**3ο Επιστημονικό Forum για τη Μείωση της Διακινδύνευσης από Καταστροφές στην Ελλάδα**

*5-6 Μαρτίου 2020, Πολιτιστικό Κέντρο ΕΚΠΑ «Κωστής Παλαμάς»*

# Θαλάσσιοι Γεωκίνδυνοι- Υποθαλάσσιες Ερευνητικές Γεωτρήσεις στο Ηφαιστειακό Συγκρότημα της Σαντορίνης

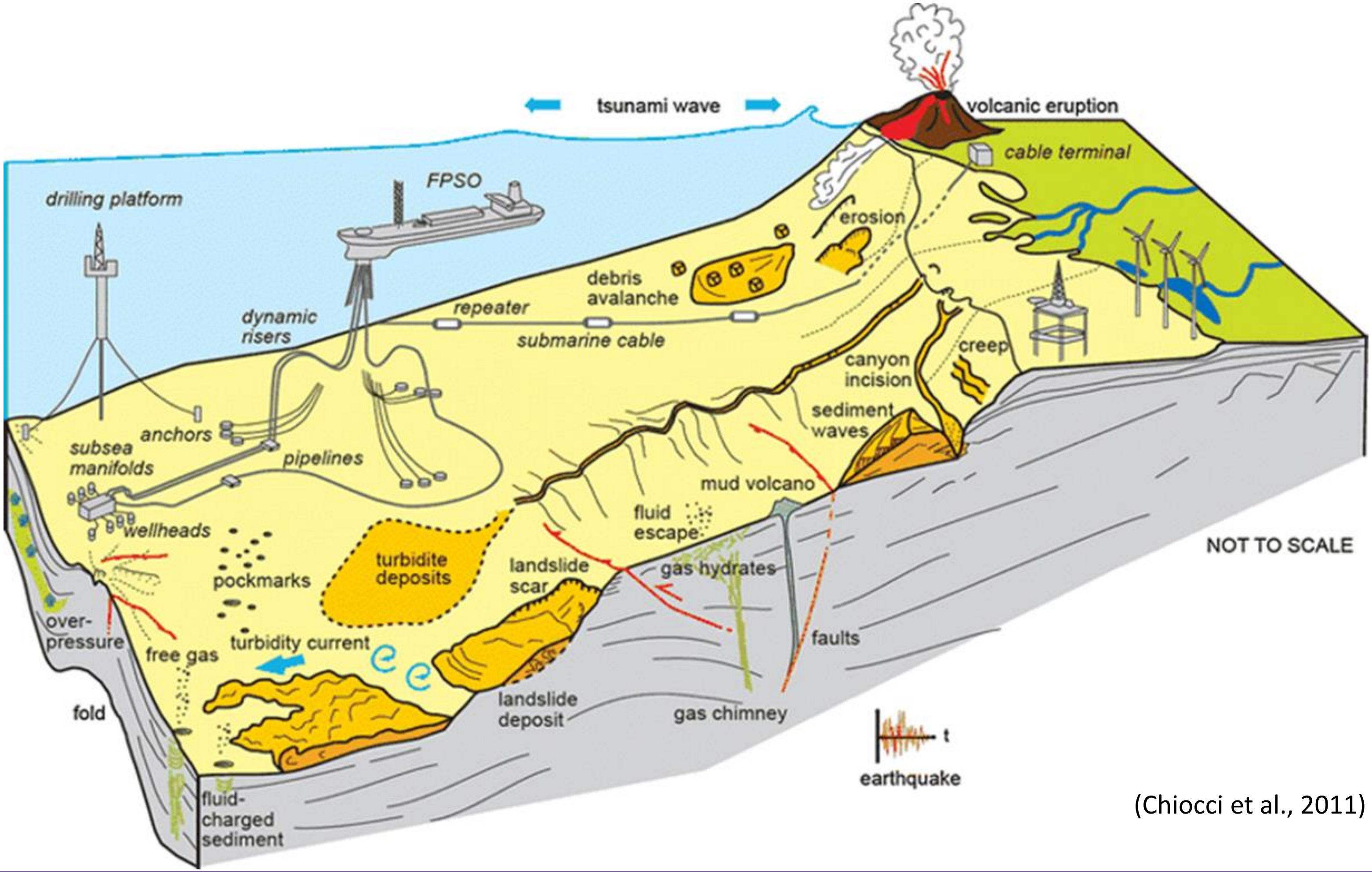
*Photo credits to Katerina Petronotis*

3ο ΕΠΙΣΤΗΜΟΝΙΚΟ FORUM ΓΙΑ ΤΗ ΜΕΙΩΣΗ ΤΗΣ ΔΙΑΚΙΝΔΥΝΕΥΣΗΣ ΑΠΟ ΚΑΤΑΣΤΡΟΦΕΣ ΣΤΗΝ ΕΛΛΑΔΑ
3rd SCIENTIFIC FORUM FOR DISASTER RISK REDUCTION IN GREECE
HDRRF

ΕΘΝΙΚΟ & ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ
ΣΤΡΑΤΗΓΙΚΕΣ ΔΙΑΧΕΙΡΙΣΗΣ
ΠΕΡΙΒΑΛΛΟΝΤΟΣ, ΚΑΤΑΣΤΡΟΦΩΝ & ΚΡΙΣΕΩΝ

**Παρασκευή Νομικού (ΕΚΠΑ), Δημήτριος Παπανικολάου (ΕΚΠΑ), Tim Druitt (Univ. of Clermont), Christian Huebscher (Univ. of Humberg), Steffen Kutterolf (GEOMAR)**

