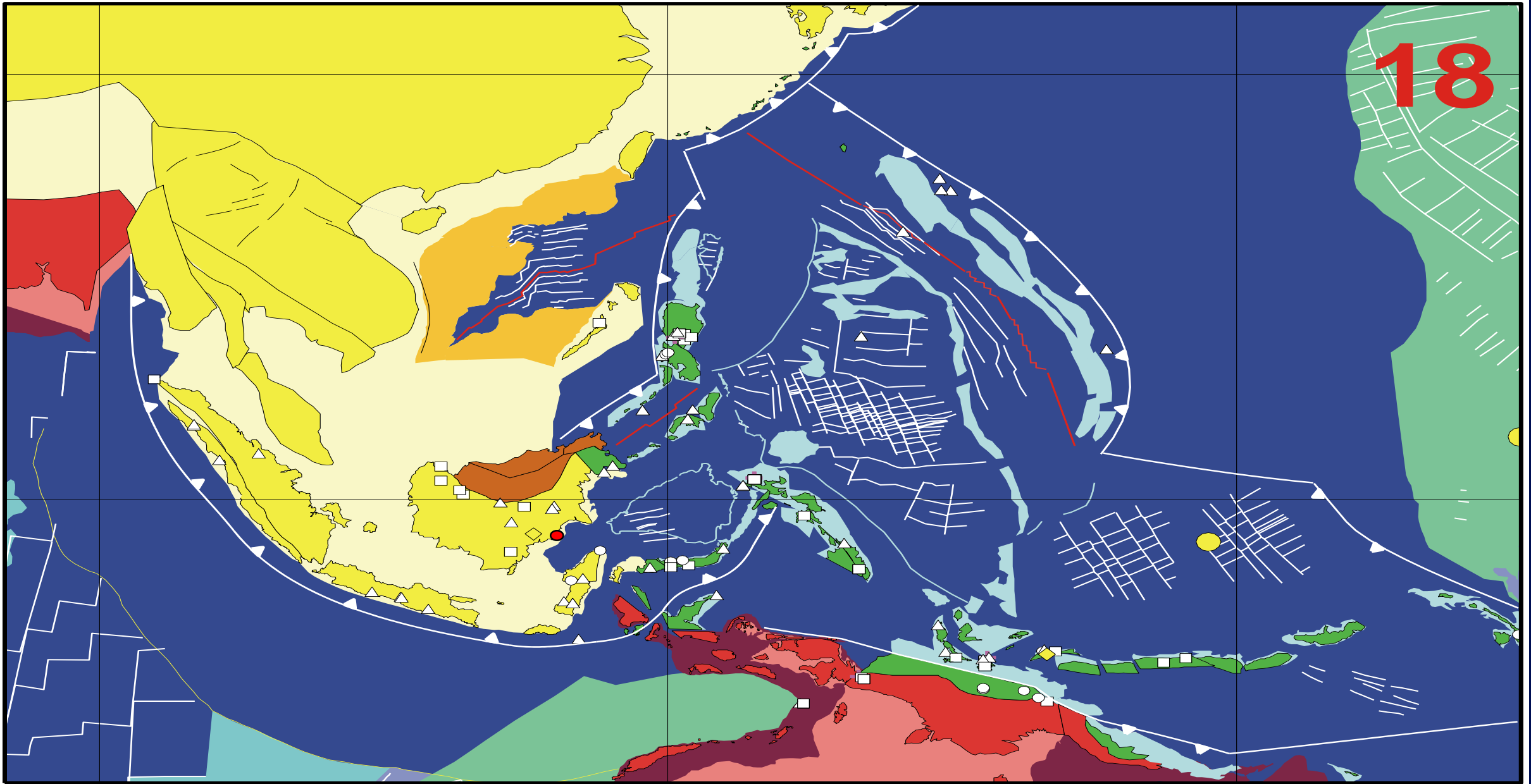




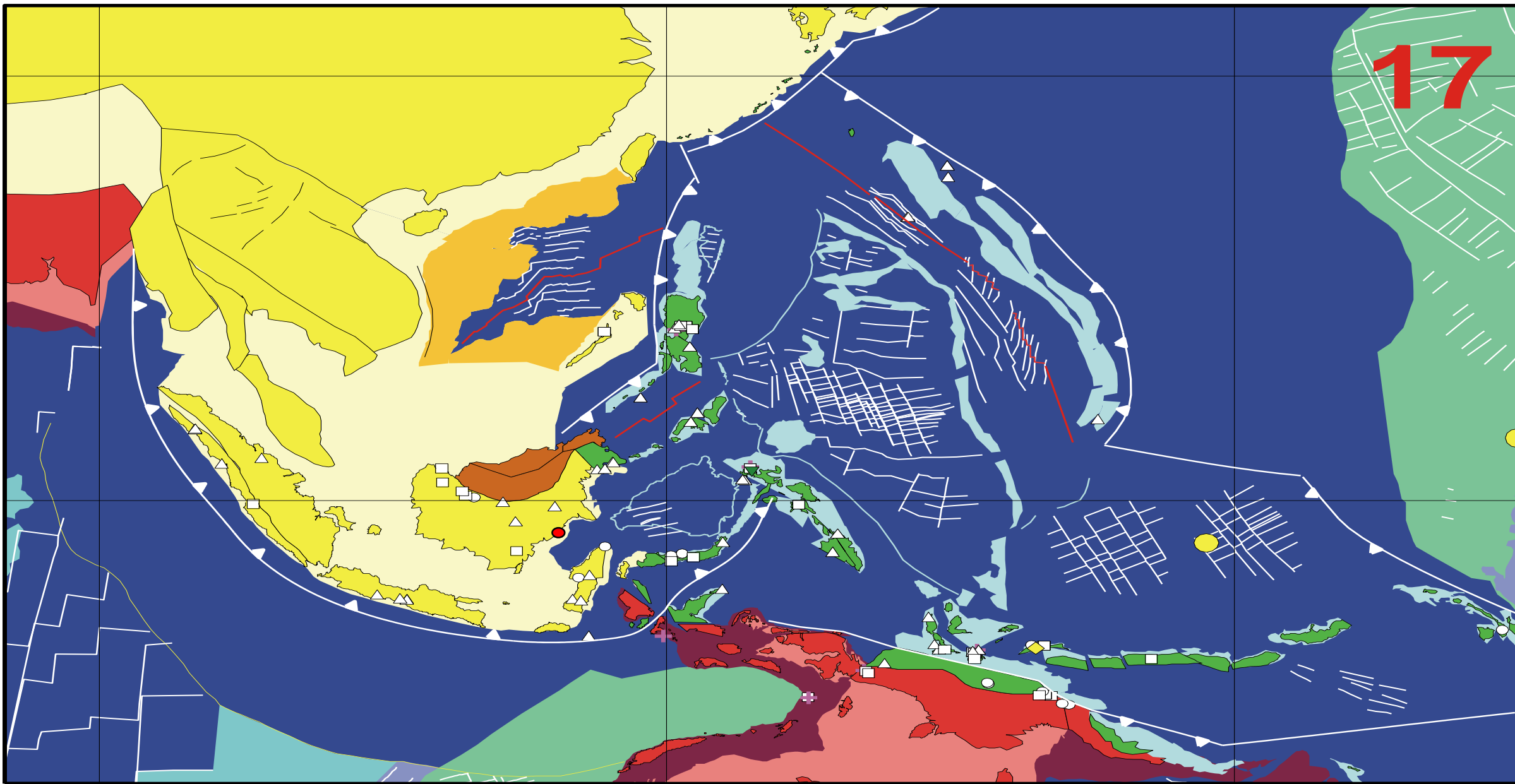




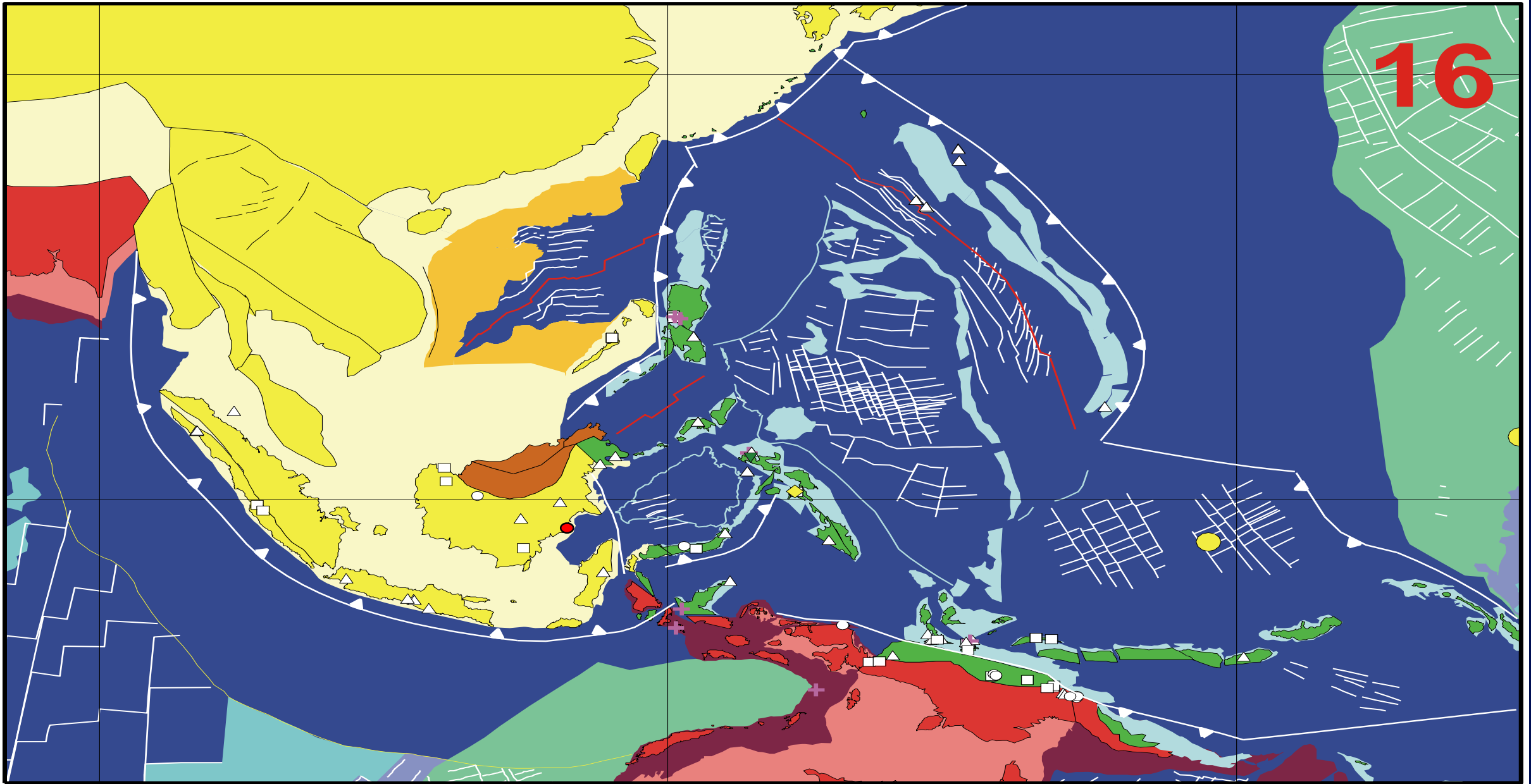
Hall, R. 2002. Cenozoic geological and plate tectonic evolution of SE Asia and the SW Pacific



