IODP Proposal Cover Sheet

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Hellenic Arc Volcanic Field

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

Subduction-related volcanism impacts life and the environment around the edges of continents. Better understanding of island-arc volcanism and associated hazards requires study of the processes that drive such volcanism, and how the volcanoes interact with their marine surroundings. What are the links and feedbacks between crustal tectonics, volcanic activity and magma genesis? What are the dynamics and impacts of submarine explosive volcanism and caldera-forming eruptions? How do calderas collapse during explosive eruptions, then recover to enter new magmatic cycles? What are the reactions of marine ecosystems to volcanic eruptions?

The Christiana-Santorini-Kolumbo (CSK) volcanic field on the Hellenic Volcanic arc is a unique system for addressing these questions. It consists of three large volcanic centres (Christiana, Santorini, Kolumbo), and a line of small submarine cones, founded on thinned continental crust in a 100-km-long rift zone that cuts across the island arc. The CSK volcanic field is notable for Santorini caldera and its Late Bronze Age eruption, an iconic event in both volcanology and archaeology. Kolumbo seamount erupted in 1650, causing many deaths from gas release and tsunami impact. The caldera unrest at Santorini in 2011-12 raised awareness of eruption threat at this major tourist destination.

The marine rift basins around the CSK field, as well as Santorini caldera, contain volcano-sedimentary fills up to several hundreds of metres thick, providing rich archives of CSK volcanic products, tectonic evolution, magma genesis and palaeo-environments accessible only by deep drilling backed up by seismic interpretations. We propose to drill four primary sites in the rifts basins and two additional primary sites inside Santorini caldera. The science has five main objectives, each with a leading testable hypothesis, and two secondary objectives. The proposal addresses all three science themes, and six of the fourteen challenges, of the IODP Science plan.

Existing onland volcanological research, sea-floor mapping, shallow coring and dredge sampling, combined with a dense network of seismic profiles and a recent seismic tomography experiment, make drilling at the CSK volcanic field very timely. Deep drilling is essential to identify, characterise and interpret depositional packages visible on seismic images, to chemically correlate primary volcaniclastic layers in the rift fills with their source volcanoes, to fill in the many gaps in the onland volcanic records, to provide a tight chronostratigraphic framework for rift tectonic and sedimentary histories, and to sample deep subsurface microbial life.

Scientific Objectives

We propose six sites (and associated alternate sites) for deep-sea drilling at the rift-hosted Christiana-Santorini-Kolumbo (CSK) volcanic field on the Hellenic island arc in Greece, with five primary objectives:

1. Arc volcanism in an active rift environment: To reconstruct the volcanic history of the CSK volcanic field since the Pliocene by exploiting a >3.8 My marine volcano-sedimentary archive [IODP Science Plan challenges 11, 12].

2. The volcano-tectonic connection: To 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 [challenges 11, 12].

3. Arc magmatism in a region of extending crust: To document magma petrogenesis at the CSK volcanic field in space and time, and to seek effects of crustal thinning on magma storage, differentiation and crustal contamination [challenges 8, 11].

4. Unravelling an iconic caldera-forming eruption: To document the processes, products and potential impacts of the late Bronze-Age eruption of Santorini [challenge 12].

5. Volcanic hazards from submarine silicic eruptions: To study the histories, dynamics and hazards of Kameni and Kolumbo submarine volcanoes [challenge 12].

Each objective is presented with a leading hypothesis, the testing of which requires ocean drilling and detailed core analysis. We also include two secondary drilling objectives: 6. Transition from continental to marine environments in the southern Aegean [challenge 11]; 7. Biological systems reactions to volcanic eruptions and seawater acidification [challenges 5, 6, 7]

Non-standard measurements technology needed to achieve the proposed scientific objectives