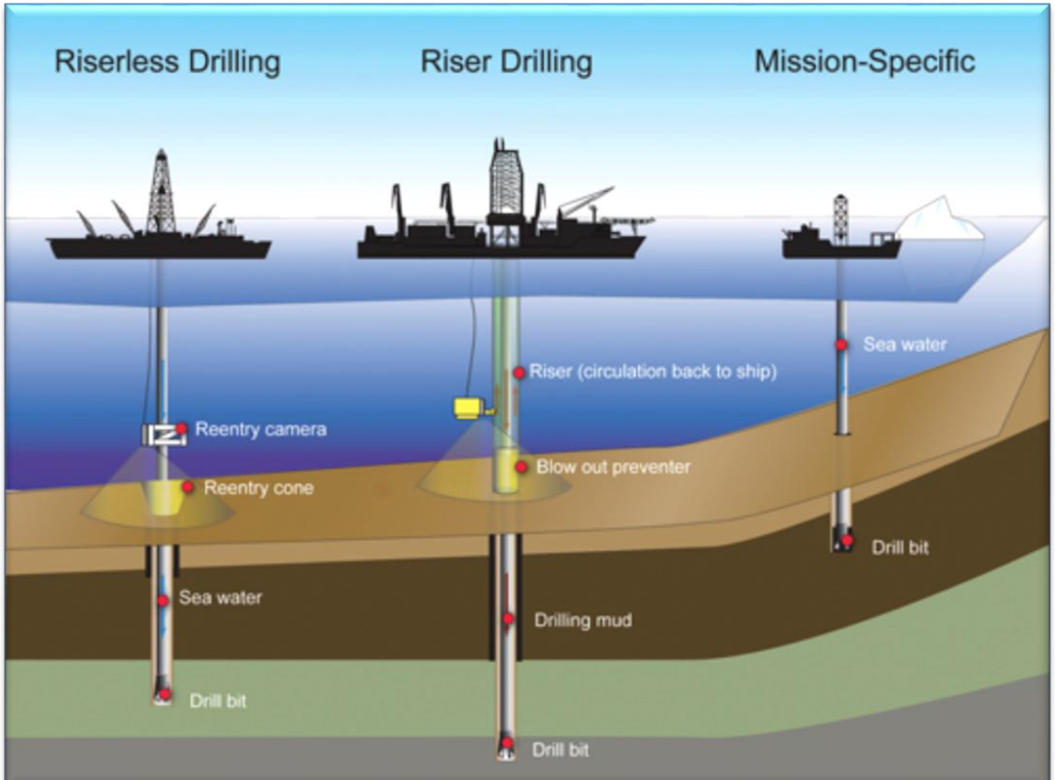
# Marine Geohazards



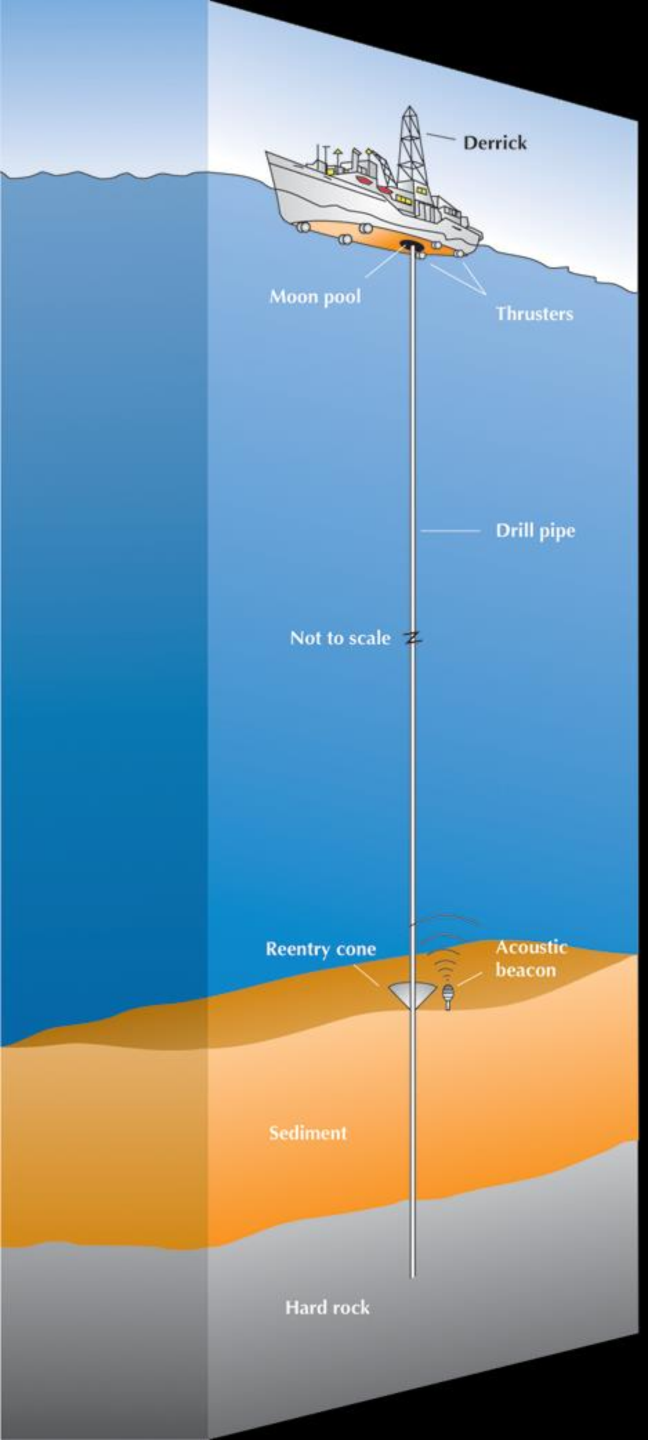

(Chiocci et al., 2011)

In marine and coastal environments, the <u>major geological hazards</u> are linked to the occurrence of events such as **earthquakes, volcanic eruptions, submarine landslides** or other rapid processes that are able to modify the morphology and character of the seafloor such as **gravity-driven sediment flows, fluid emissions, bedform migration, retrogressive erosion at canyon heads,** etc. Secondary effects such as **tsunamis** (either triggered by earthquakes or landslides) also need to be considered, as both their genesis and propagation are strongly controlled by seafloor morphology.

# Integrated Ocean Drilling Program (IODP)




Understanding the spatial and temporal variability of submarine geohazards, their physical controls, and their societal effects requires a diverse array of observational techniques. Ocean drilling can be a key element in understanding oceanic geohazards, given that the submarine geologic record preserves structures and past evidence for earthquakes, landslides, volcanic collapse, and even bolide impacts. This record can be read and interpreted through drilling, coring, in situ characterization, observatory studies, monitoring, and laboratory studies to provide insight into future hazards and associated risks to society (Morgan et al., 2009).





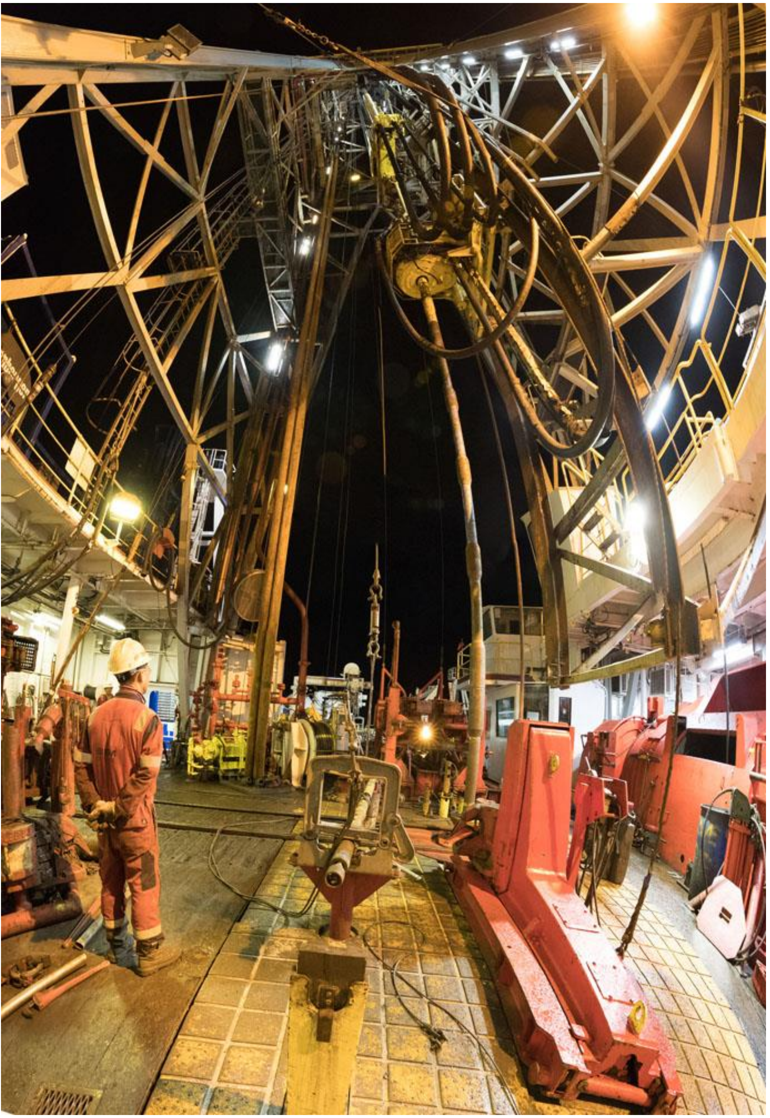

## *JOIDES Resolution* (JR) Specifications

- Built in 1978 (Sedco/BP471)
  - Converted for scientific research in 1985
  - Major renovation completed in 2009
- Owner: Overseas Drilling Limited, Inc., Siem Offshore
- Length: 143 m (471 ft)
- Dynamic positioning: 12 thrusters: 10 retract, 2 fixed

## Crew and Scientists

- ~65 crew (marine, drilling, engineering, electrical, catering)
- ~60 IODP (scientists, lab technicians, operations, engineers, outreach)