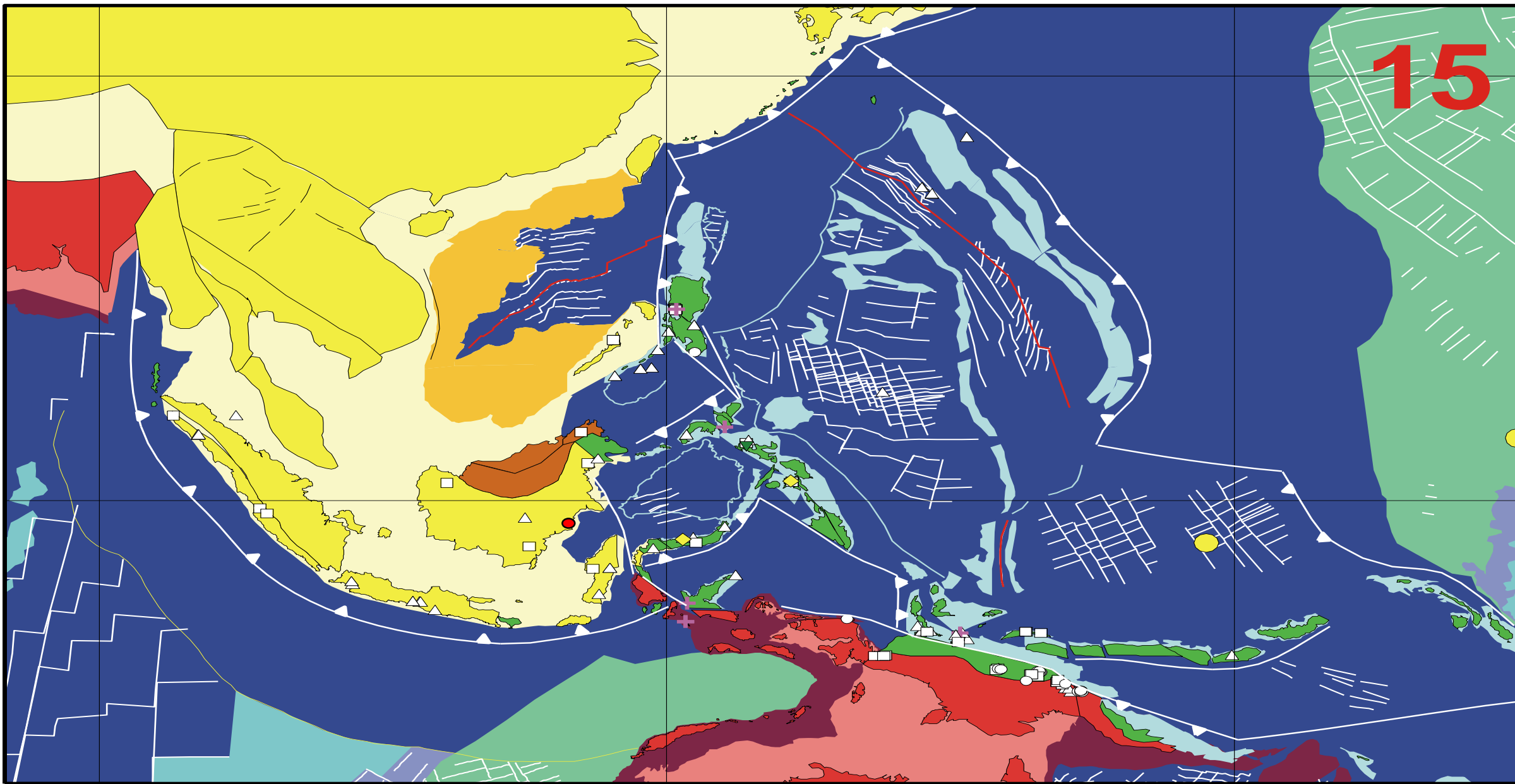
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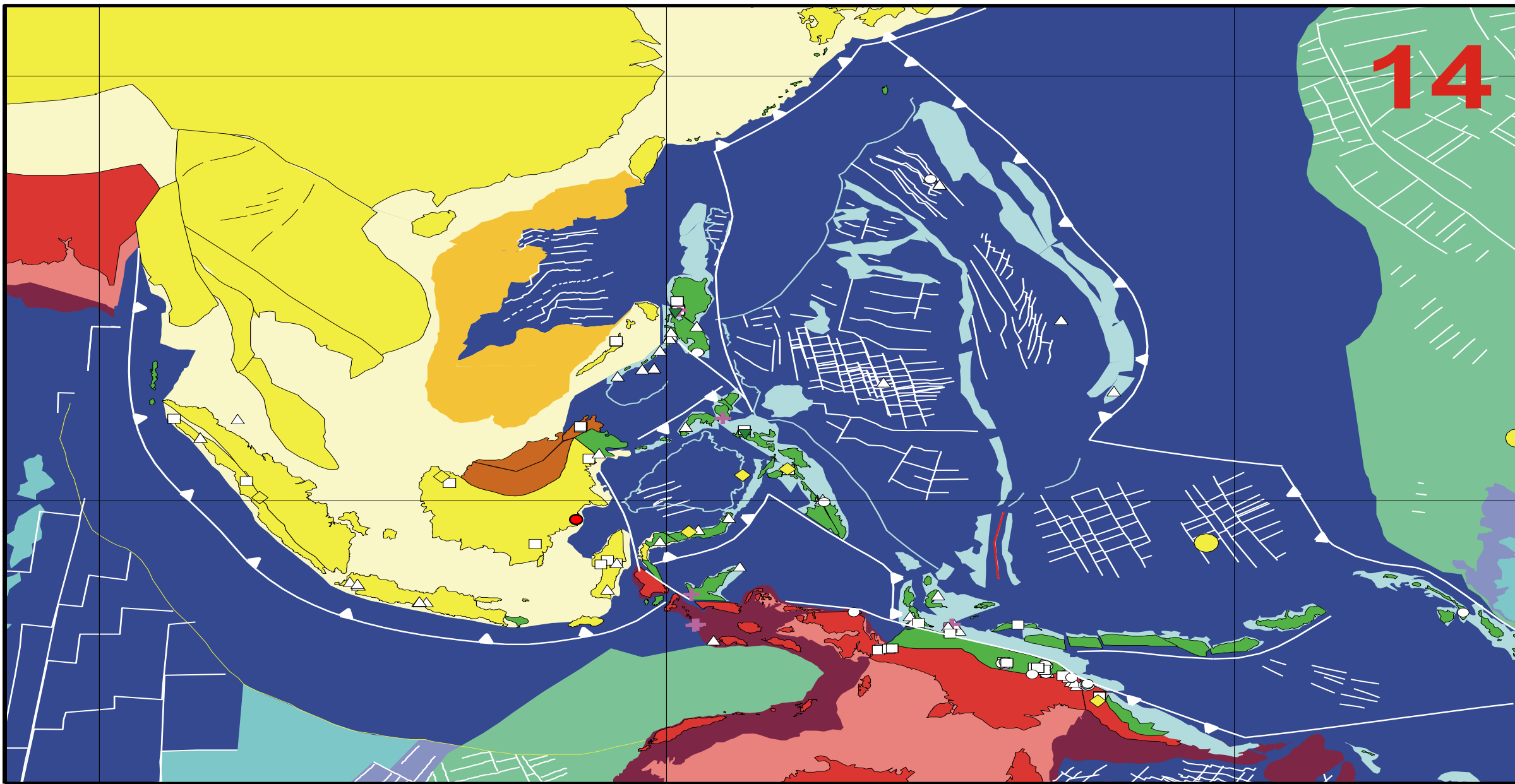
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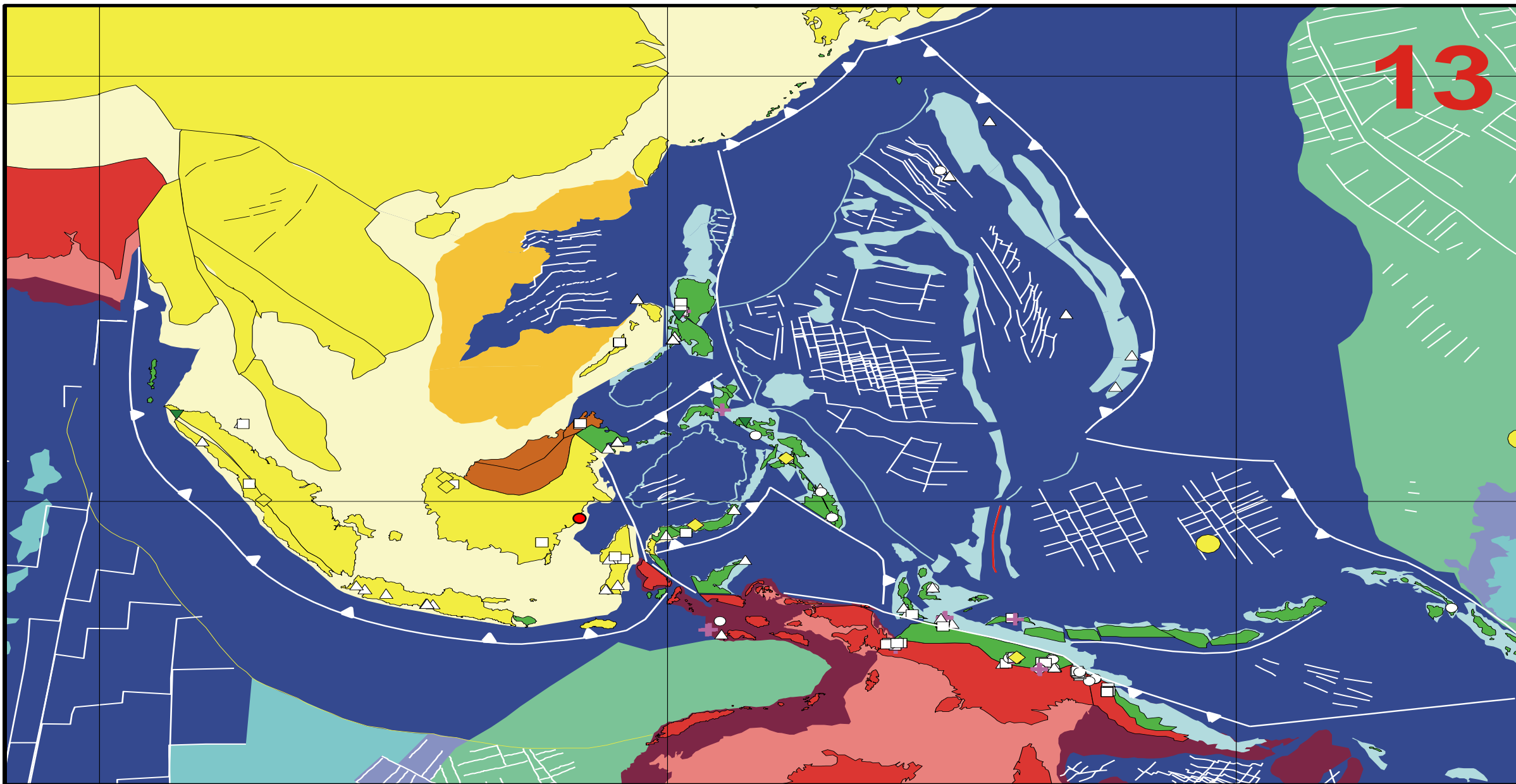
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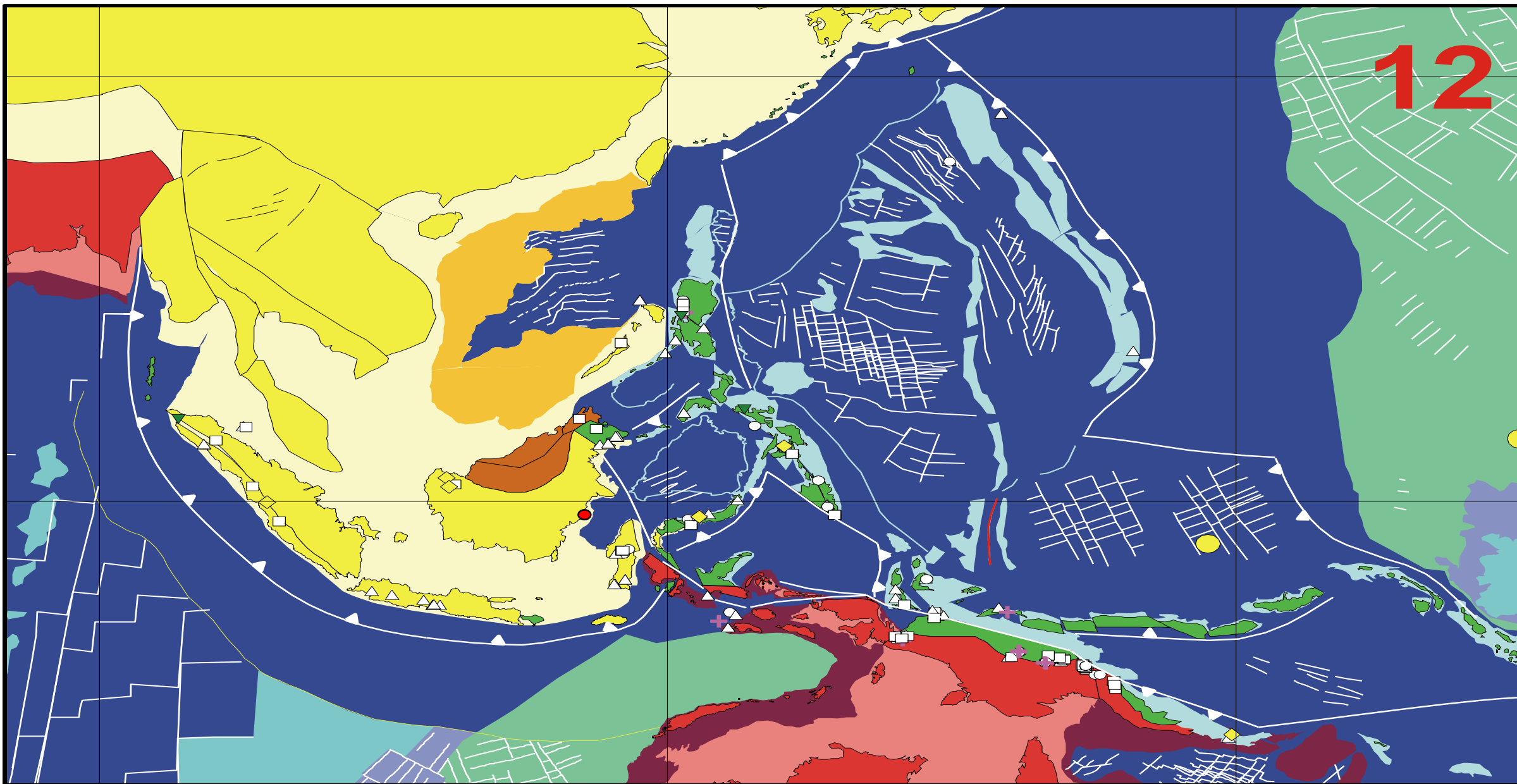
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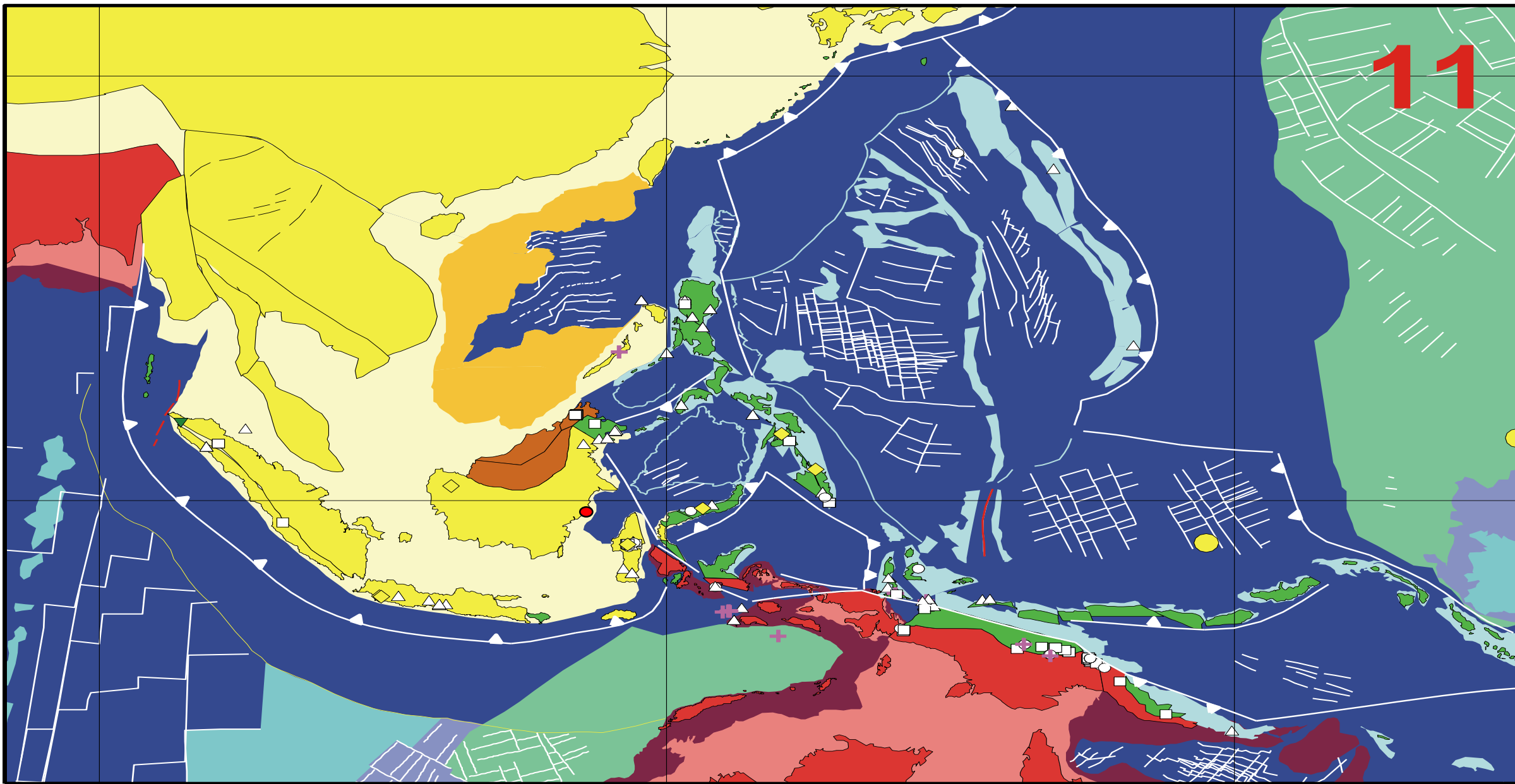