Proposed Sites (Total proposed sites: 13; pri: 6; alt: 7; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
CSK-01A (Primary)	36.7293 25.6482	505	756	9	765	CSK-01A targets the plio-quaternay volcano-sedimentary fill of the Anhydros Basin, to the depth of the Alpine basement. The site lies near the basin axis in a position downstream of Santorini and Kolumbo Volcanoes. The aim is to use the core (and seismic profiles) to reconstruct the volcanic, sedimentary and tectonic histories of the basin, and to access a near-continuous time series of volcanism in the area since rift inception. The hole will transect and characterize all six seismic packages of the Anhydros rift basin (B1 to B6).
CSK-02A (Alternate)	36.7438 25.7146	511	437	10	447	CSK-02A targets the plio-quaternay volcano-sedimentary fill of the Anhydros Basin, to the depth of the Alpine basement. The site lies near the basin axis in a position downstream of Santorini and Kolumbo Volcanoes. The aim is to use the core (and seismic profiles) to reconstruct the volcanic, sedimentary and tectonic histories of the basin, and to access a near-continuous time series of volcanism in the area since rift inception. The hole will transect and characterize all six seismic packages of the Anhydros rift basin (B1 to B6).
CSK-03A (Primary)	36.5549 25.4398	397	566	0	566	CSK-03A lies in the Anhydros Basin on the NW submarine flank of Kolumbo Volcano. The aim is to penetrate four seismically recognized volcanic eruption units from Kolumbo (K2, K3, K5 and the thin lateral continuation of K1), as well as many eruption units from Santorini. This will enable characterisation of the products of the Kolumbo eruptions, as well as construction of a coherent stratigraphy for Santorini and Kolumbo together.
CSK-04A (Alternate)	36.5728 25.4092	403	545	0	545	CSK-04A lies in the Anhydros Basin on the NW submarine flank of Kolumbo Seamount Volcano. The aim is to penetrate seismically recognized volcanic eruption units from Kolumbo, as well as many units from Santorini. This will enable characterisation of the products of the Kolumbo eruptions, as well as construction of a coherent stratigraphy for Santorini and Kolumbo together. However this site only clearly transects one Kolumbo eruption unit (K5), and has been replaced since the pre-proposal by site CSK-04B, which is better placed for our objectives.
CSK-04B (Alternate)	36.5068 25.5053	300	730	0	730	CSK-04B lies in the Anhydros Basin on the SE submarine flank of Kolumbo Seamount Volcano. The aim is to penetrate seismically recognized volcanic eruption units from Kolumbo (K1, K3, K5), as well as many units from Santorini. This will enable characterisation of the products of the Kolumbo eruptions, as well as construction of a coherent stratigraphy for Santorini and Kolumbo together. This site replaces CSK-04A (pre-proposal alternate) as the favoured alternate to site 03A, since CSK-04A only transects one Kolumbo eruption unit whereas CSK-04B samples three.
CSK-05A (Primary)	36.4355 25.3805	385	360	0	360	CSK-05A is sited in the northern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them and confirm (or not) published hypotheses, as well as to penetrate below unit S3 (probably intracaldera tuff of the LBA eruption). The hole is located north of a low-velocity seismic anomaly detected by the PROTEUS seismic tomography experiments and centered on the focus of caldera floor uplift during the unrest period of 2011-12.
CSK-06A (Alternate)	36.4424 25.3751	383	381	0	381	CSK-06A is sited in the northern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them and confirm (or not) published hypotheses, as well as to penetrate below unit S3 (probably intracaldera tuff of the LBA eruption).
CSK-07A (Primary)	36.3890 25.4171	292	400	0	400	CSK-07A is sited in the southern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them, as well as to penetrate below unit S3 (probable intracaldera tuff of the LBA eruption). This site is complementary to sites CSK-05A/06A in the northern caldera basin, as together they will provide a complete understanding of the caldera fill and collapse history.
CSK-08A (Alternate)	36.3816 25.4061	293	400	0	400	CSK-08A is sited in the southern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them, as well as to penetrate below unit S3 (probable intracaldera tuff of the LBA eruption). This site is complementary to sites CSK-05A/06A in the northern caldera basin, as together they will provide a complete understanding of the caldera fill and collapse history.