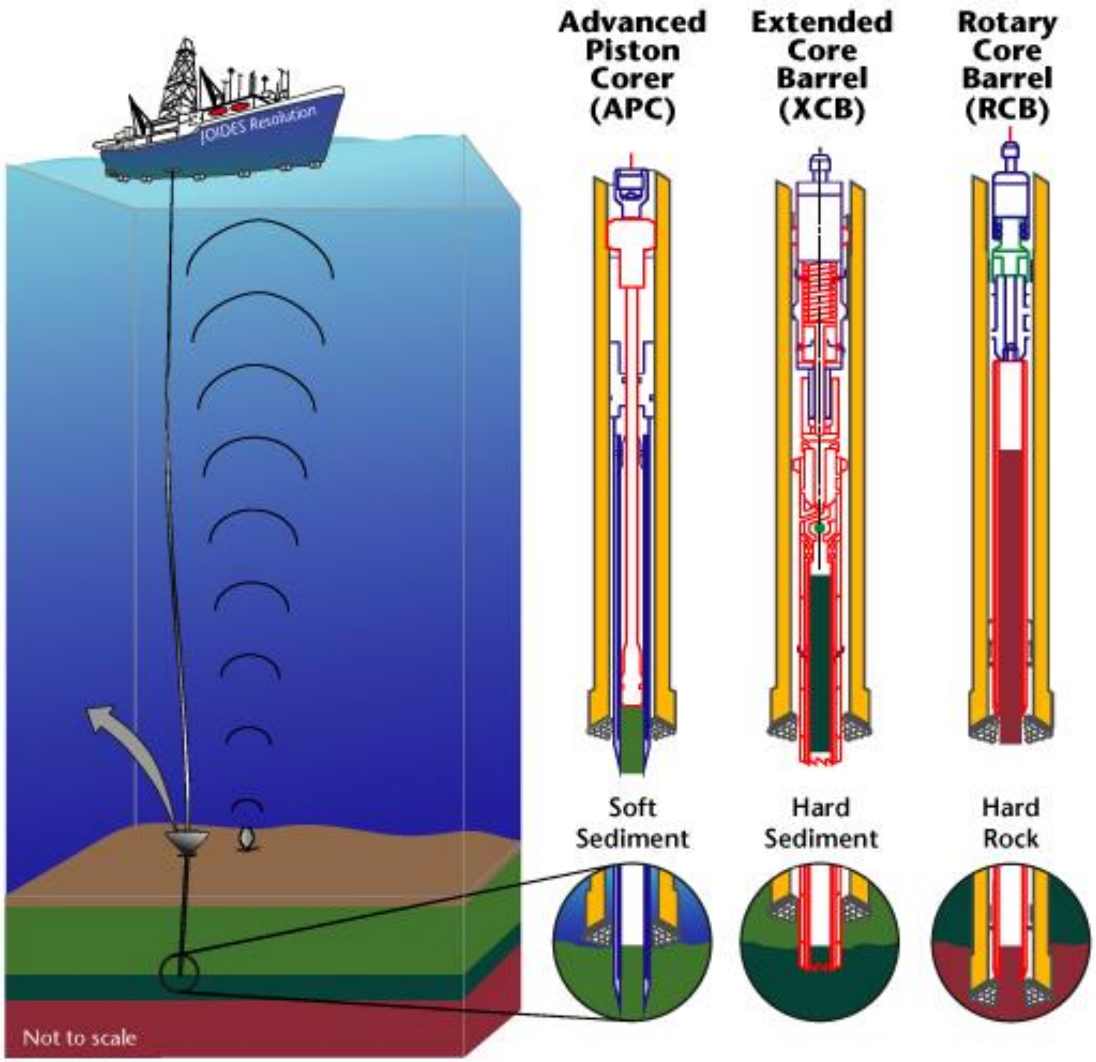
***credits to Katerina Petronotis***



## JR Operational Capabilities

- Deepest Water
  - 5980 m, Mariana Basin (Hole 802A)
- Longest drill string
  - 6919 m, Ninetyeast Ridge (Hole 756D: 5724 m water, 1195 m penetration)
  - Current limit used ~6300 m
- Penetration Records
  - 2111 m, Costa Rica Rift (Hole 504B)
    *~1 yr operational time (hard rock)*
  - 1927 m, Canterbury Basin (Hole U1352)
    *15 days operational time (sediment)*
- Shallow Water
  - Only operate in >75 m water
  - Restrictions in <650 m water

***credits to Katerina Petronotis***

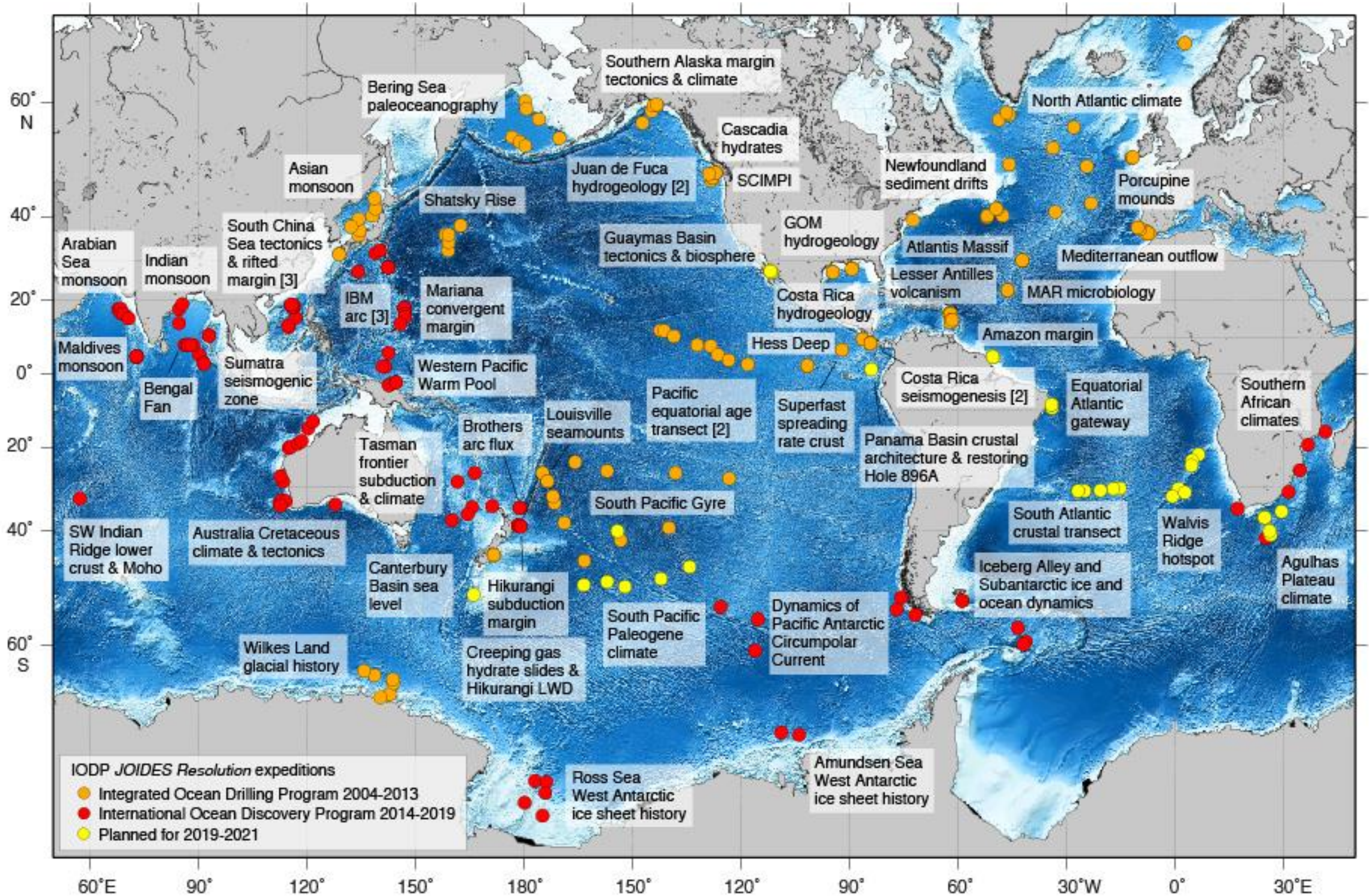



## JR Coring Systems for

soft to firm sediment | hard sediment | lithified sediment, igneous rock

***credits to Katerina Petronotis***

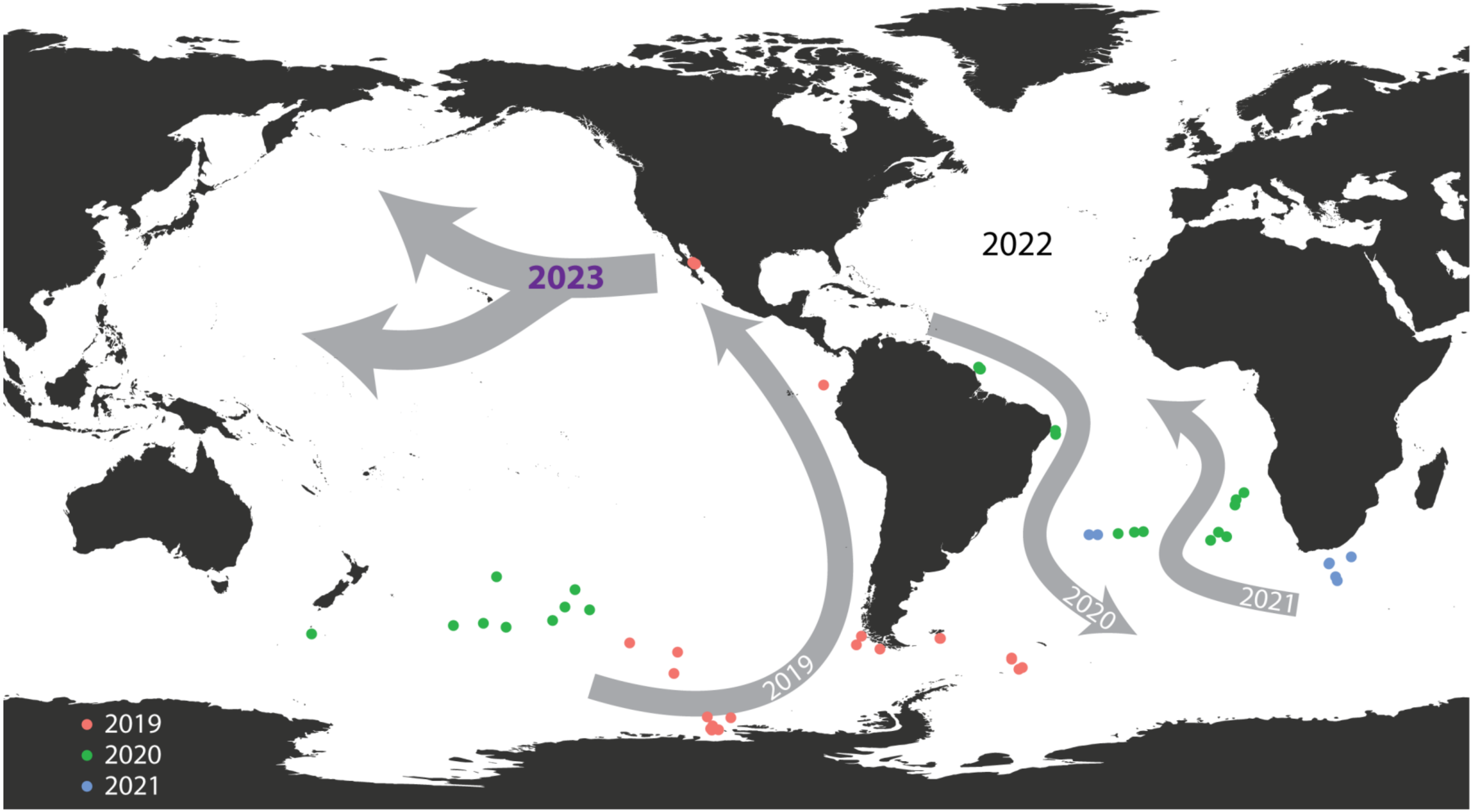
# *JOIDES Resolution* Expeditions in 2004–2021