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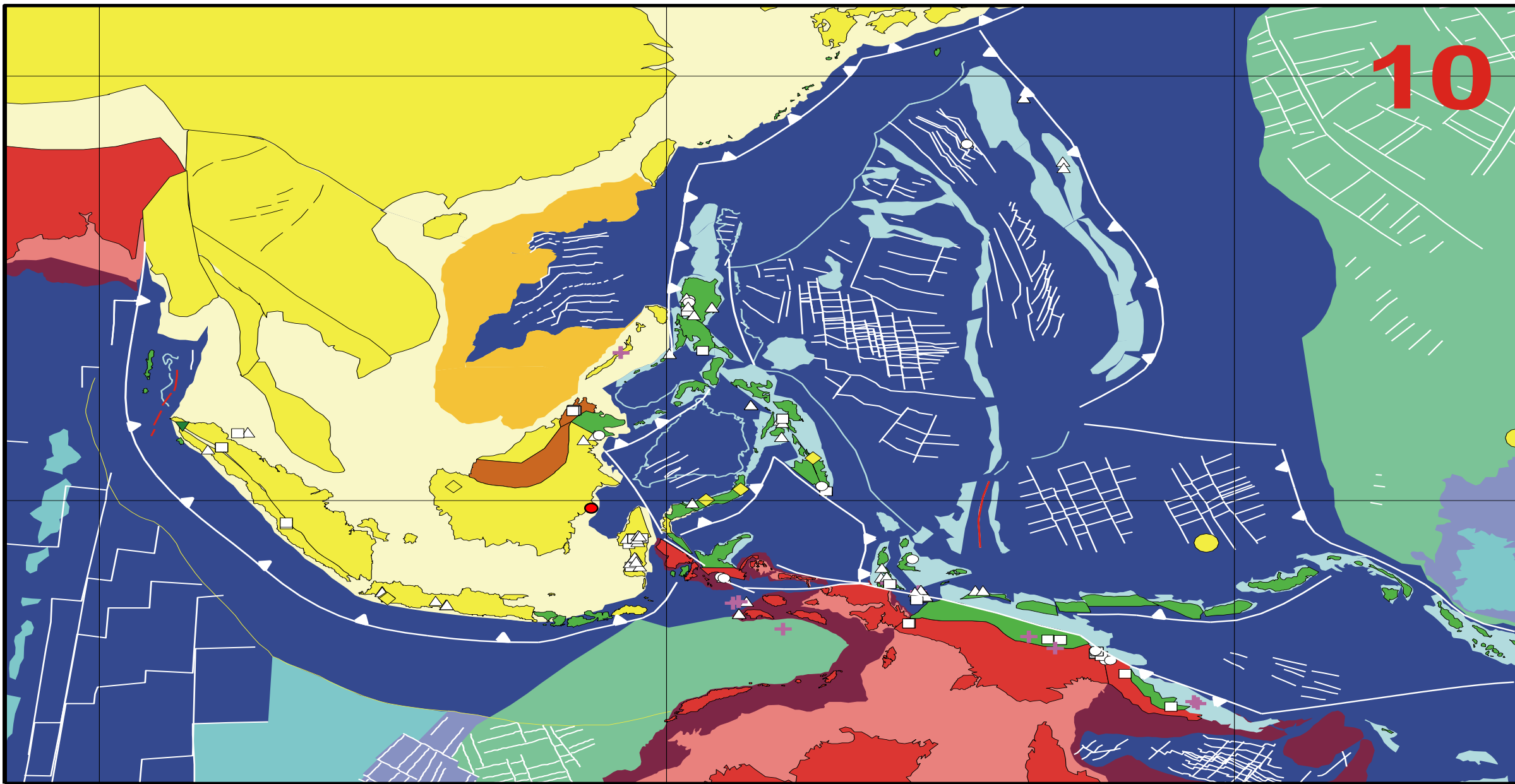
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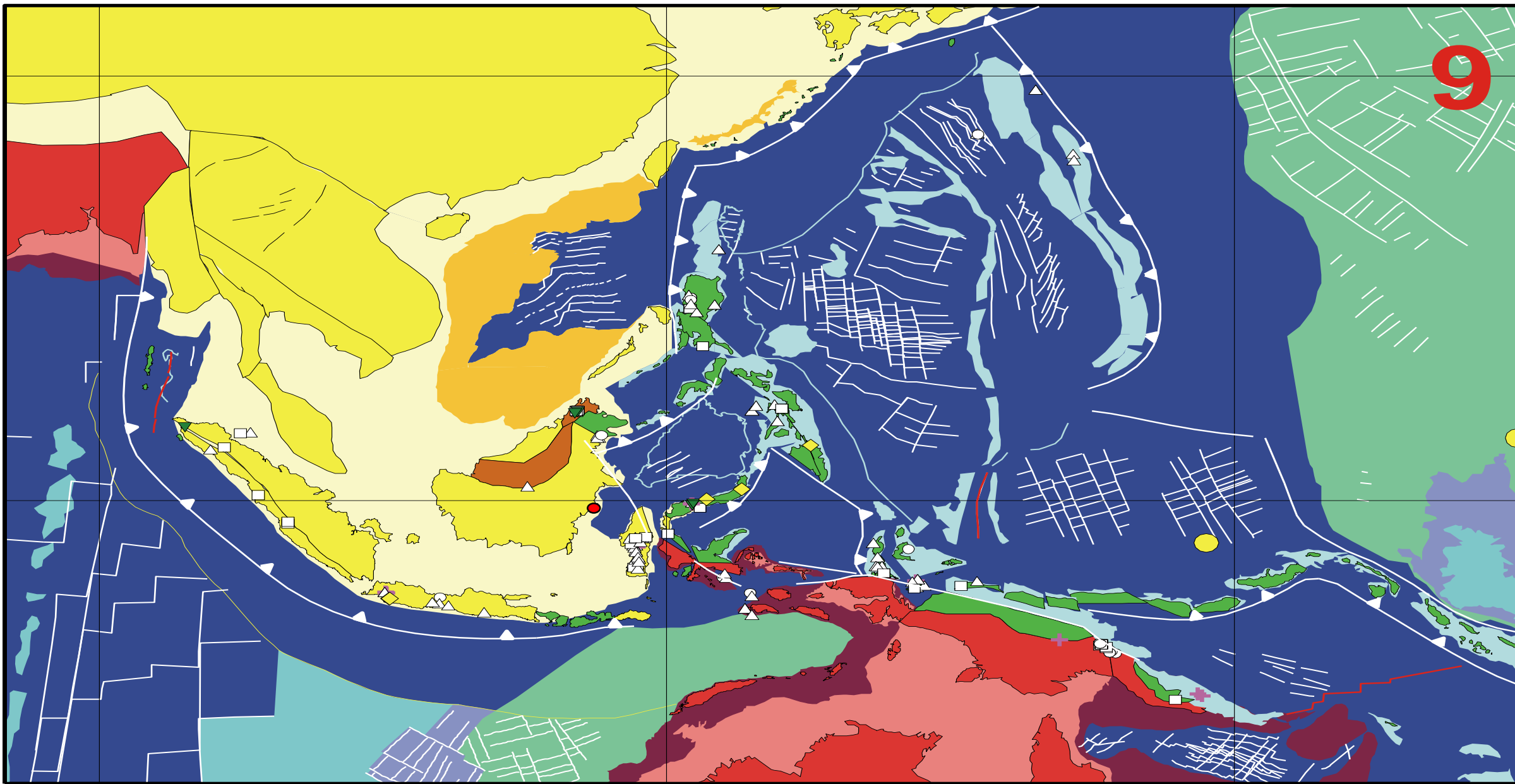
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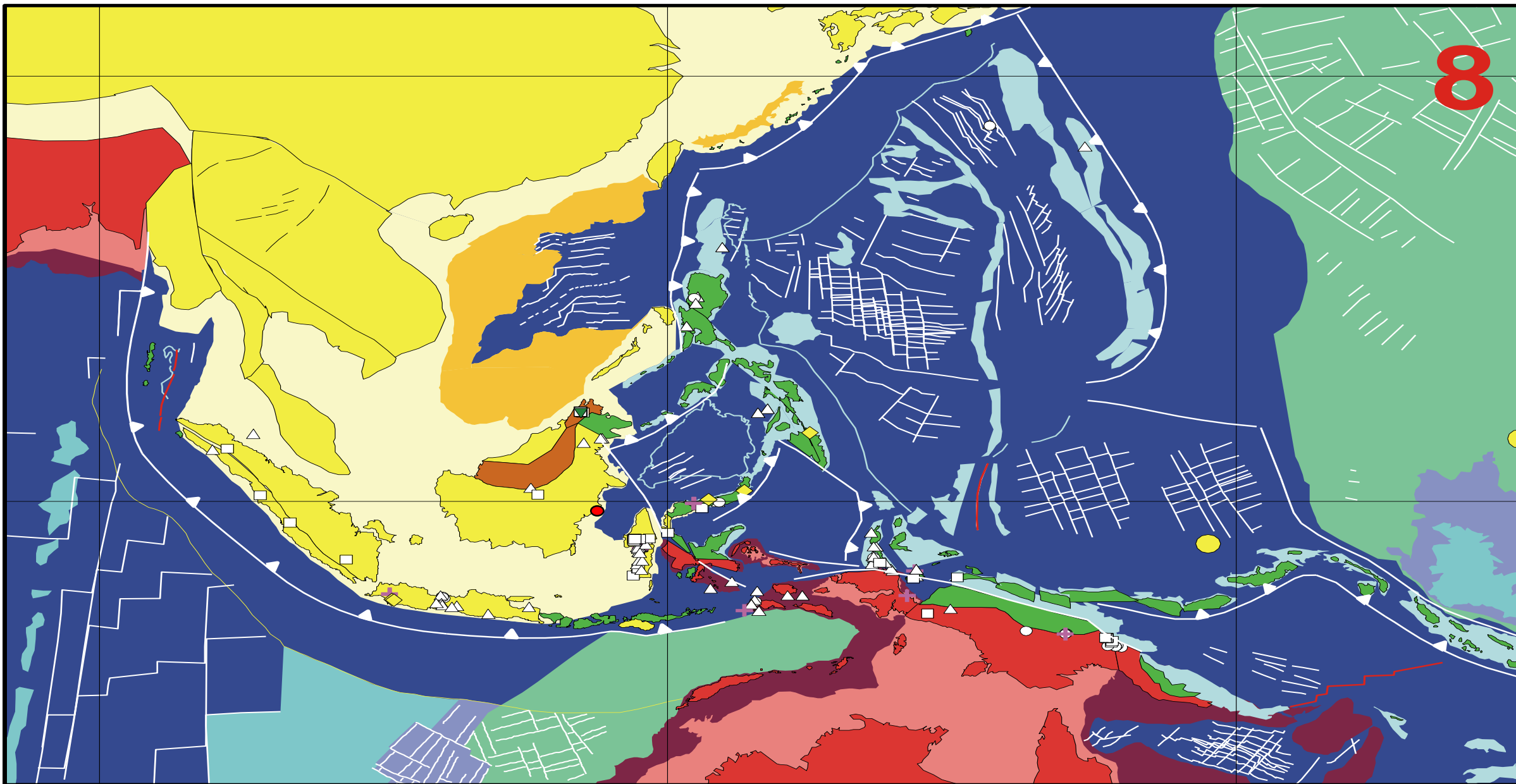
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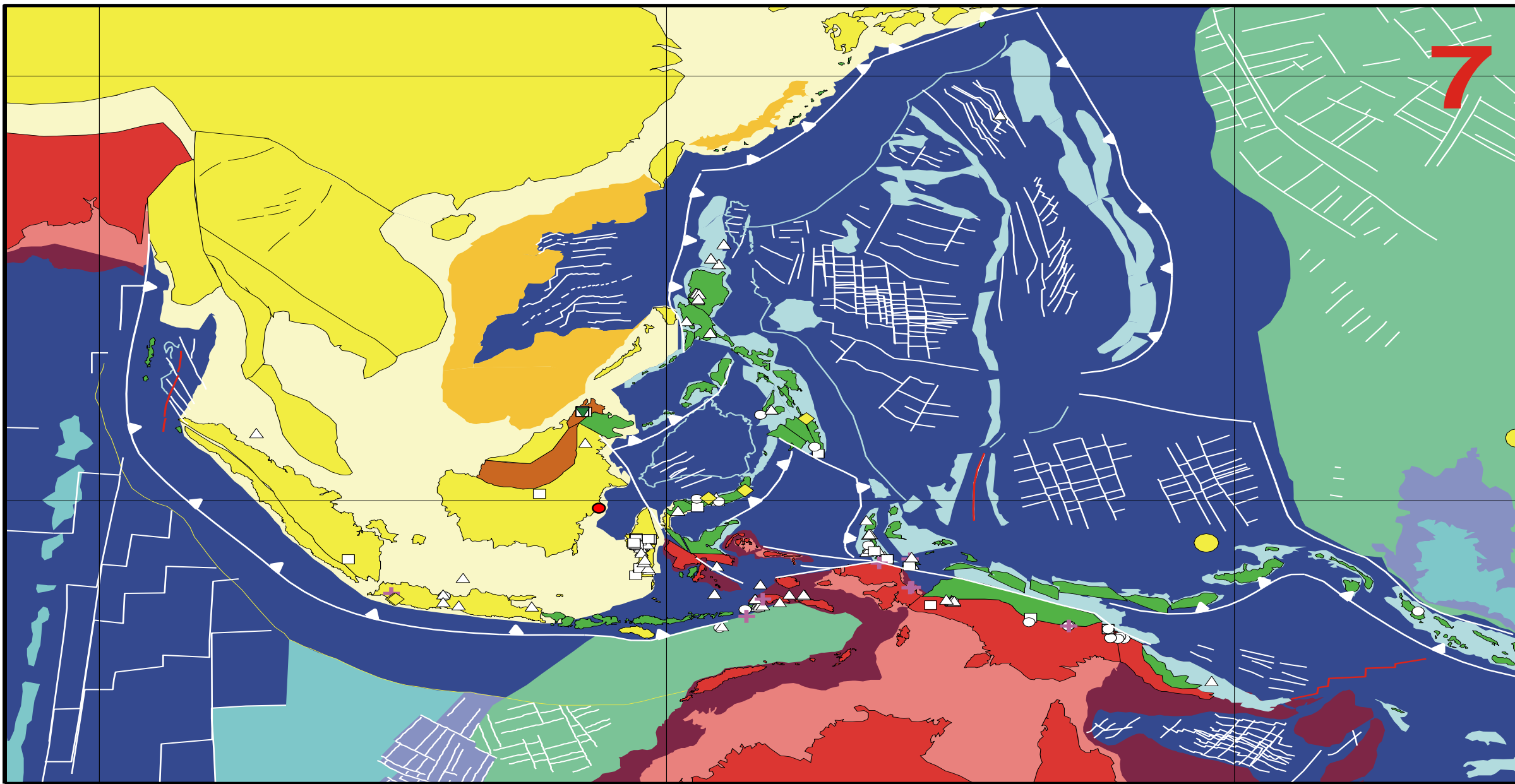