Proposed Sites (Continued; total proposed sites: 13; pri: 6; alt: 7; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
CSK-09A (Primary)	36.5656 25.7613	694	585	10	595	CSK-09A is sited in the Anafi Basin. The aim is to penetrate the entire volcano-sedimentary fill of this basin as far as the Alpine basement. The basin potentially records the full volcanic history of Santorini (and any older centres) since rift inception, but not of Kolumbo Volcano. The hole will reconstruct the subsidence and sedimentary history of this basin, to compare with that of the Anhydros Basin. It will transect all six seismic units present in the basin (B1 to B6).
CSK-10A (Alternate)	36.5494 25.7714	672	368	9	377	CSK-10A is sited in the Anafi Basin. The aim is to penetrate the entire volcano-sedimentary fill of this basin as far as the Alpine basement. The basin potentially records the full volcanic history of Santorini (and any older centres) since rift inception, but not of Kolumbo Volcano. The hole will reconstruct the subsidence and sedimentary history of this basin, to compare with that of the Anhydros Basin. It will transect the topmost five of the six seismic units present in the basin (B2 to B6).
CSK-11A (Primary)	36.3897 25.2142	408	823	0	823	CSK-11A is sited in the Christiana Basin. This basin is deeper than the Anhydros and Anafi Basins, and is located SW of Santorini. Its volcano-sedimentary fill potentially records the earlier volcanic history of the CSK volcanic field (including the products of Christiana and early Santorini), as well as younger Santorini and possibly Milos Volcano. The hole will pass through three prominent volcanic units (PFI to PFIII) seen on seismic records. This site may move slightly following planned acquisition of new seismic data in the Christiana basin.
CSK-12A (Alternate)	36.3842 25.2352	367	836	0	836	CSK-12A is sited in the Christiana Basin. This basin is deeper than the Anhydros and Anafi Basins, and is located SW of Santorini. Its volcano-sedimentary fill potentially records the earlier volcanic history of the CSK volcanic field (including the products of Christiana and early Santorini), as well as younger Santorini and possibly Milos Volcano. The hole will pass through three prominent volcanic units (PFI to PFIII) seen on seismic records. This site may move slightly following planned acquisition of new seismic data in the Christiana basin.

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

1. Introduction and rationale

Volcanic hazards and risk lie at the heart of global geoscience, with about 800 million people threatened by eruptions (Loughlin et al. 2015). Volcanoes in island arc settings impact humans and the environment through submarine explosions, tephra fallout, pyroclastic flows, earthquakes, tsunamis, and ocean acidification (Sigurdsson et al. 2015). Some large eruptions, such as the Late Bronze Age eruption of Santorini, destabilize entire civilizations (Bruins et al. 2008). On the other hand, volcanoes can host rich ecosystems and fertilize the oceans (Duggen et al. 2010; Christakis et al. 2017).

Better understanding of the processes governing arc volcanoes and their hazards is important as the 21st century unfolds (McGuire et al. 2017; National Academies of Sciences, Engineering, and Medicine, 2017). Crustal tectonics is one process that strongly influences volcanism, but it has rarely been studied at high spatial and temporal resolutions (e.g., Cembrano and Lara 2009). 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 (Farner and Lee 2017). Extensional crustal motions across many island arcs create space for magma ascent and influence the depths and sizes of magma storage regions (Acocella and Funiciello 2010; Bachmann and Huber 2016). Large earthquakes cause changes in crustal stresses sufficient to induce eruptions up to several hundreds of km away (Walter and Amelung 2007). Changes in sea level driven by tectonics or climate modulate volcanic activity by loading or unloading the magma plumbing system (Kutterolf et al. 2013; Sternai et al. 2017).

We propose to study these processes by deep-sea drilling at the rift-hosted Christiana-Santorini-Kolumbo (CSK) volcanic field on the Hellenic island arc in Greece (Fig. 1), with five primary objectives:

1. *Arc volcanism in an active rift environment:* To reconstruct the volcanic history of the CSK volcanic field since the Pliocene by exploiting a >3.8 My marine volcano-sedimentary archive **[IODP Science Plan challenges 11, 12]**.

2. *The volcano-tectonic connection:* To 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 **[challenges 11, 12]**.
3. *Arc magmatism in a region of extending crust:* To document magma petrogenesis at the CSK volcanic field in space and time, and to seek effects of crustal thinning on magma storage, differentiation and crustal contamination **[challenges 8, 11]**.
4. *Unravelling an iconic caldera-forming eruption:* To document the processes, products and potential impacts of the late Bronze-Age eruption of Santorini **[challenge 12]**.
5. *Volcanic hazards from submarine silicic eruptions:* To study the histories, dynamics and hazards of Kameni and Kolumbo submarine volcanoes **[challenge 12]**.

We also include two secondary drilling objectives: *6. Transition from continental to marine environments in the southern Aegean **[challenge 11]**; 7. Biological systems reactions to volcanic eruptions and seawater acidification **[challenges 5, 6, 7].***

This initiative arose from a MagellanPlus meeting held in Athens in 2017, attended by 30 researchers and early career scientists, followed by a successful pre-proposal (932-Pre).