***credits to Katerina Petronotis***

# *JOIDES Resolution* Future Track

South Atlantic Ocean (2020–2021); North Atlantic & Mediterranean (2022–2023); Pacific Ocean (2023–2024)

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# IODP proposal: Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece

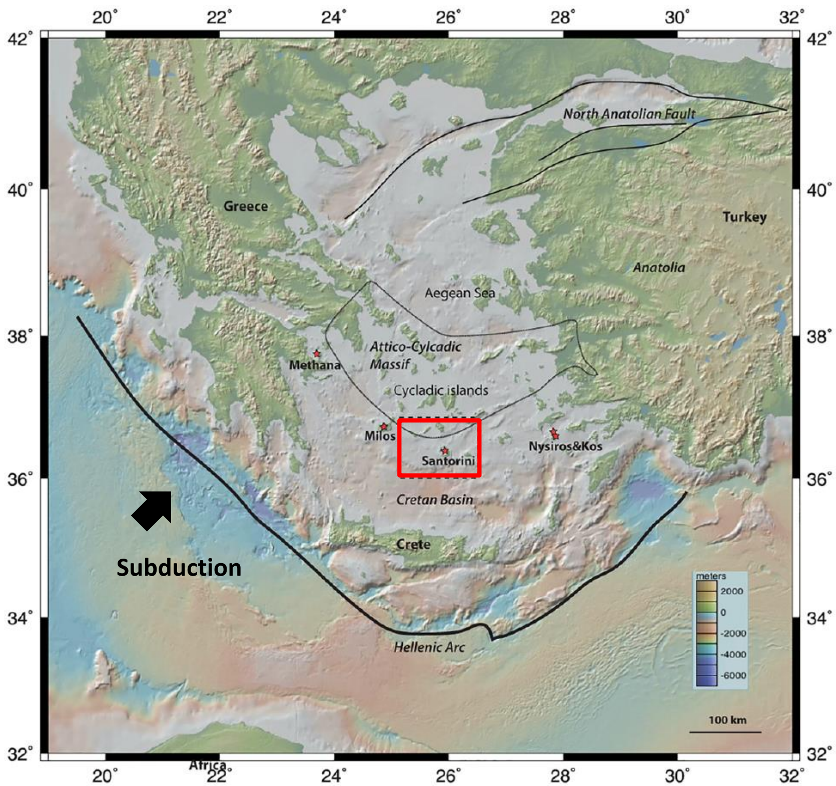
***Crustal tectonics strongly influences volcanism, but the link has rarely been studied at high spatial and temporal resolutions***

- Extensional crustal motions across many island arcs create space for magma ascent, and influence the depths and sizes of magma storage regions

- Crustal thickness and thermal structure affect the production of magmas in the mantle and their subsequent evolution through crystal fractionation, crustal contamination and magma mixing

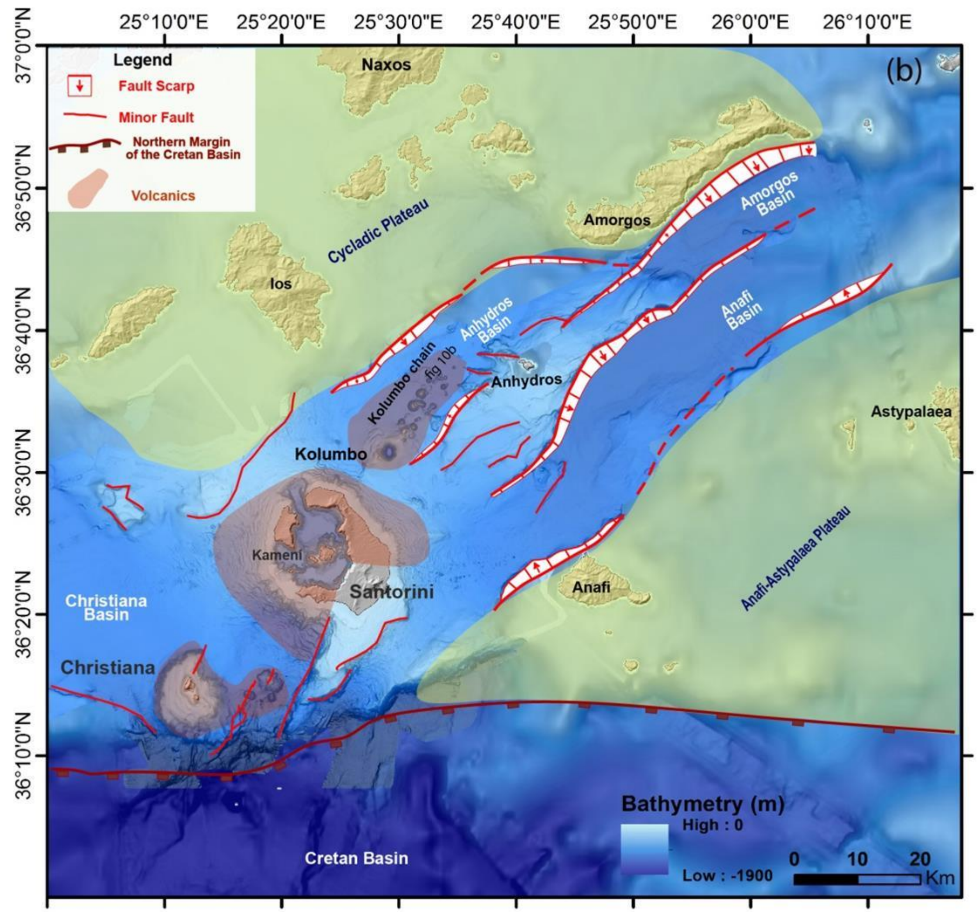
- Magma bodies focus crustal deformation and change stresses on faults, generating feedbacks between magmatism and tectonics

# Christiana-Santorini-Kolumbo Volcanic Field – rift-hosted arc system




South Aegean Volcanic Arc active since 4.7 Ma

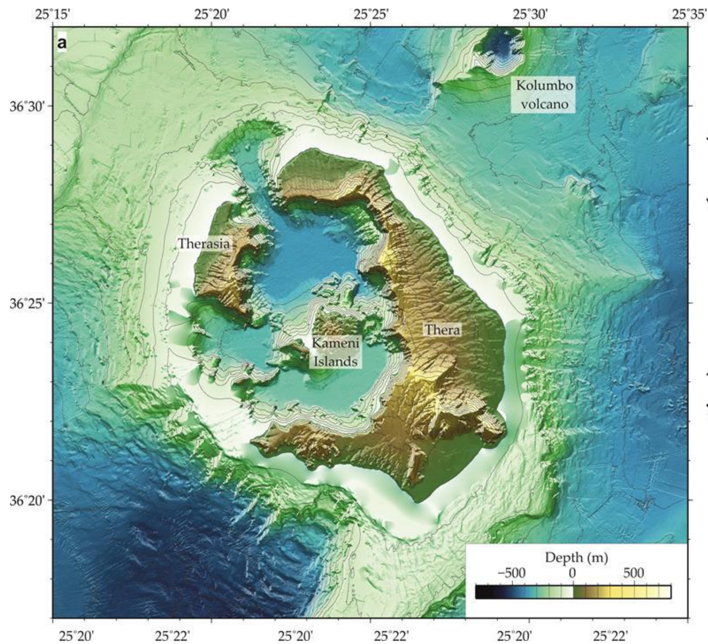
(Hooft et al. Tectonophysics, 2017)




Rift 100 km long, on 22 km thick continental crust

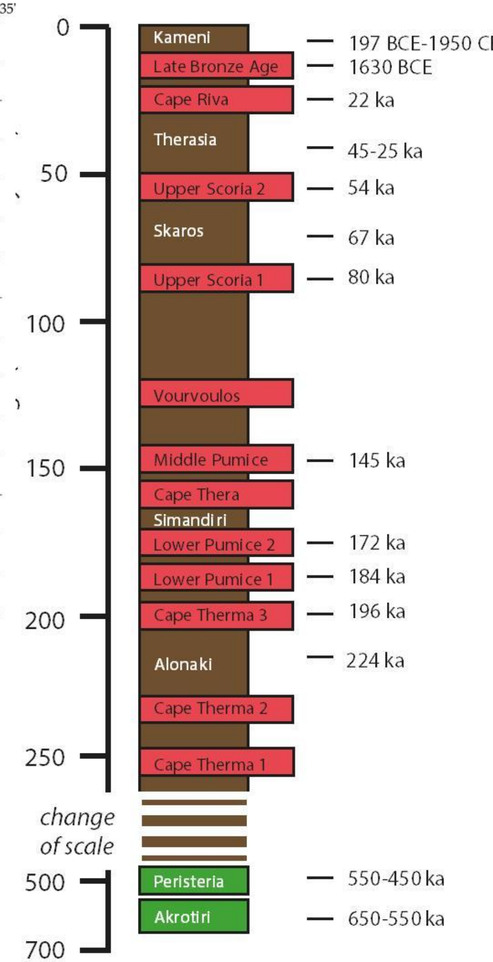
(Nomikou et al., 2019)