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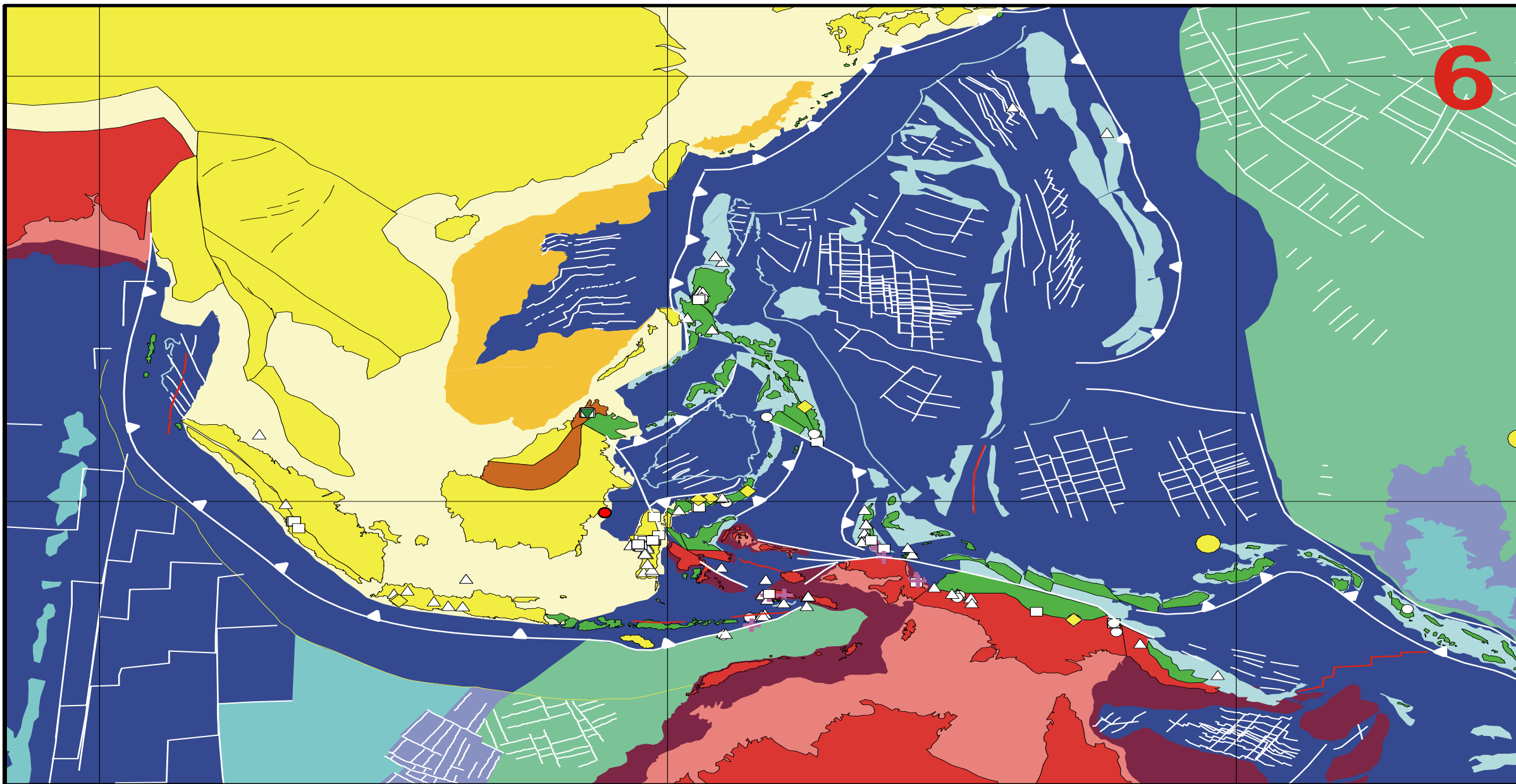
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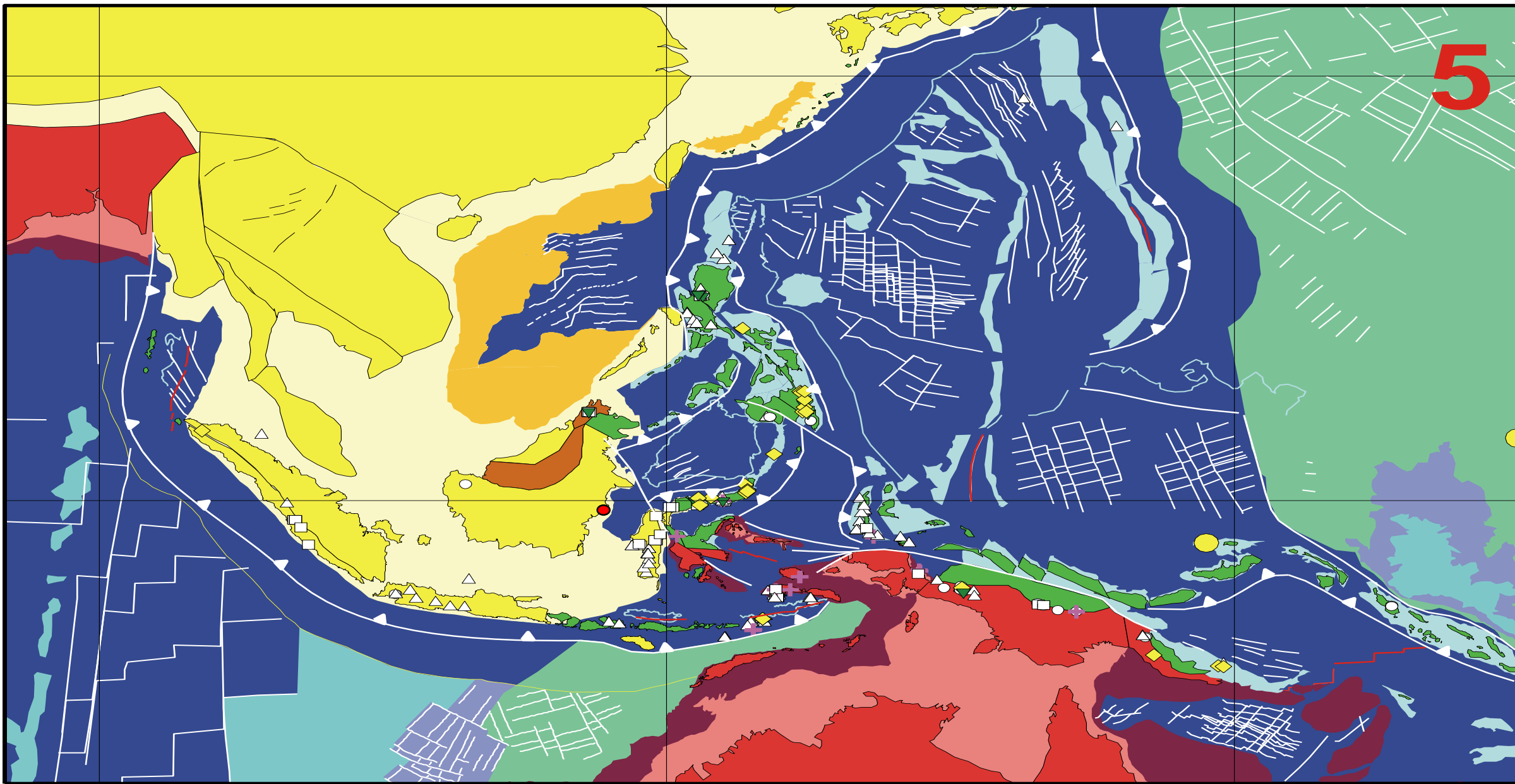
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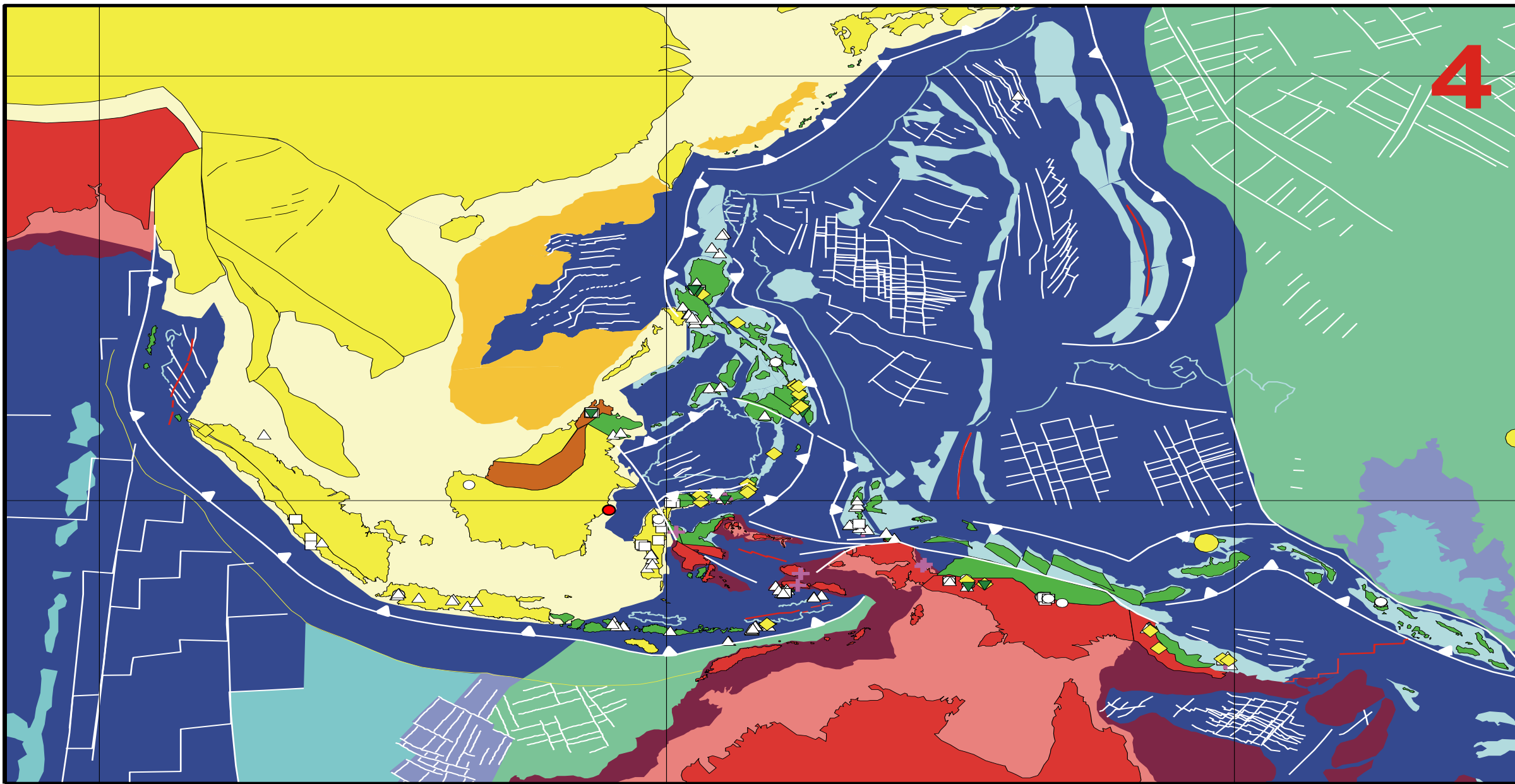
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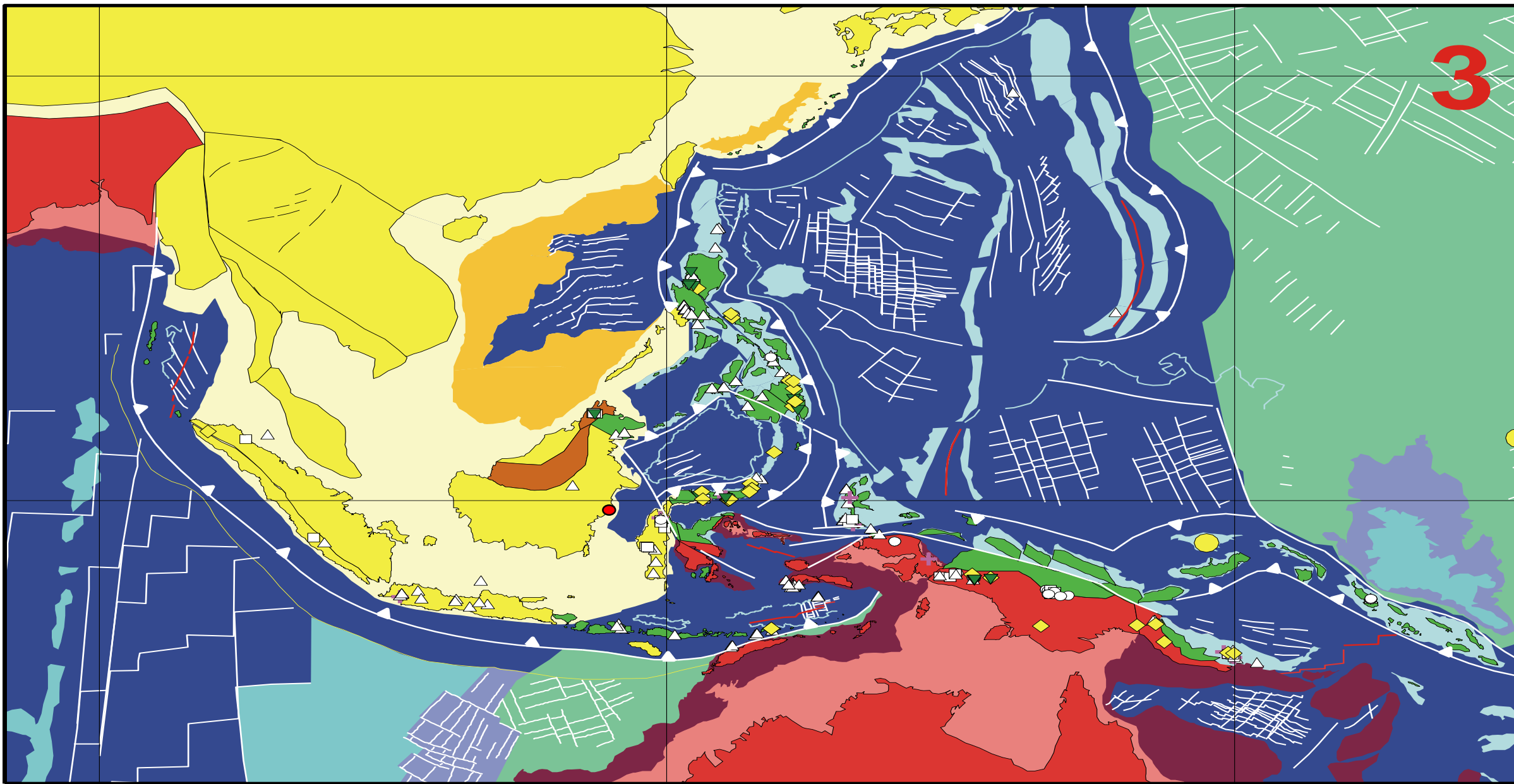
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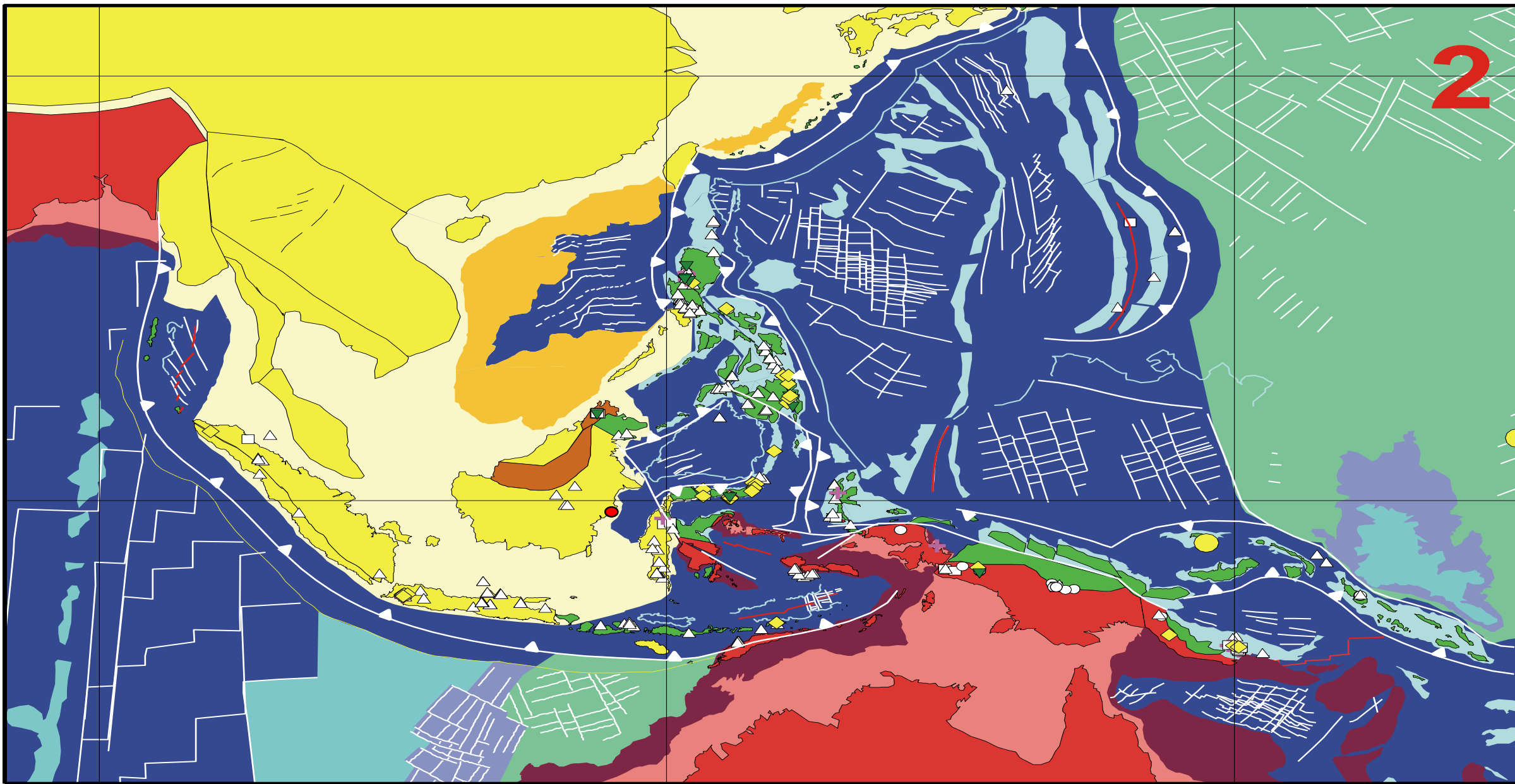