2. Why Christiana-Santorini-Kolumbo volcanic field, why ocean drilling, why now?

Unique site at the international scale. The CSK volcanic field is one of the most active in Europe, having produced over 100 explosive eruptions in the last 250,000 years (Druitt et al. 1999). Lying in a rift zone that cuts NE-SW across the island arc, the field includes the extinct Christiana Volcano, Santorini caldera with its intracaldera Kameni Volcano, Kolumbo Volcano, and the 22 submarine cones of the Kolumbo chain (Figs. 1b, 2a) (Hooft et al. 2017; Nomikou et al. 2013), all of which have discharged their volcanic products into adjacent marine basins creating a rich archive of past eruptions. Santorini is one of the most explosive arc volcanoes in the world (Fig. 3a); its onland products have been mapped, dated and chemically fingerprinted, and its historical eruptions are very well documented (Druitt et al. 1999; Pyle and Elliott 2006). Kolumbo Volcano has had at least five large explosive eruptions, the last in 1650 (Hübscher et al. 2015).

Need for Ocean drilling. We have a record of Santorini volcanism since 650,000 y, but it is only detailed since 250,000 y. While the onland record is inevitably discontinuous, the marine record promises to be much more complete (e.g. Schindlbeck et al. 2016). Apart from the 1650 eruption, the past volcanism of Kolumbo is poorly documented and that of Christiana unknown. Offshore drilling will enable us to 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. Drilling will allow (i) ground-truthing of marine seismic profiles, (ii) characterisation and dating of seismic packages, (iii) measurements of the physical properties of submarine strata, and (iv) sampling of subsurface ecosystems. Neither DSDP Hole 378 in the Cretan Basin (344 mbsf; Hsü et al. 1978), nor the 1987-88 onland Kameni Island drilling initiative (201 m penetration; Arvanitides et al. 1988) were suitably located to recover fresh, continuous volcaniclastic sequences. Neither onland drilling, nor shallow piston coring, can address our scientific questions in a similar way.

Major hazard to the Eastern Mediterranean region. Hazards from the CSK rift zone include earthquakes, eruptions, and tsunamis (Vougioukalakis et al. 2016). The level of seismicity is amongst the highest in Europe (Sachpazi et al. 2016), and the largest 20th century shallow earthquake in Europe (M 7.5) took place there in 1956 (Okal et al. 2009). The Late Bronze Age (LBA) eruption of Santorini in about 1630 BCE was one of the largest of the Holocene Epoch worldwide; it may have influenced the decline of the Minoan civilization on Crete and is an iconic event in volcanology and archaeology (Bruins et al. 2008). The 1650 eruption of Kolumbo killed 70 people on Santorini through gas release and tsunami inundation (Cantner et al. 2014). In 2011-12, Santorini had an episode of seismic unrest (Parks et al. 2015), raising awareness of eruption threat at these islands visited by two million tourists per year.

Large database of seismic profiles and marine characterization. A dense network of sub-seafloor seismic reflection profiles exists across the rift zone and within Santorini caldera, giving high-resolution images of sedimentary fills and faults (Fig. 2a). In 2015, an active seismic tomography experiment of the CSK system was carried out (PROTEUS: Plumbing Reservoirs Of The Earth Under Santorini) (Hooft et al. 2017). It identified an enigmatic, low-density anomaly extending from 400 to 3000 m beneath Santorini caldera (Hooft et al. 2019), the stratigraphic and structural contexts of which can only be constrained by drilling. Multibeam bathymetric surveys have imaged submarine volcanic edifices and calderas

(Nomikou et al. 2012; 2013; 2016a). Sea floor volcanic products, hydrothermal deposits and bacterial mounds have been sampled (Hanert 2002; Camilli et al. 2015), and the surface biosphere documented (Oulas et al. 2016). Deep-sea ash layers have been sampled by gravity coring across the Eastern Mediterranean (Fig. 2b), and many have been correlated with onland products. The resulting marine ash stratigraphy extends back to 200,000 y (but not earlier; Satow et al. 2015; Kutterolf et al. 2019), and includes eight ashes from Santorini.

The time is right. The planned track of the Joides Resolution into the North Atlantic in 2022 favours drilling now. Additionally, the existing onland and offshore research, the high-quality site-survey data, and the PROTEUS experiment make application timely. It is rare to drill in the context of high-resolution seismic tomography.