# Santorini – one of the most explosive arc volcanoes in the world



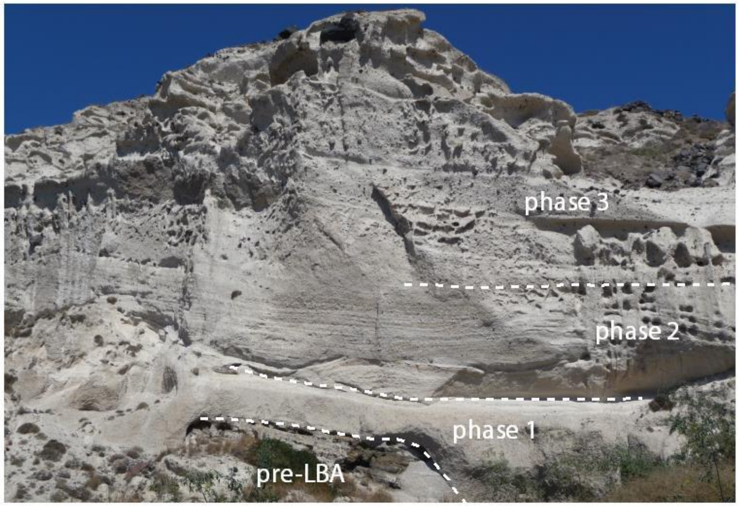

(Nomikou et al., 2016)

➢ Caldera 11 x 7 km, 400 m deep
➢ Active since >650 ka
➢ Highly explosive since 250 ka



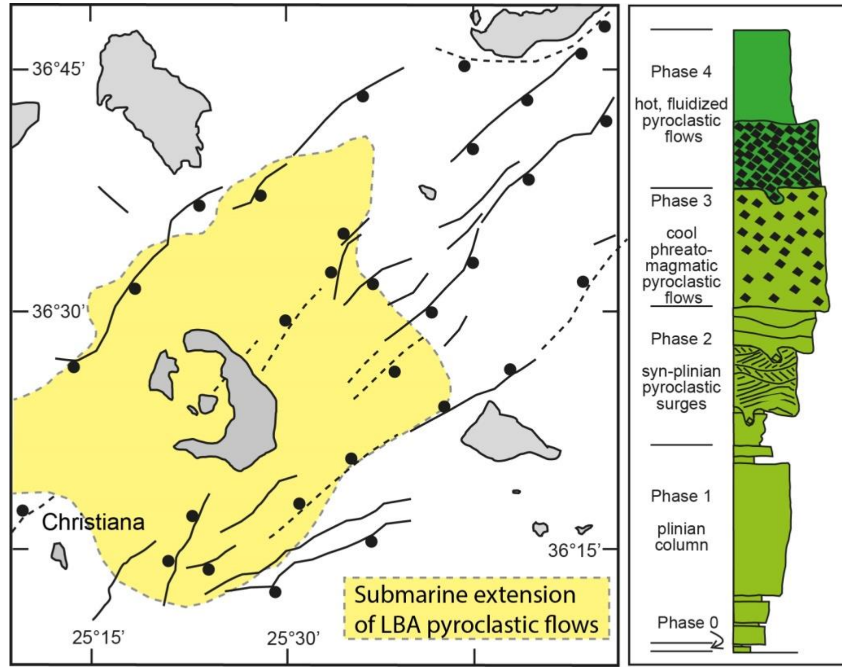

(Druitt, 2014)

# Santorini: The Late Bronze-Age (LBA) eruption
## (also called the Minoan eruption)





Bronze-Age Akrotiri archaeological site, Santorini




(Druitt, 2014)

- Iconic event in volcanology and archaeology
- 1630 BCE (3600 years ago)
- Volume estimate 48-86 km$^3$ (dense-rock equivalent)
- Largest eruption of the Holocene?
- Tsunamis to Minoan Crete

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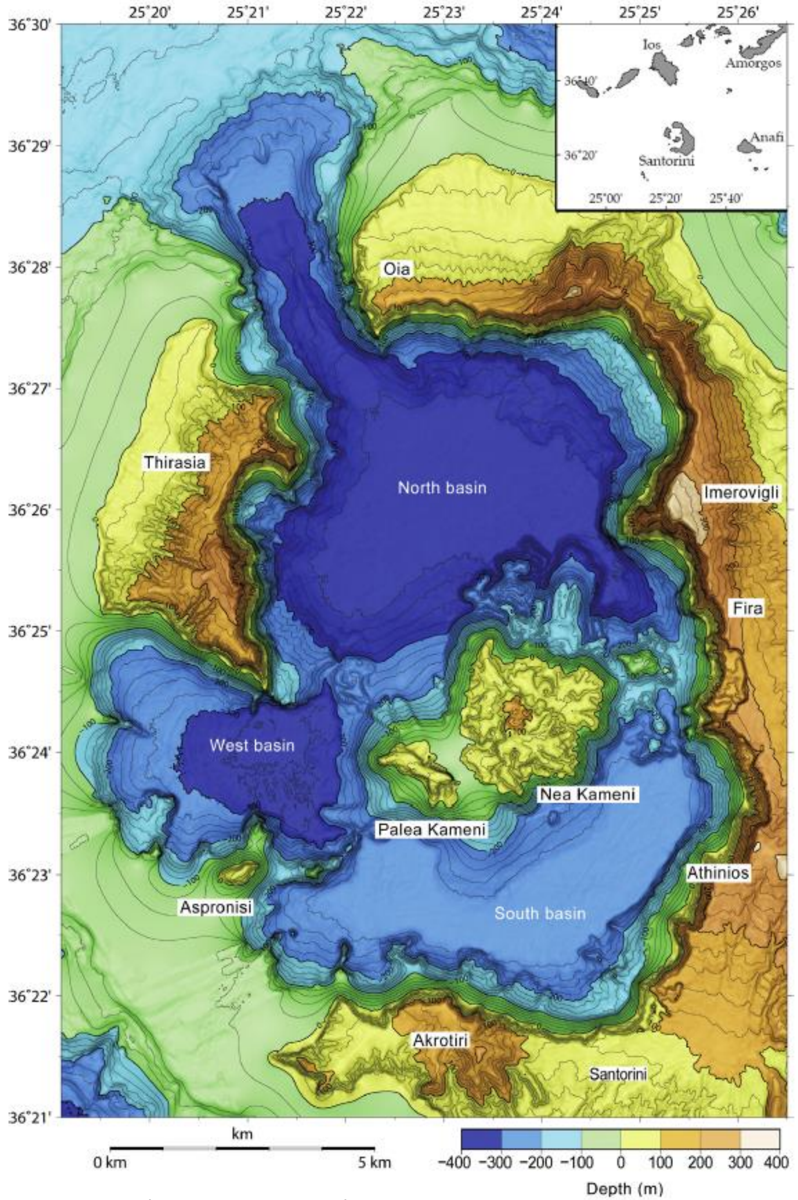
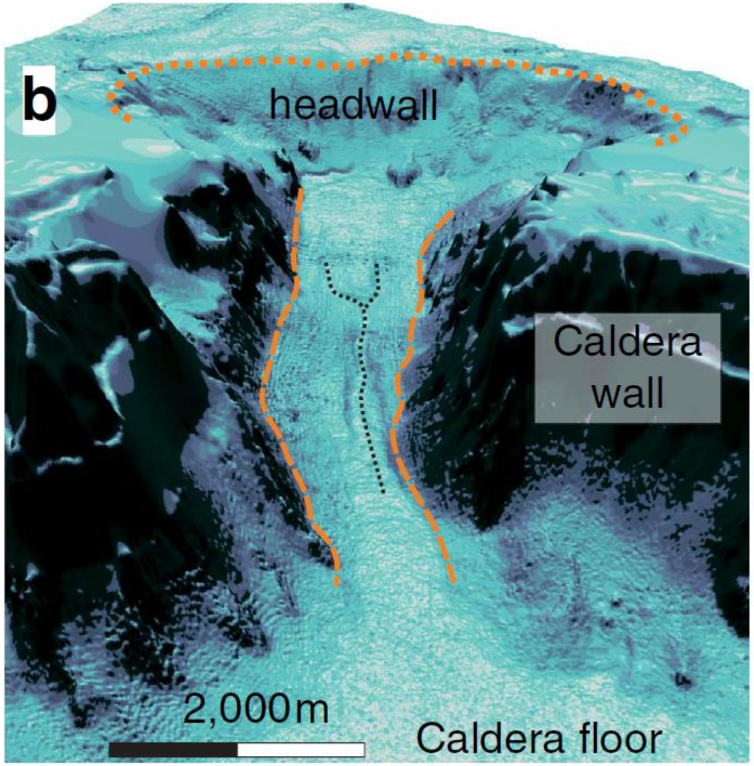
# Santorini caldera