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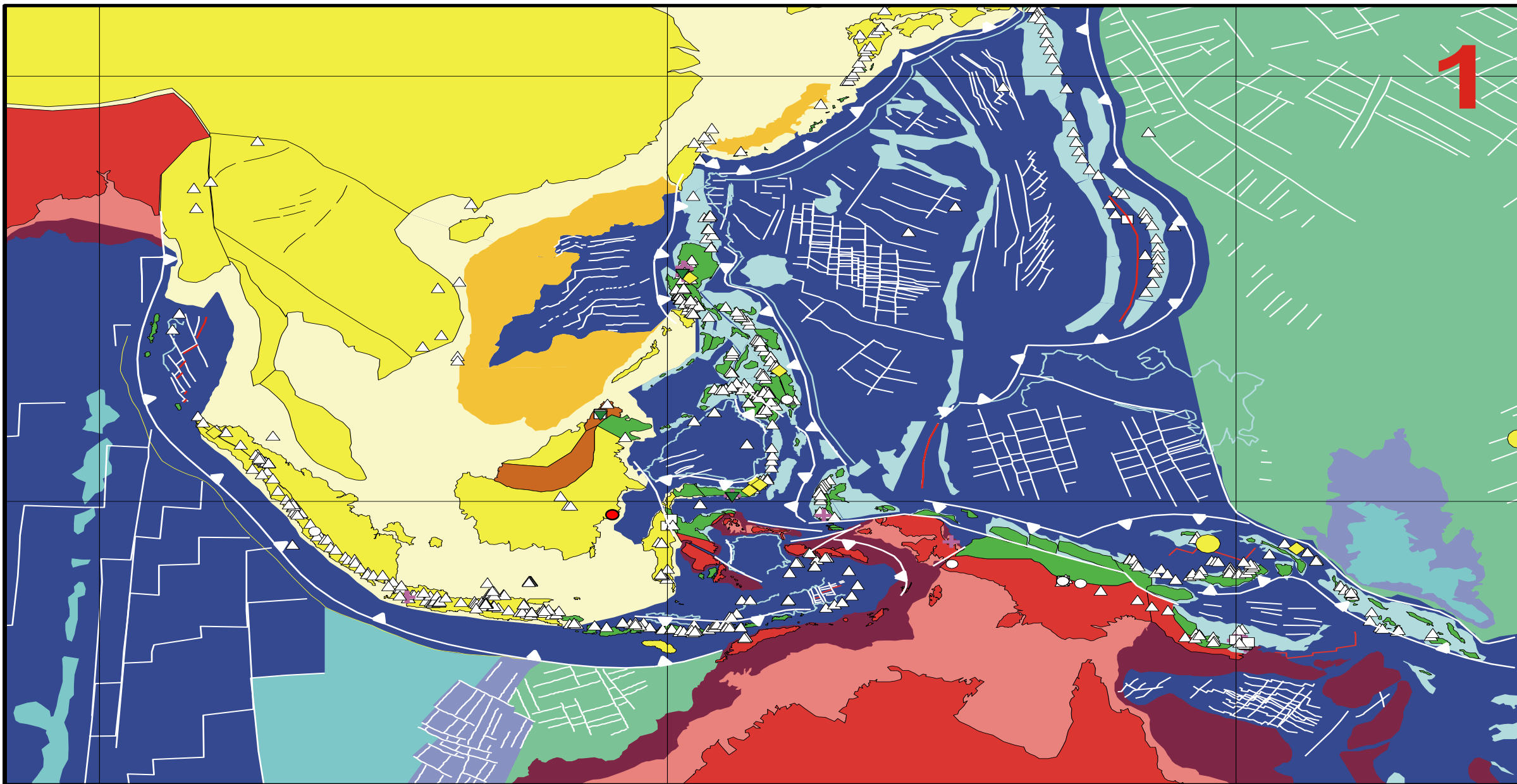
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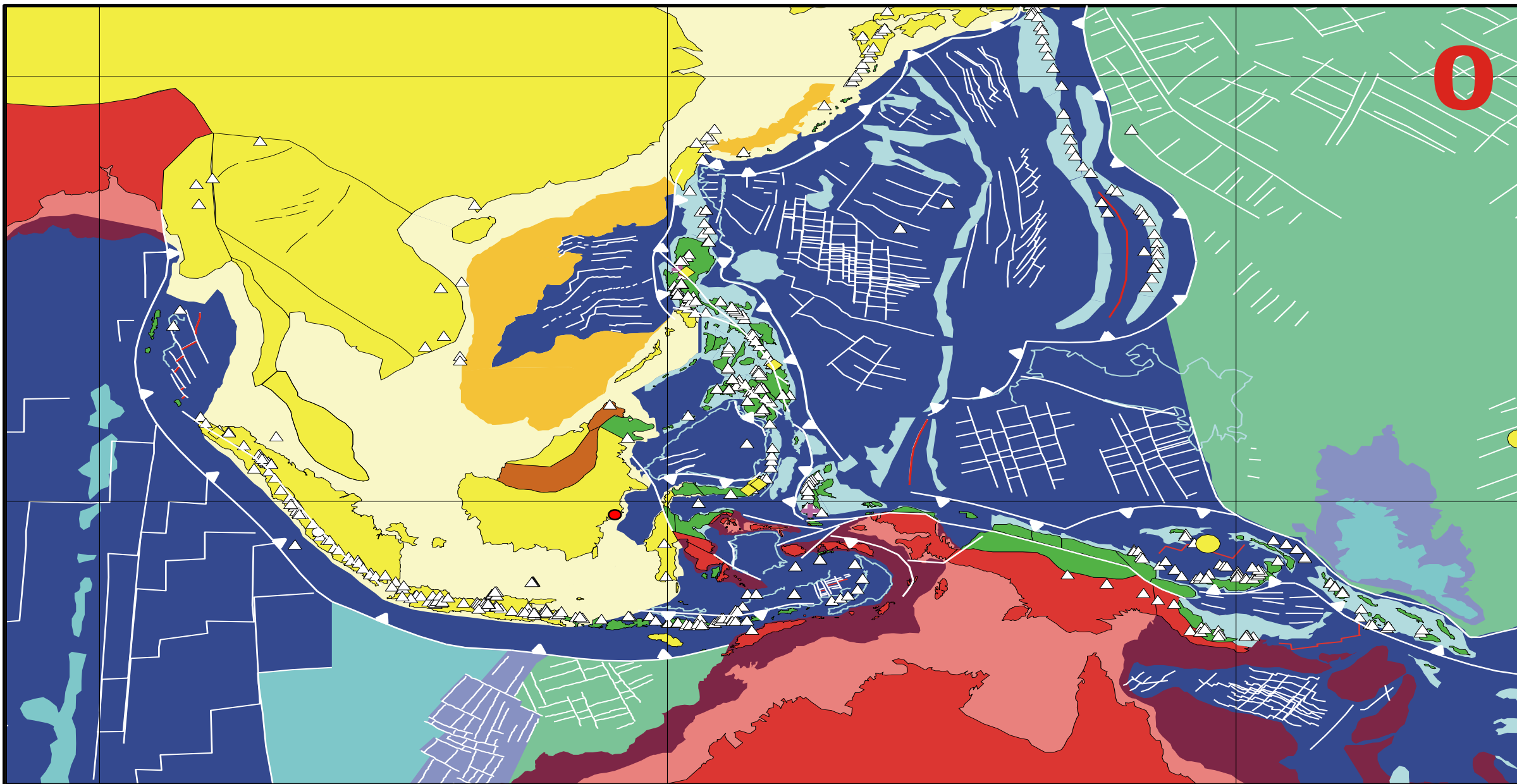
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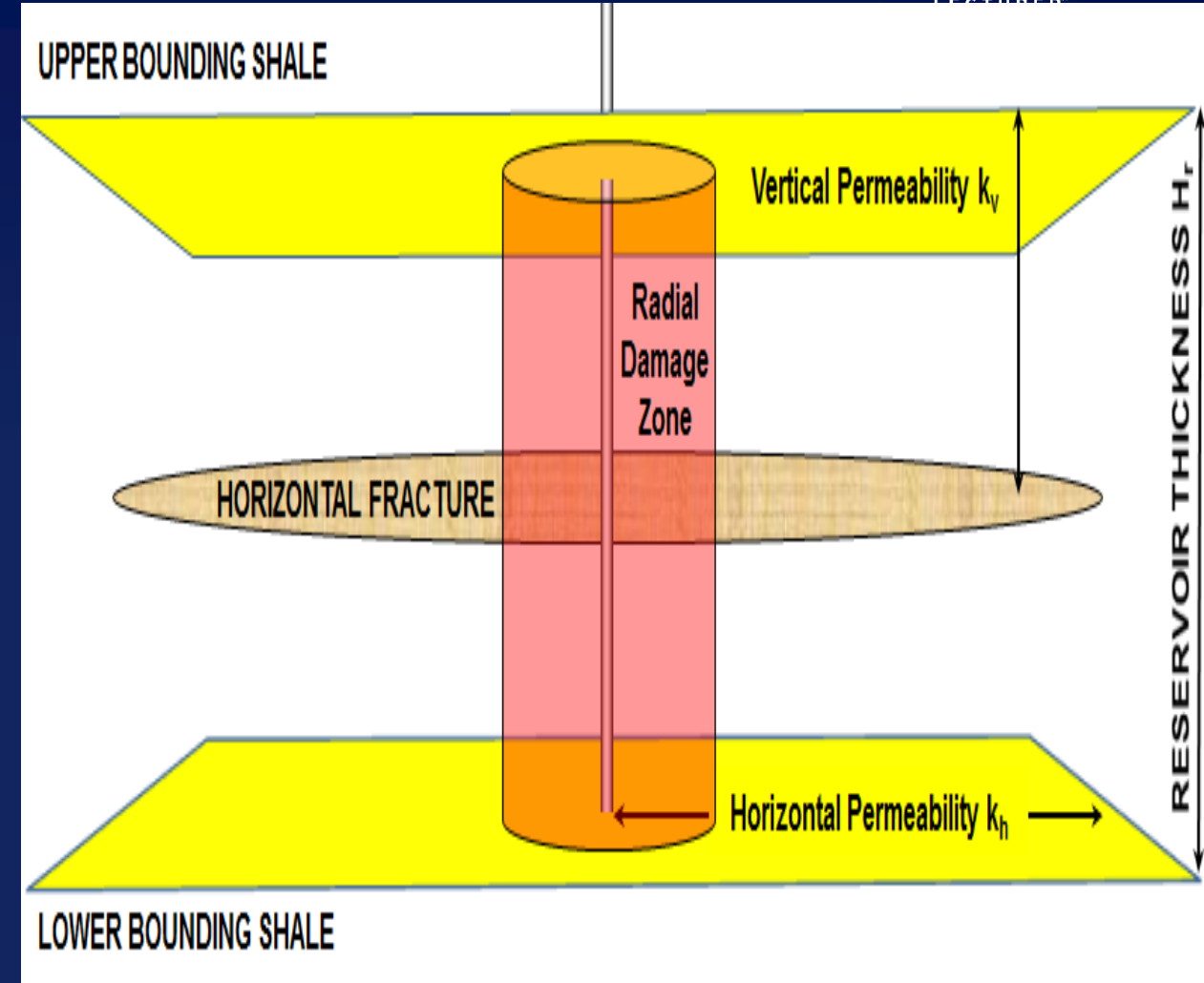
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THE “FRACTS” OF LIFE Geo-Mechanics “Issue”