3. Relationship to the IODP science plan and other initiatives

Our proposal relates to all three science themes, and 6 out of the 14 challenges, of the IODP Science plan (Fig. 1a). It builds on IODP Expedition 381 in the Gulf of Corinth, which focussed on rift development in the absence of volcanism (McNeil et al. 2017). It complements Expedition 376 at Brothers caldera, which is on oceanic crust whereas Santorini is on extended continental crust. It also complements the proposal for drilling at Campi Flegrei (Italy), a large, resurgent caldera (De Natale et al. 2017). Santorini is a smaller caldera that lacks post-collapse resurgence, so the processes of intracaldera activity and unrest are different from those at Campi Flegrei. The proposal links to the Geoprisms, Subduction Zone 4D (McGuire et al. 2017) and Deep Carbon Observatory (Sloan Foundation) international initiatives. It addresses key issues raised in the 2017 report by the U.S. National Academies, entitled "Volcanic Eruptions and Their Repose, Unrest, Precursors, and Timing". Deep drilling at the CSK volcanic field will build on the 2015 PROTEUS seismic tomography experiment, and the shallow gravity coring of POSEIDON cruises 511-513. A European Union COST application ('MARVELOUS'-SubMARine Volcanoes European coLlaboratiOn Uniting experts and Society) on submarine volcanism (PI: P. Nomikou) is currently under evaluation. An issue of the professional Earth Science magazine *Elements* devoted to the South Aegean Volcanic Arc (Druitt and Vougioukalakis 2019) will be published in June 2019.

4. Response to pre-proposal review

The pre-proposal review remarked that our scientific objectives were very broad. We focus here on five primary objectives, with two secondary ones, and present the science as testable hypotheses. The penetration depth of hole CSK-05A/06A is reduced from 1200 to <400 mbsf (the maximum depth of seismic profiles), and the science aims are clearly stated. Available heat flow data are provided, and a seismic velocity model is included in the SSDB and online Form 5. Since volcaniclastics may limit recovery in some depth intervals, we propose to drill at least three holes at each site in order to maximise recovery. We provide SSDB descriptions of volcaniclastics encountered in gravity cores as a guide for deep drilling strategy. The Nagoya Protocol is addressed. A request for new seismic profiles has been submitted; following consultation with the watchdogs, we are proceeding with full submission while awaiting those data. Clarifications of specific review remarks are given in the text.

5. Background

The CSK rift zone and its regional setting

The Hellenic volcanic arc has formed by subduction of the African plate beneath the European plate (Shaw and Jackson 2010). The present-day arc was initiated 3-4 My ago, and stretches from mainland Greece eastwards through Milos, the CSK volcanic field, to the Kos-Nisyros-Yali complex (Pe-Piper and Piper 2005). Back-arc extension has thinned the Aegean continental crust, creating horsts and grabens (Le Pichon and Kreemer 2010; Royden and Papanikolaou 2011) (Fig. 1b).

The CSK rift zone lies on 18-20 km of extended continental crust (Makris et al. 2013). It is 100 km long, 45 km wide, and comprises three main NE-SW-oriented marine basins with Plio-Quaternary sedimentary fills up to 800 m thick (Piper and Perissoratis 2003; Nomikou et al. 2016b; 2018) (Figs. 4, 5). Anhydros Basin contains the Kolumbo volcanic chain, whereas Amorgos and Anafi Basins lack volcanoes. Anhydros and Anafi Basins each contain six seismic stratigraphic units (here named B1 to B6, upwards), separated by onlap surfaces (Fig. 4), whereas Amorgos only contains B3-B6 (Nomikou et al. 2018). Thickness variations of the units record initial symmetric rifting (B1-B3) followed by NW-tilted, more asymmetric rifting (B4-B6). Rifting began 3.8-5.3 My ago in the Pliocene and is proceeding at about 2.5 mm/y (Reilinger et al. 2010; Nomikou et al. 2018).

The Christiana Basin, a broad, fault-bounded basin at the SW entrance of the rift zone – Fig. 6), contains Plio-Quaternary sediments and three units of probable pyroclastic flow origin: the oldest (PF III) is estimated at 0.42-1.25 Ma and the middle one (PF II) at $\leq$0.42 Ma; the youngest (PF I) is interpreted as pyroclastic flow deposits from the LBA eruption of Santorini. (Tsampouraki-Kraounaki et al. 2018).

The CSK volcanic centres

Santorini caldera is a complex 11 x 7 km structure caused by at least four collapse events over the last 200,000 y, the last of which was the LBA eruption (Druitt and Francaviglia 1992). It has a northern basin 390 m deep, a southern basin 280m deep, and is connected to the sea via three breaches (Fig. 7a) (Nomikou et al. 2014). The caldera's volcano-sedimentary fill is 1 km thick (Budetta et al. 1984). The Kameni islands are the subaerial summit of a 470-m-high intracaldera edifice formed since the LBA eruption.