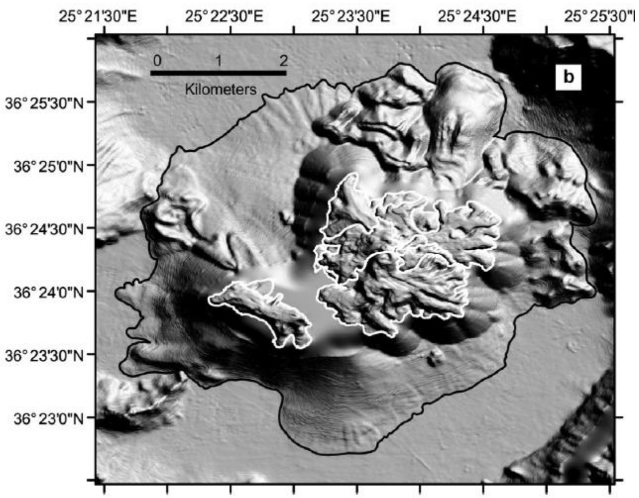

Nomikou et al. (GeoResJ, 2014)



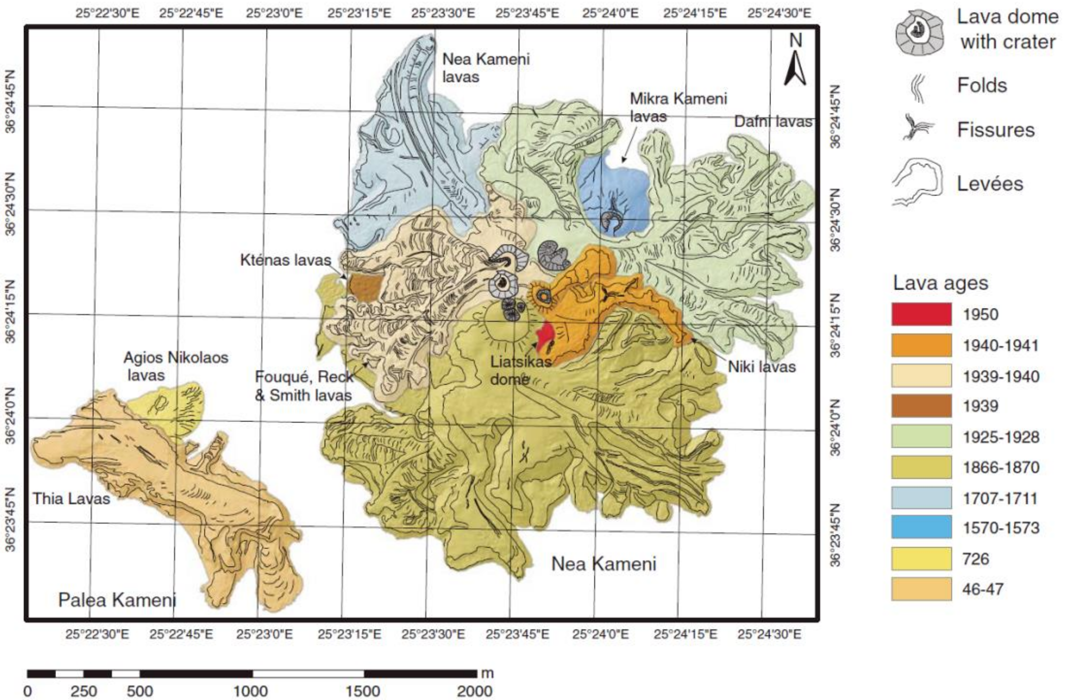

The caldera flooding channel

Nomikou et al. (Nature Geoscience, 2016)

# Santorini: the postcaldera Kameni edifice



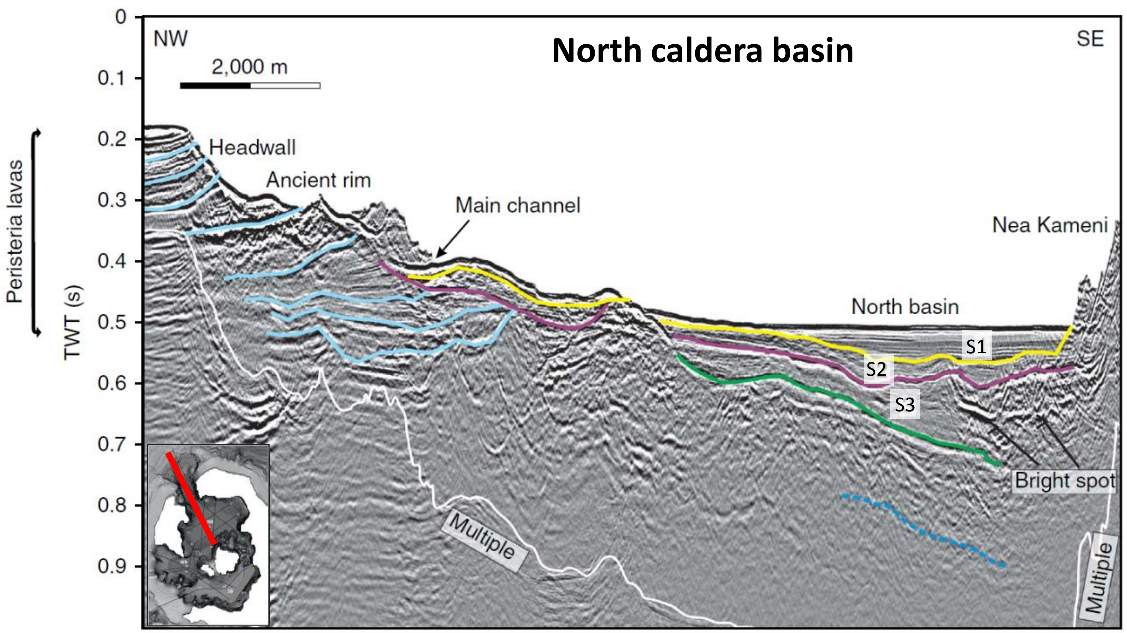

Nomikou et al. (GeoResJ, 2014)



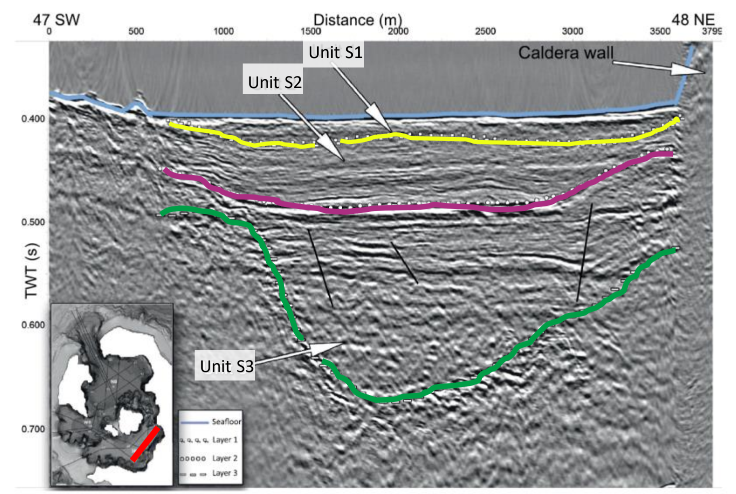

Edifice 470 m high, 3.5 km basal diameter, 4.3 ± 0.7 km$^3$

Pyle and Elliot (Geosphere, 2006)

# Santorini: the shallow caldera fill



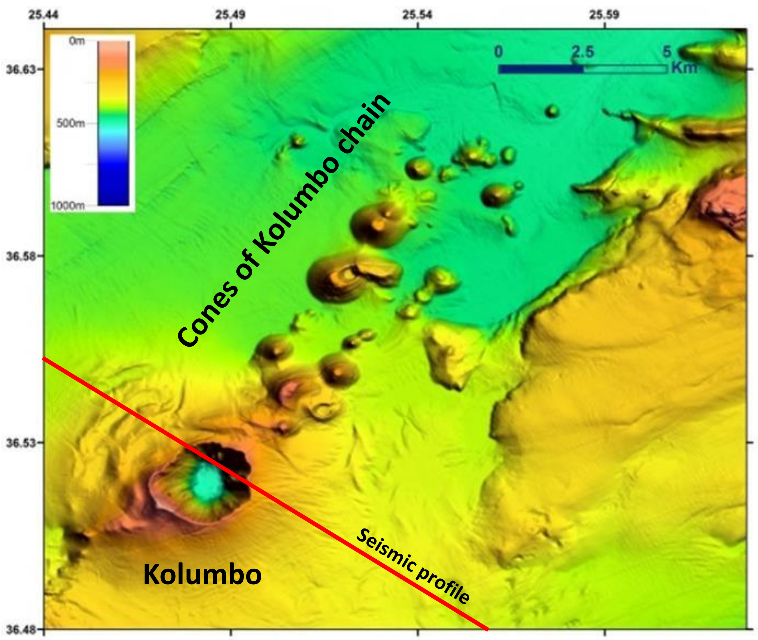

**South caldera basin**




Nomikou et al. (Nature Geoscience, 2016)