- Poor fracturing fluid QA/QC (55 lb/Tg)
- Poor proppant quality/excessive crush
- Poor well design and casing integrity
- Horizontal or T-Shaped Fractures
 - In-Situ Stress Ordering ($\sigma_v < \sigma_h < \sigma_H$)
 - Horizontal and T-Shaped Fractures
 - Heavily Gel-Damaged Vertical Well
 - Frac Parallel Boundaries and k_v/k_h



THE “FRACTS” OF LIFE

Geo-Mechanics “Issue”

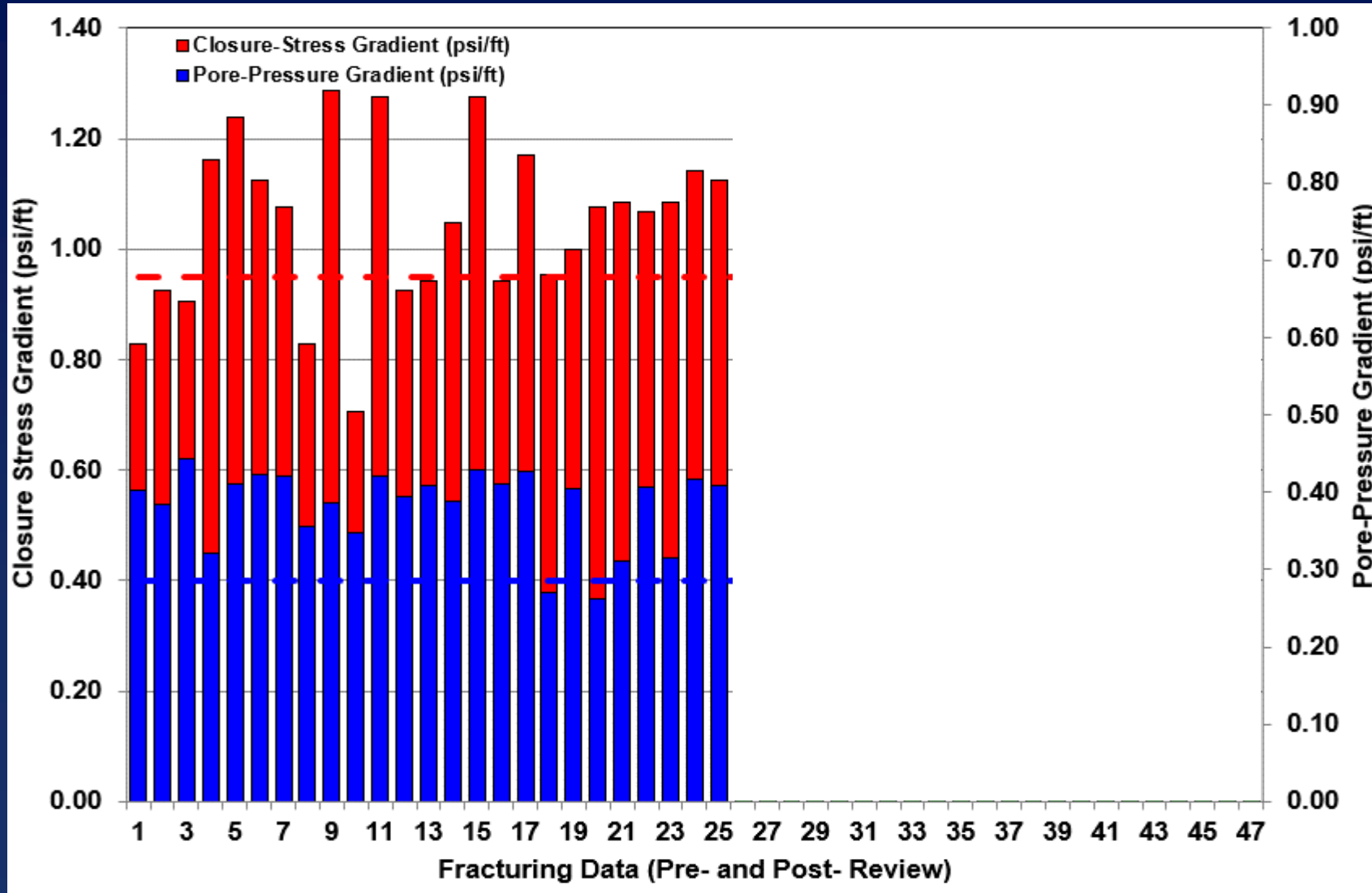


Pre-Review

- Fracturing close to or above the overburden for 30 years
- Horizontal Fracs with poor or non-existent delivery/uplift
- Also clearly a complex form of relationship for PPGF