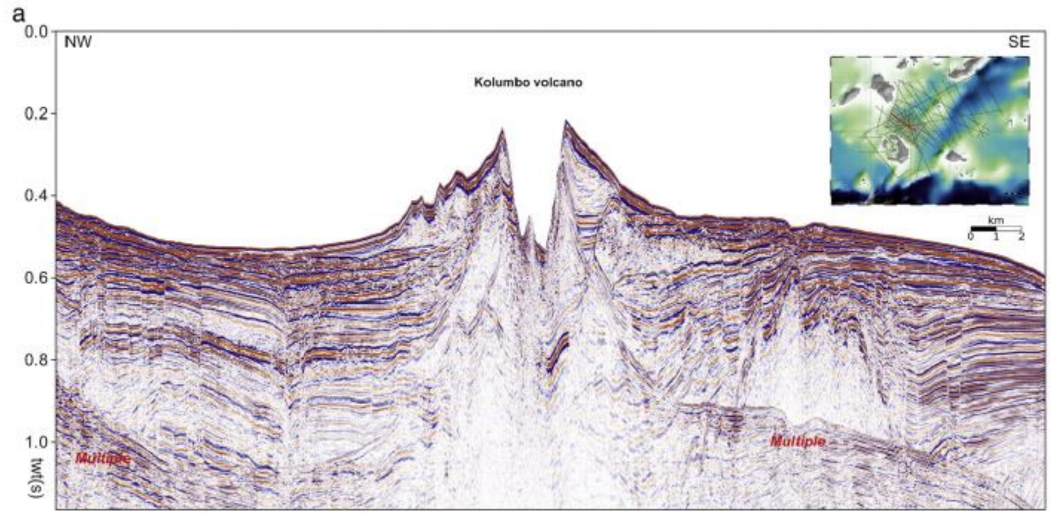
- Unit S1: mass wasting (<2000 years) – up to 40 m thick
- Unit S2: phreatomagmatic tephra and hyaloclastites from submarine Kameni (3600 to 2000 years) – up to 100 m
- Unit S3: possible debris from caldera flooding (3600 years) – up to 250 m thick
- Sub-unit S3: intracaldera tuffs of the Late Bronze Age eruption (3600 years)

# Kolumbo: the killer submarine-to-emergent eruption of 1650 (and before………)

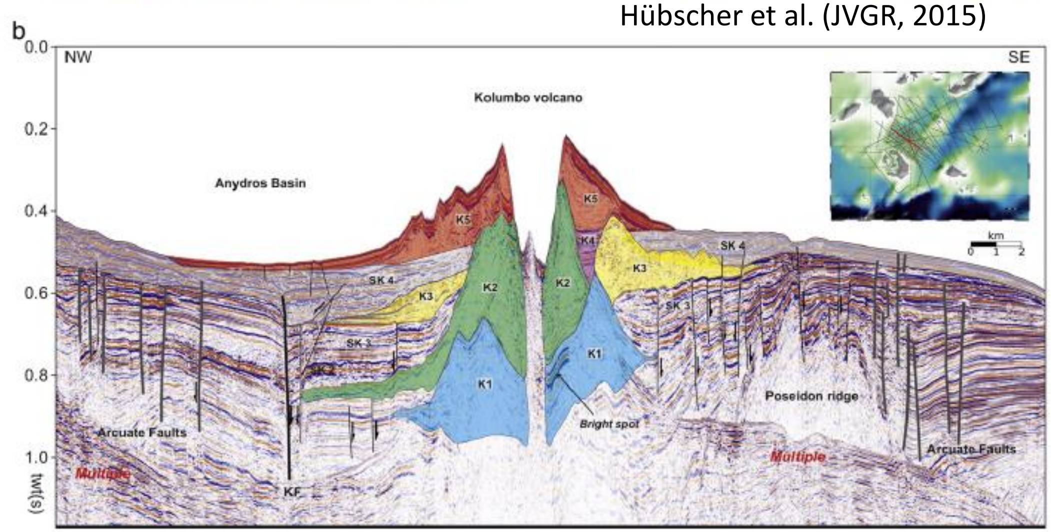



(Nomikou et al., 2012)

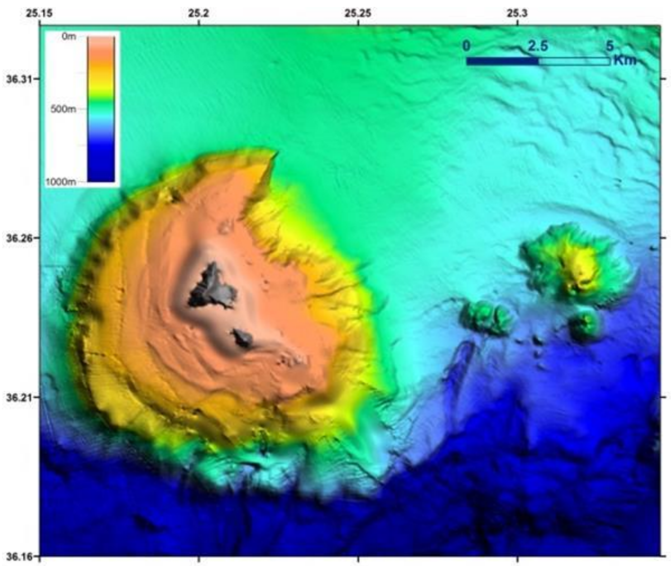
480 m high, 11 km basal diameter
Crater 1.7 km in diameter



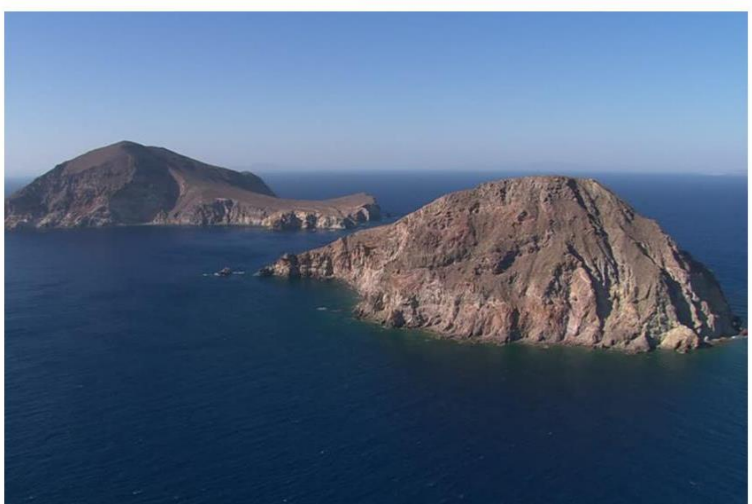

Hübscher et al. (JVGR, 2015)

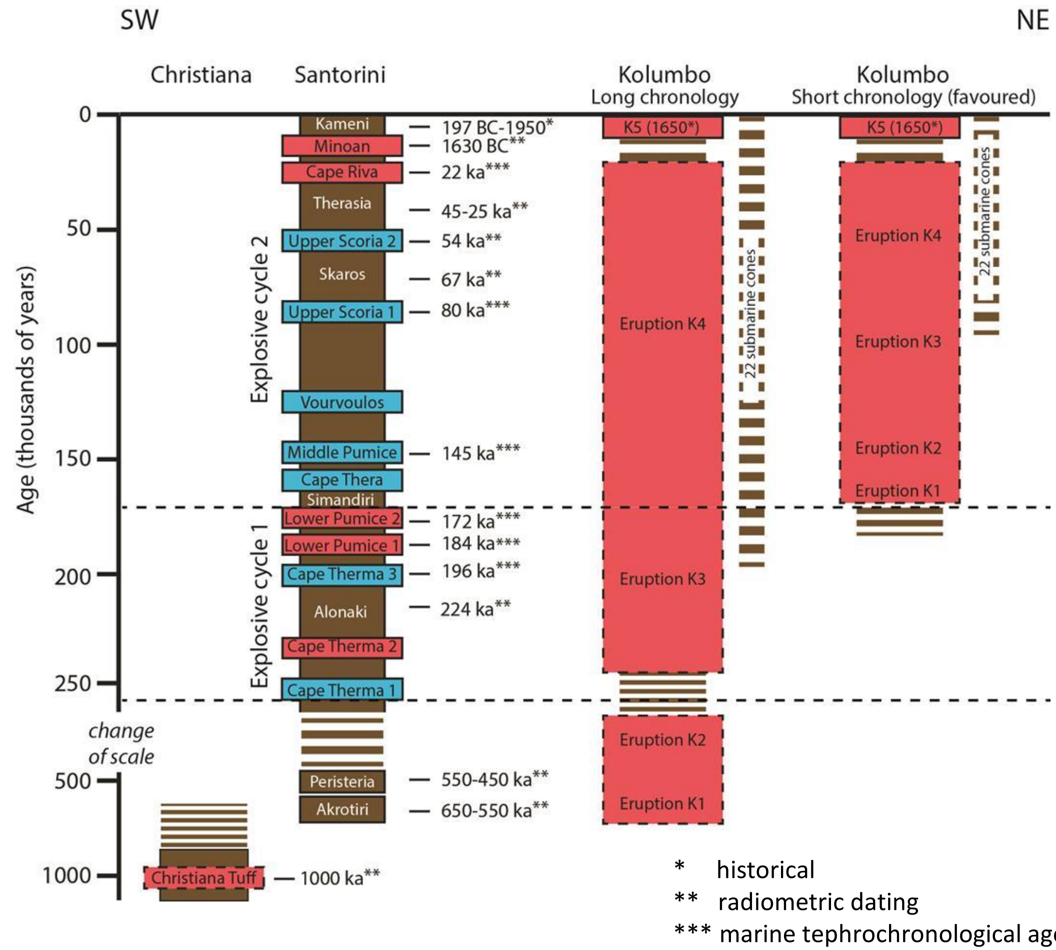


# Christiana: Volcano with a large explosive eruption ~1 Ma, probably now extinct

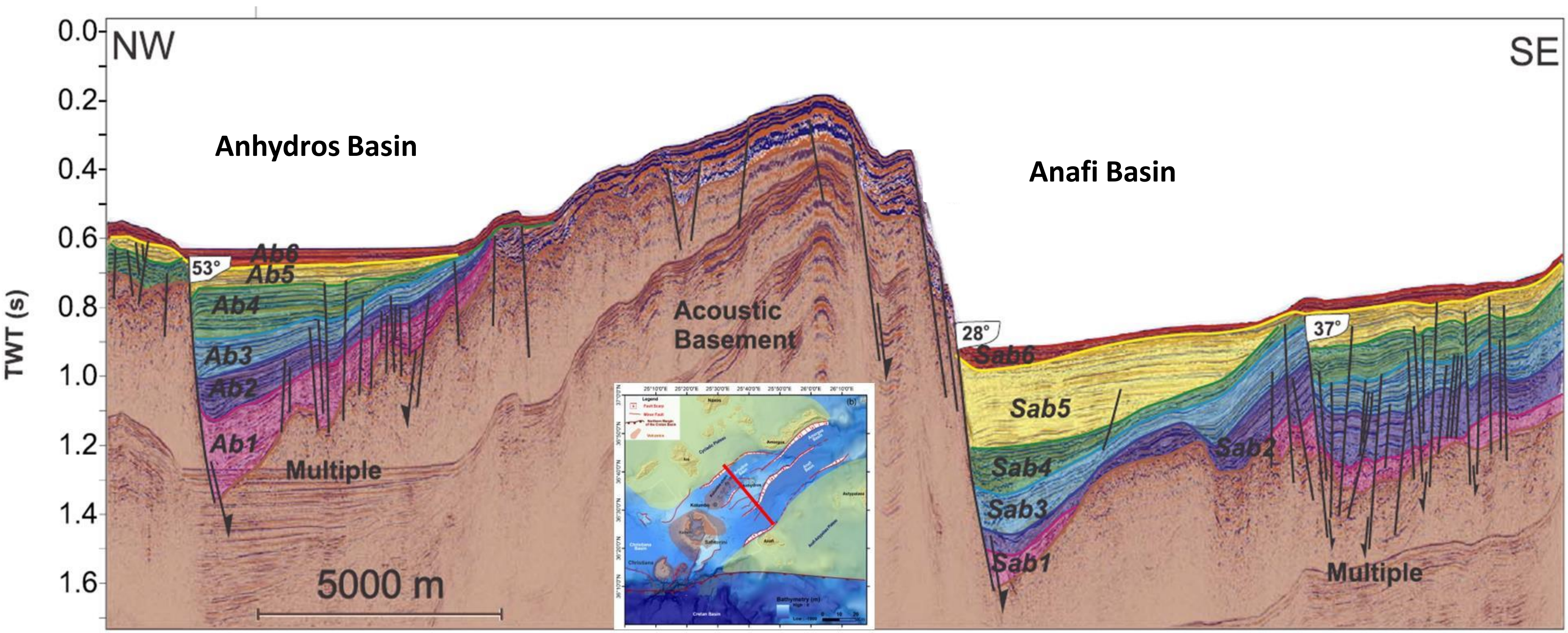



(Nomikou et al., 2013)





# The rift basins: rich archives of volcanic, sedimentary and tectonic history since 4-5 Ma




Nomikou et al. (Tectonophysics, 2018)

Basin Plio-Quaternary fills up to 800 m thick
Six major subsidence events marked by main onlap surfaces

**Why deep drilling and why now?**

- ➢ Deep offshore drilling (360 to 909m below sea floor) will enable:
- Use the thick volcano-sedimentary records of the rift basins and Santorini caldera as time capsules for reconstructing the volcanic and tectonic histories of the area since rift inception in the Pliocene.
- Build on detailed knowledge of onland (incomplete) volcanic history, accessing more continuous marine records
- Recognition and dating of primary eruption products
- Relate to tectonic history from seismic imagery
- ➢ Build on dense seismic reflection networks, extensive shallow-marine coring, and recent PROTEUS tomography experiment
- ➢ Exploit planned presence of Joides Resolution in the North Atlantic in 2002-23

**Primary objectives 1-3 – Volcanism, magmatism tectonics** *[IODP Science Plan challenges 8, 1, 12]*

**Primary objective 4 – The Late Bronze Age eruption and its caldera** *[IODP Science Plan challenge 12]*

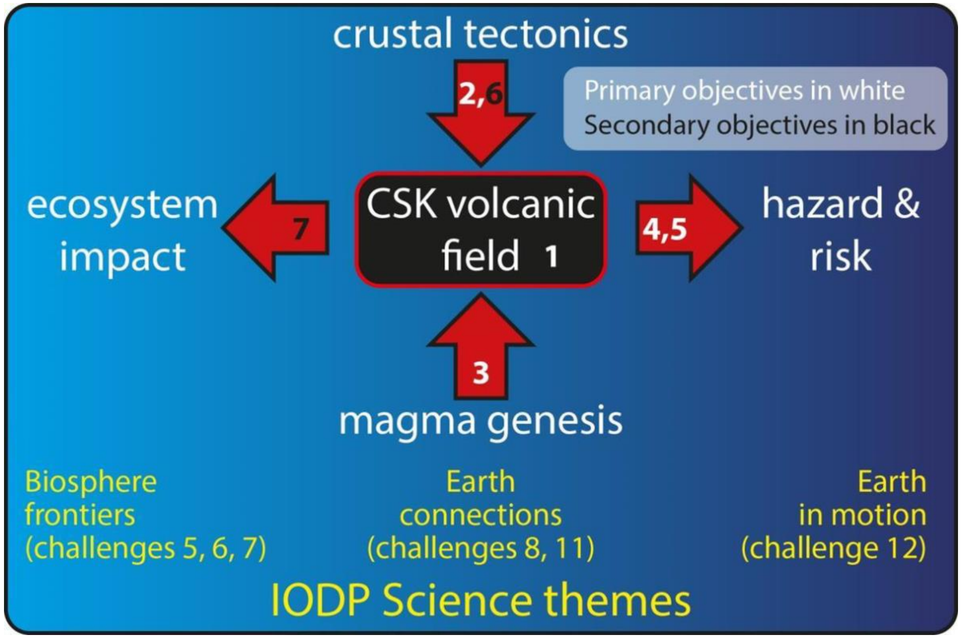
**Primary objective 5 – Volcanic hazards from submarine silicic eruptions** *[IODP Science Plan challenge 12]*

**Secondary objectives** *[IODP Science Plan challenges 5, 6, 7, 11]*

6.Transition from continental to marine environments in the southern Aegean

7.Biological systems reactions to volcanic eruptions and seawater acidification

## Deep offshore drilling will allow us to answer some key questions




- How do eruptive styles at individual centres evolve through time?
- How are large eruptions distributed spatially and temporally along the volcanic field?
- What are the eruptive volumes of the different centres, and magma fluxes through time?
- Do large tectonic events (onlap surfaces, big seismogenic turbidites, homogenites) correlate with
  - activation of the different volcanic centres?
  - changes in eruptive style?
  - particularly large explosive eruptions?
- Does hypothesized younging of volcanism from SW to NE result from NE-wards rift propagation?
- Does magma genesis change as the crust stretches and thins?

## Primary objectives 1-3 – Volcanism, magmatism, tectonics

*[IODP Science Plan challenges 8, 1, 12]*

1. ***Arc volcanism in an active rift environment***: Reconstruct the volcanic history of the CSK volcanic field since the Pliocene by exploiting a >3.8 My marine volcano-sedimentary archive

2. ***The volcano-tectonic connection***: Reconstruct the subsidence and tectonic histories of the rift basins, and use the rift as a natural experiment for studying the relationship between CSK volcanism and major crustal tectonic events

3. ***Arc magmatism in a region of extending crust:*** Document magma petrogenesis at the CSK volcanic field in space and time, and seek effects of crustal thinning on magma storage, differentiation and crustal contamination

## Primary objective 4 – Unravelling an iconic caldera-forming eruption

*[IODP Science Plan challenge 12]*

4. **To penetrate the products inside and outside the caldera and document the processes, products and potential impacts of the Late Bronze Age eruption**

- Was the eruption the largest of the Holocene?
- What happens when pyroclastic flows enter the sea?
- Is the caldera-flooding hypothesis correct?
- How and when (during or after eruption) did the caldera collapse?
- How did a caldera recover and enter a new magmatic cycle?

# Primary objective 5 – Volcanic hazards from submarine silicic eruptions in a region visited by two million tourists per year

***[IODP Science Plan challenge 12]***

5. **To study the histories, dynamics and hazards of Kameni and Kolumbo submarine volcanoes**

➢ Did previous eruptions of Kolumbo have similar dynamics to that of 1650?

➢ Has Kameni had explosive submarine phases like Kolumbo that would need to be accounted for in hazard assessments?

➢ Can we arrive at a general model for this rarely accessible type of silicic submarine volcanism?