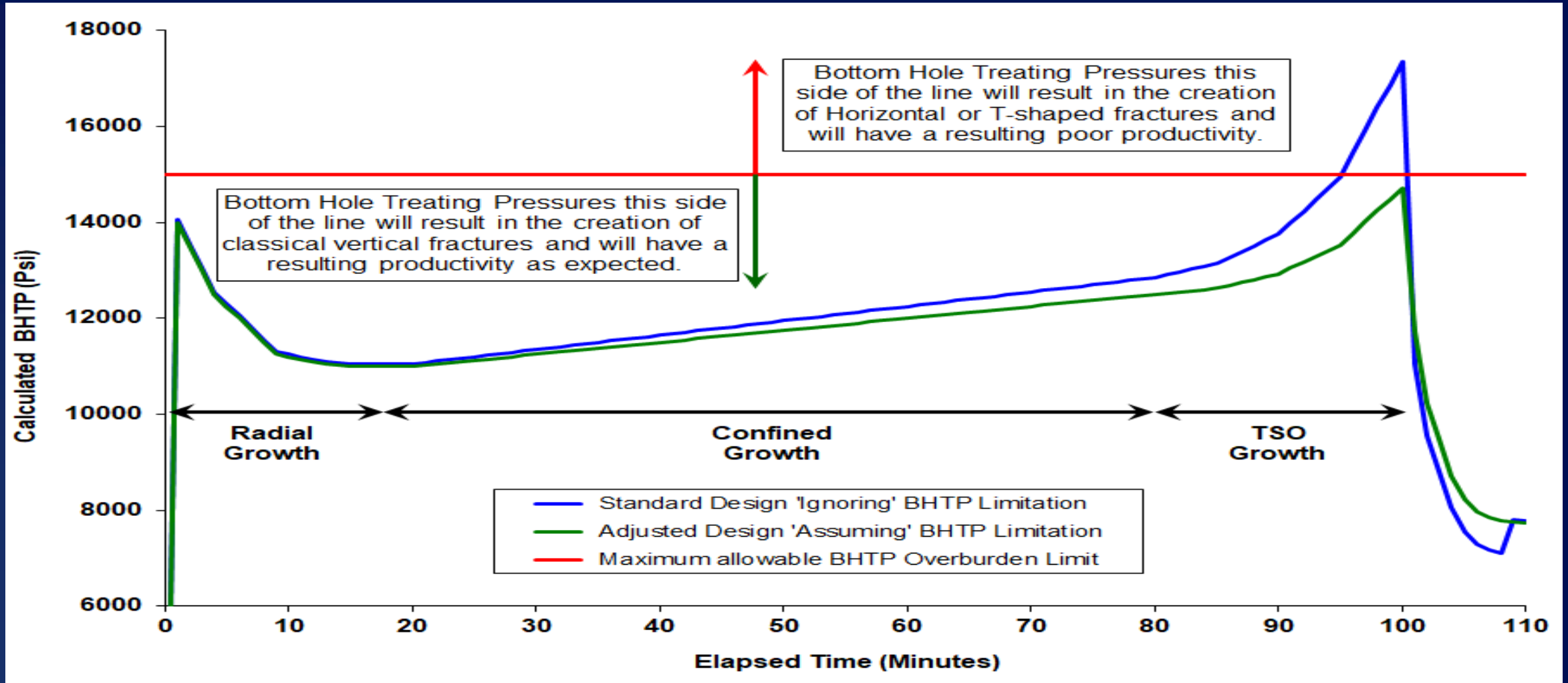
Post-Review

- Fracturing below the value of overburden consistently
- Pore-Pressure depletion has reduced horizontal stresses
- Stress reduction not quite as consistent as we would expect

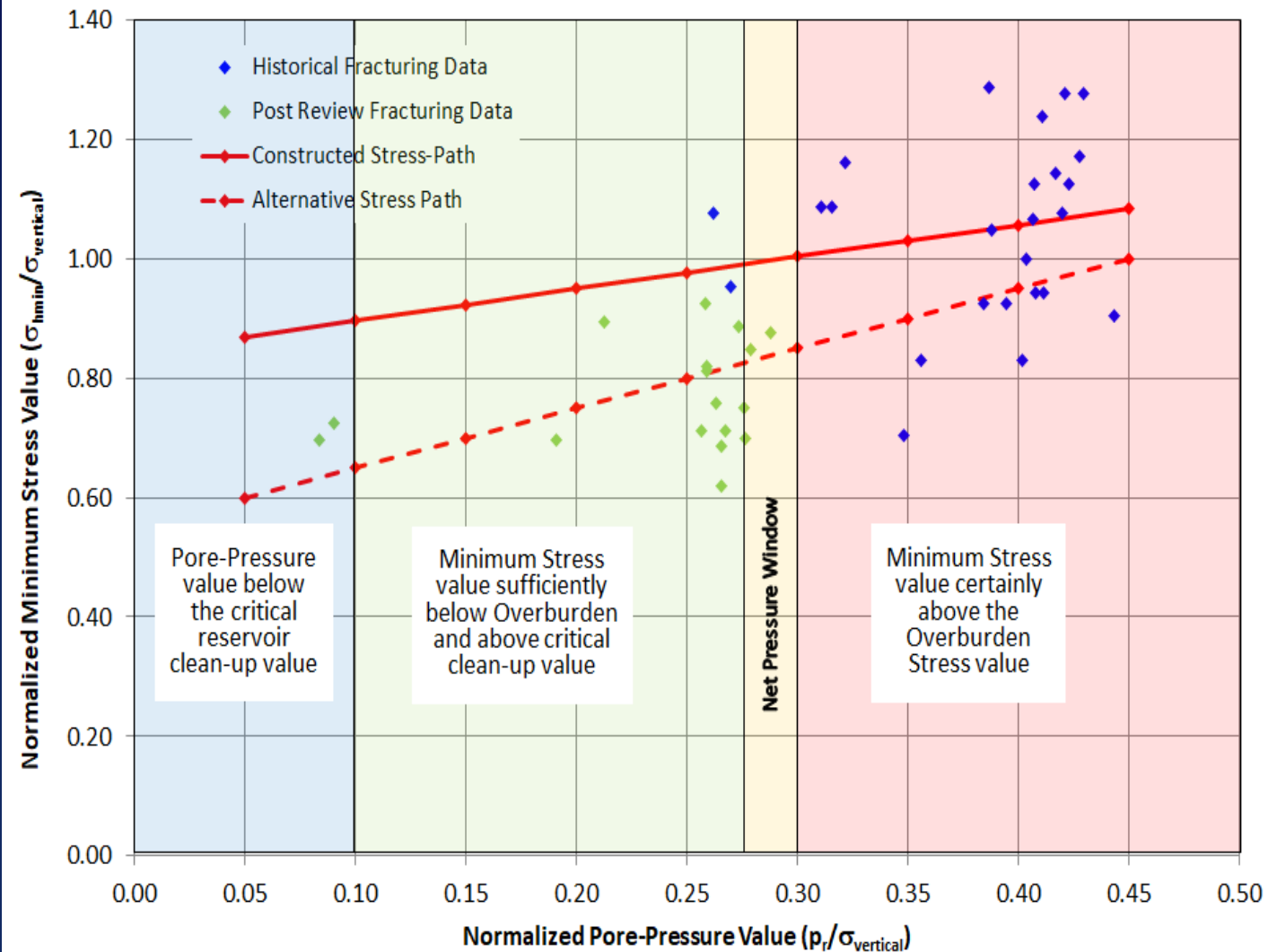
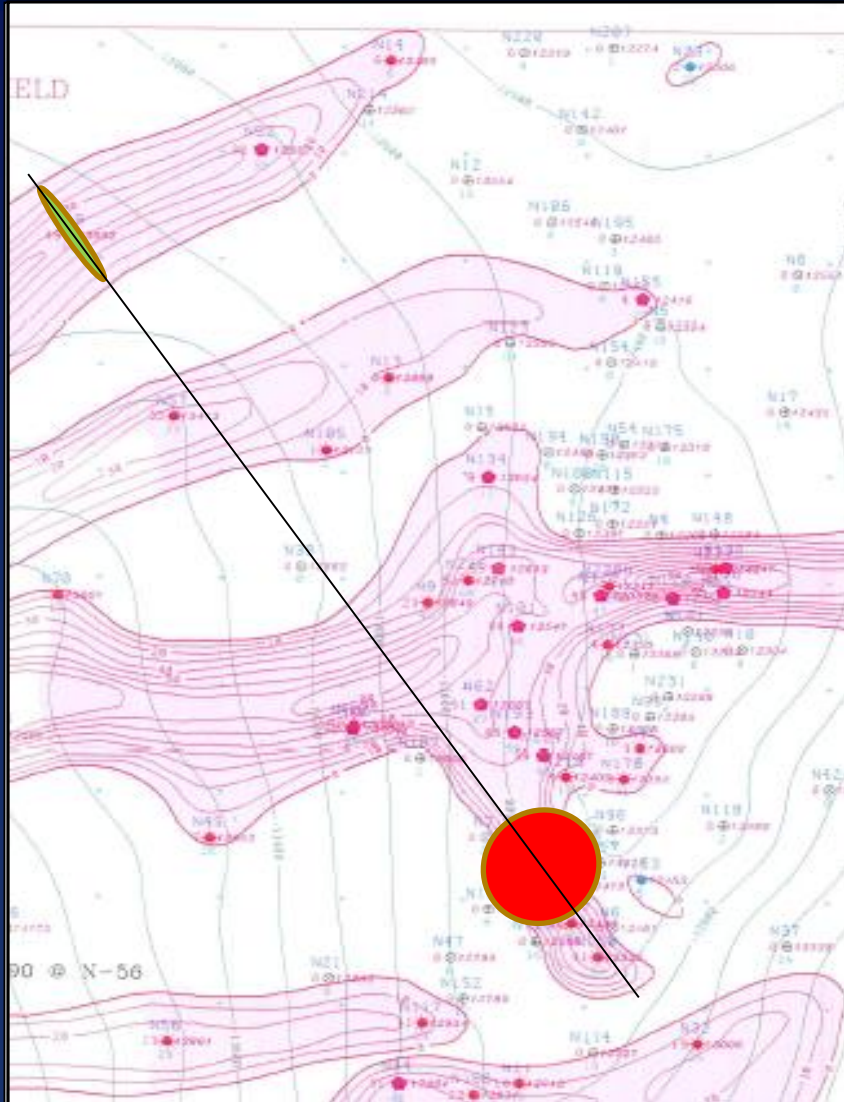


THE “FRACTS” OF LIFE

Geo-Mechanics “Issue”



THE “FRACTS” OF LIFE Geo-Mechanics “Issue”



- **A deep understanding of the actual in-situ stress-state is essential.**
- **There are very few valid ‘rules-of-thumb’ that are safe to use.**
- **When BHTP crosses the 2nd or even 3rd stress then expect issues.**
- **Micro-Frac (WFT) is an excellent surveillance method in new areas.**

THE “FRACTS” OF LIFE

Five Key Aspects



- ***GEOMECHANICS***

Geometry is the basis of delivery

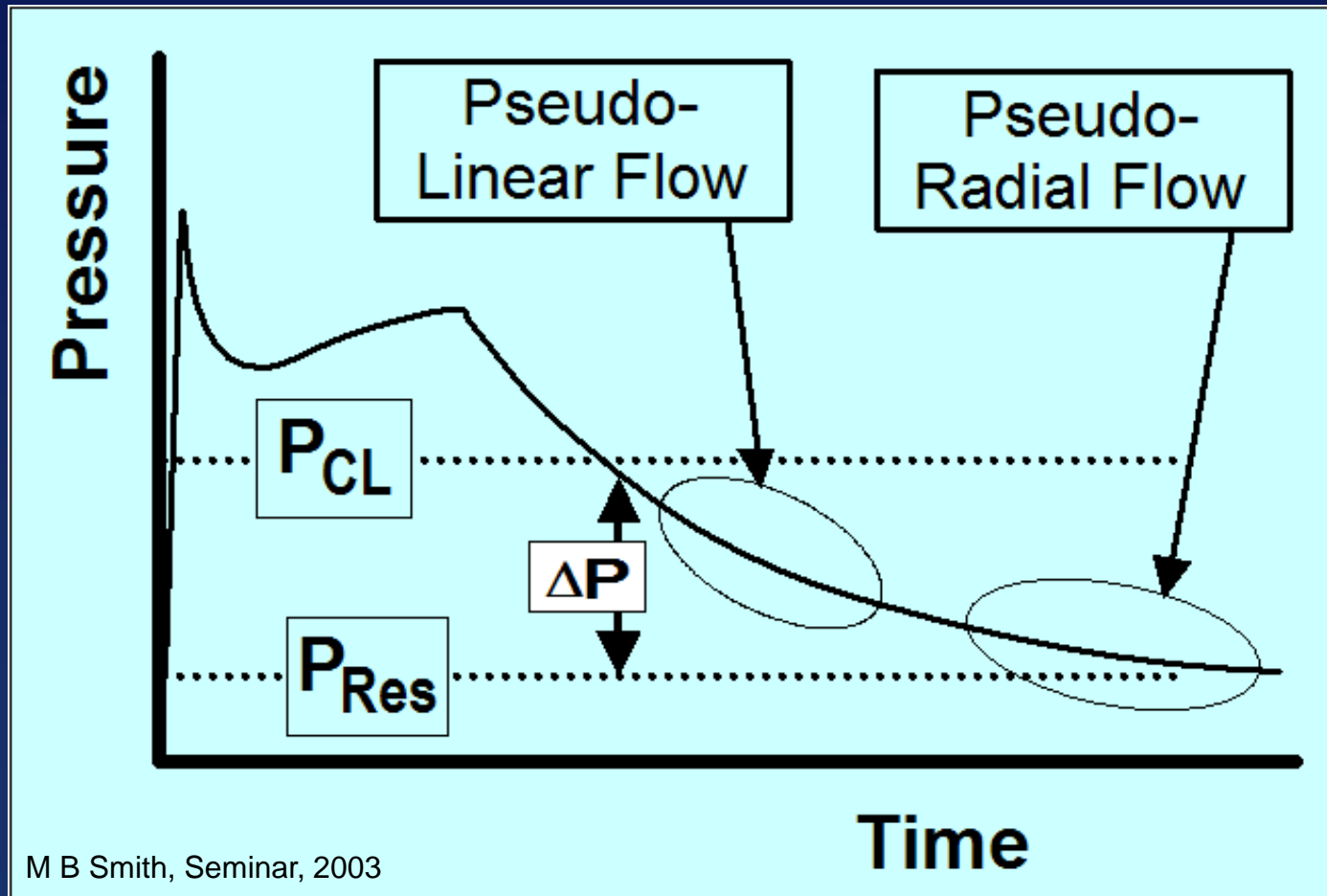
- ***PERMEABILITY***

Need accurate order of magnitude of $k_{eff}h$

THE “FRACTS” OF LIFE

Permeability “Issue”

- We must use all available techniques to estimate.*



Linear Flow

$$\Delta P = (P(t) - P_i) = M_L F_L(t)$$

Radial Flow

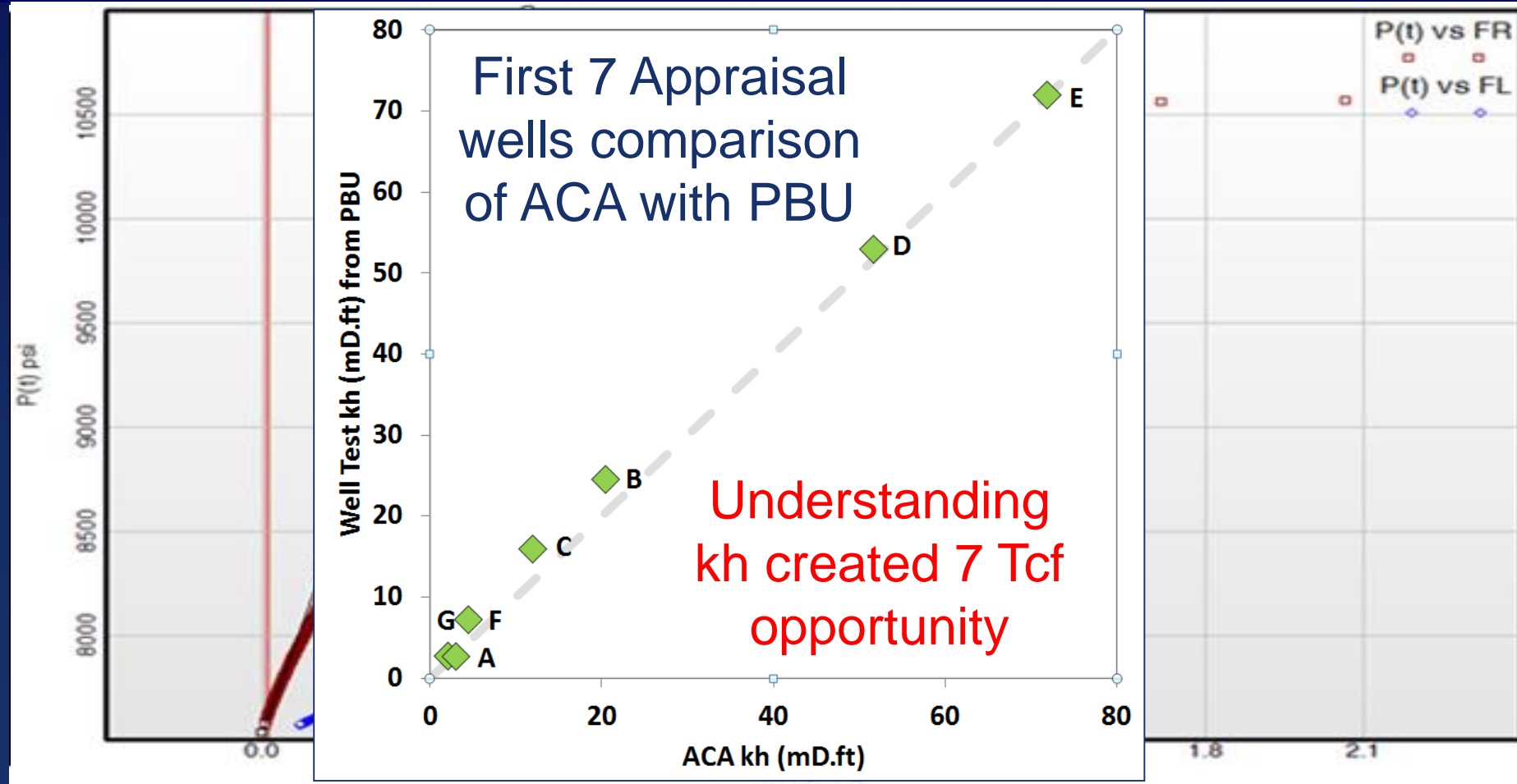
$$\Delta P = (P(t) - P_i) = M_R F_R(t)$$

**Two distinct Flow Regimes
so we MUST know P_R with
reasonable accuracy.**

THE “FRACTS” OF LIFE

Permeability “Issue”

- Highly accurate early estimation of kh for design and planning.*



THE “FRACTS” OF LIFE

Permeability Summary



- **As the rock quality reduces, the petro-physics becomes “challenging”.**
- **Log derived k in tight rock often inaccurate (1 or 2 orders of magnitude).**
- **ACA (DFIT) is quick, accurate & ideally suited to E&A environments.**
- **$k_{\text{eff}}h$ is key, importance of early/accurate assessment is fundamental.**

THE “FRACTS” OF LIFE

Five Key Aspects



- **GEOMECHANICS** *Geometry is the basis of delivery*
- **PERMEABILITY** *Need accurate order of magnitude of $k_{eff}h$*
- **FRAC QA/QC** *Defines the Success or the Failure*

THE “FRACTS” OF LIFE

QA/QC “Issue”

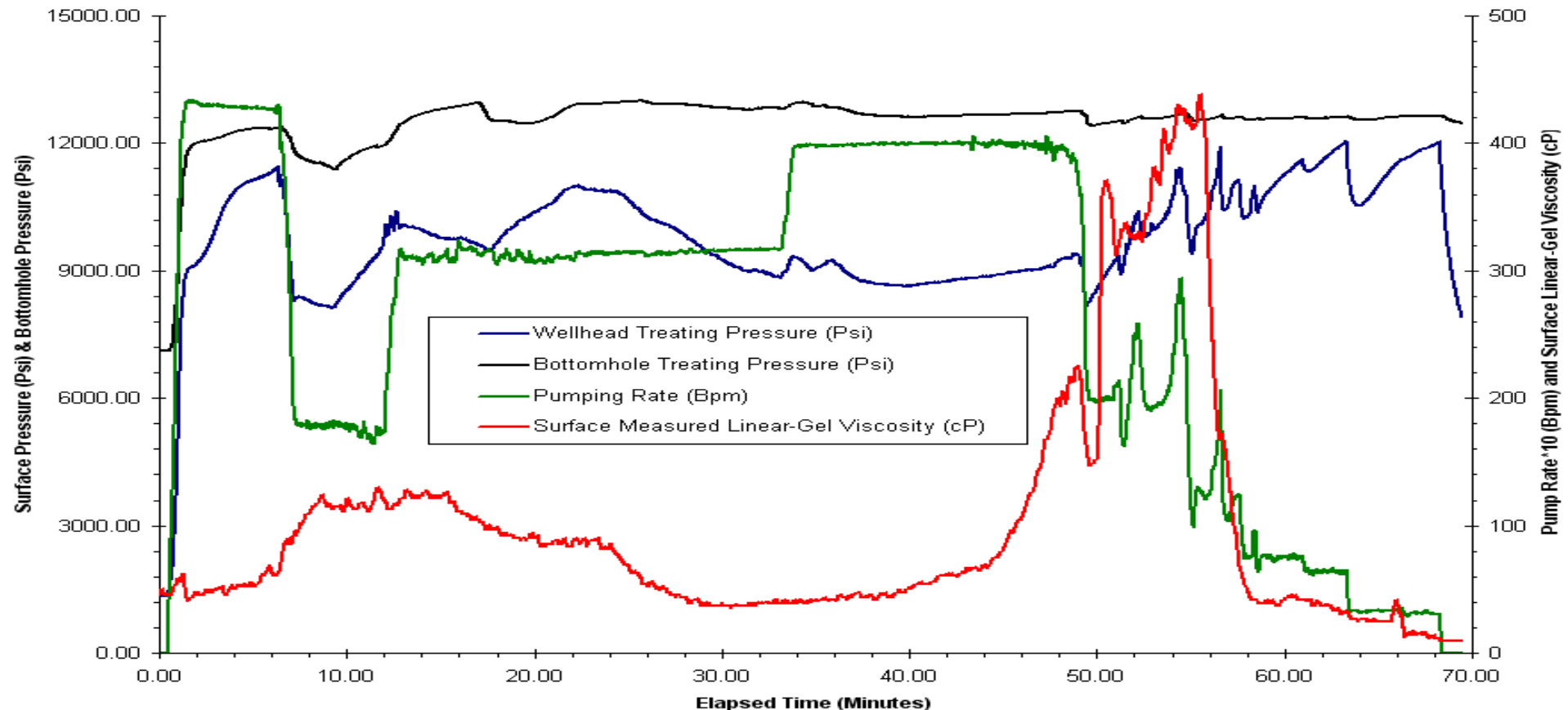


Photos of debris, valve-seat remover from Manifold and Pumps.

THE “FRACTS” OF LIFE

QA/QC “Issue”

Operator: Right pump it past the surface lines and clear of the tree-saver but not as far as the perforations; then RU CT and clean this mess out.



- **QA/QC must be established quickly in new areas to deliver basics.**
- **Fundamental system cleanliness often an issue (especially start-up).**
- **Complex fluid system skills and knowledge, are being forgotten.**
- **Evidence that automation is surpassing/even exceeding capability.**

THE “FRACTS” OF LIFE

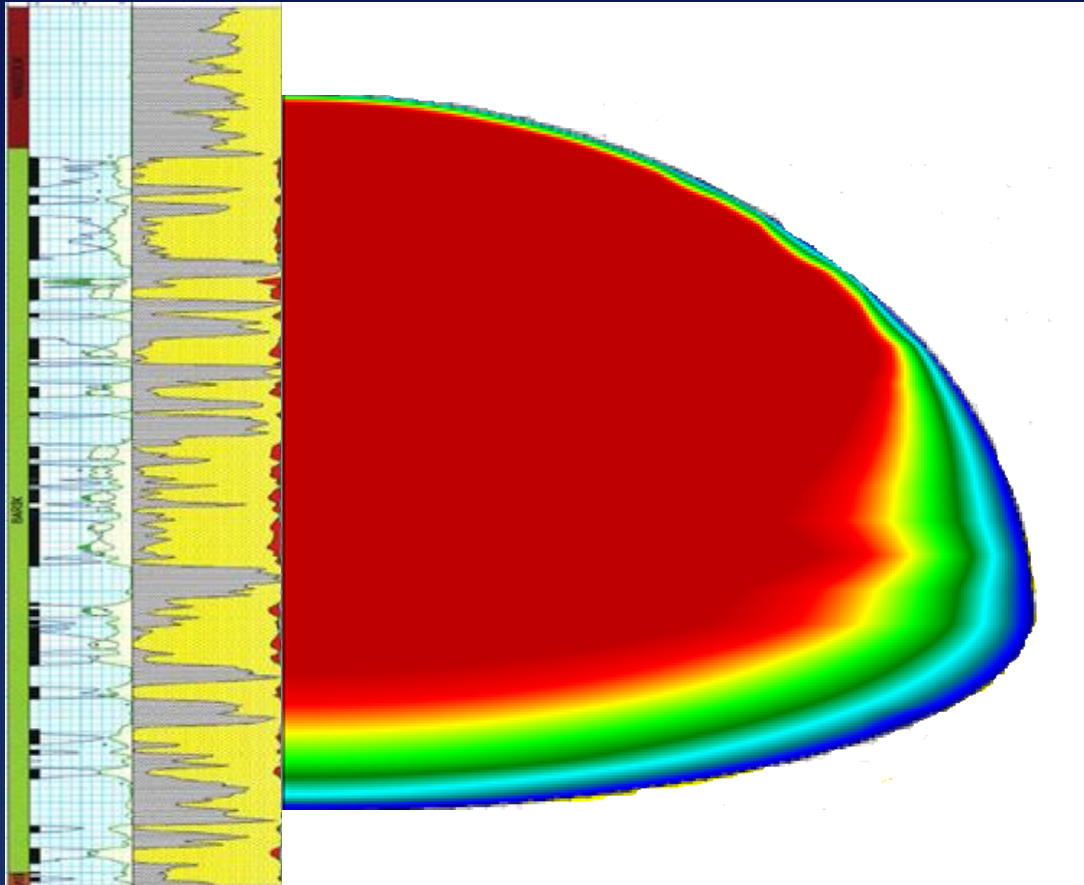
Five Key Aspects



- **GEOMECHANICS** *Geometry is the basis of delivery*
- **PERMEABILITY** *Need accurate order of magnitude of $k_{eff}h$*
- **FRAC QA/QC** *Defines the success or the Failure*
- **HORIZONTALS** *Understand Vertical frac/well behaviour*

THE “FRACTS” OF LIFE

Horizontals “Issue”



- *Fully perforated interval gives extensive fracture height.*
- *Stress variation can create 'corrugated' fractures.*
- *Land Horizontal in one lens and Frac can be confined.*
- *Confinement can push the BHTP above σ_H and even σ_V*

THE “FRACTS” OF LIFE

Horizontals “Issue”



- *There are “Trade-Offs” when moving from Vertical to Horizontal wells, which the user must appreciate.*
 - *Knowledge of the Vertical fracture growth behaviour is absent.*
 - *Logs not representative of what the frac actually encounters.*
 - *Almost all staging techniques result in some amount of over-flush.*
 - *Partial mono-layer/infinite conductivity is a strategic compromise.*

THE “FRACTS” OF LIFE

Horizontals Summary



- *Why does the Vertical dimension no longer concern us?*
- *Frac Height/Landing point requires early knowledge/data gathering.*
- **As Horizontals ‘move’ into good k/kh, we must do Engineering.**
- **‘Staging’ developed for ultra-low perm., needs careful application.**
- **Popular ‘pillar fracs’, insist on extensive proppant near wellbore.**

THE “FRACTS” OF LIFE

Five Key Aspects



- ***GEOMECHANICS*** *Geometry is the basis of delivery*
- ***PERMEABILITY*** *Minimum accurate order of magnitude*
- ***FRAC QA/QC*** *Defines the success or the failure*
- ***JOURNEY from V to H*** *Understand Vertical frac behaviour*
- ***There is always more to learn so expect the unexpected.***

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