Volcanism at Santorini began 650,000 y ago with submarine, then subaerial, effusive activity, and became highly explosive 250,000 y ago (Fig. 3a). There have since been 12 plinian eruptions (and approximately 100 less intense explosive eruptions) many of which generated high ash plumes and pyroclastic flows that entered the sea (Druitt et al. 1999). The LBA eruption of 1630 BCE discharged several tens of km^3 of silicic magma as fallout and pyroclastic flows (Sparks and Wilson 1990; Druitt 2014), and the resulting caldera collapse deepened an already-existing caldera, probably sited north of the present-day Kameni Islands (Athanassis et al. 2016). After the caldera had collapsed, the sea broke through the NW breach, carving out a 2-km-wide submarine channel (Nomikou et al. 2016a). The Kameni Volcano has had nine subaerial effusive eruptions from 197 BCE to 1950, but bathymetry suggests a long previous submarine history (Pyle and Elliot 2006; Nomikou et al. 2014).

Seismic profiles reveal three main units in the topmost caldera fill (here named S1 to S3; Figs. 7d-f, 8a, 9), interpreted most recently as follows (Johnston et al. 2015; Nomikou et al. 2016a):

- S1 - Flat-lying sediments up to 40 m thick: mass wasting of the caldera cliffs;
- S2 - Sediments up to 100 m thick that merge into the clastic apron of Kameni edifice: tuffs and hyaloclastites from the submarine phase of Kameni;
- S3: Down-faulted deposits up to 250 m thick: uppermost levels of LBA intracaldera tuffs and/or sediments related to post-eruptive flooding of the caldera.

Sub-S3 deposits lack layering on seismic images, and are interpreted as LBA intercaldera tuffs. Other, less detailed, interpretations have also been proposed (Perissoratis 1995; Sakellariou et al. 2012)

The low-density anomaly imaged by PROTEUS is a vertical cylinder 3.0 ±0.5 km in diameter extending from 400 to 3000 mbsf beneath the northern basin of the caldera (Figs. 7b,c, 8b,c). It may be a large vent or collapse structure related to the Kameni Volcano, the LBA eruption, or earlier caldera-forming eruptions (Hooft et al. 2019). An episode of seismic unrest at Santorini from January 2011 to March 2012 was accompanied by up to 10 cm of inflation on Nea Kameni island; it has been attributed to intrusion of magma 3-6 km beneath the caldera (Parks et al. 2015). The focus of uplift in 2011-12 directly overlies the low-density anomaly (Figs. 7b,c), suggesting a relationship between them (Hooft et al. 2019).

The extinct Christiana Volcano produced lavas and tuffs of unknown ages (Aarbourg and Frechen 1999), but a particularly large ignimbrite found on neighbouring islands is dated at 1.00 +/- 0.05 Ma (Keller et al. 2010). This 'Christiana Tuff' may be pyroclastic flow PF III (0.42-1.25 Ma) in the Christiana Basin, and it is expected to occur at depth throughout the entire rift area. Geochemical and $^{40}Ar/^{39}Ar$ dating studies of onland Christiana volcanics are in progress (Vrije Universiteit, Amsterdam).

Kolumbo Volcano is 480 m high, with a 1.7-km-diameter summit crater formed in 1650 (Nomikou et al. 2012; Carey et al. 2013). Seismic profiles across it reveal five units interpreted as Kolumbo-derived volcaniclastics (K1 to K5 from the base up), unit K5 being the 1650 eruption (Hübscher et al. 2015) (Fig. 10b,c). All five units postdate seismic unit B3 in the Anhydros Basin, and hence the onset of asymmetric subsidence in the rift. The submarine cones NE of Kolumbo postdate unit K3 on seismic profiles; they are much smaller than Santorini or Kolumbo, and their products are not expected to be prominent in our drill cores.

6. Proposed drilling

Six primary drill sites (and seven alternate sites) are proposed, with water depths of 292-694 m and penetrations of 360-836 mbsf (Fig. 2a). Sediments are expected to include Plio-Quaternary turbidites/debris flows, hemipelagic sediments and volcaniclastics. For brevity, we refer to turbidites/debris flows as 'turbidites'. We also shorten the site names (e.g., CSK-01A is denoted site 01).

Sites 01/02 in Anhydros Basin and 09/10 in Anafi Basin (Fig. 4b) will penetrate seismic units B1-B6 to the basement unconformity (Mesozoic limestones, schists and/or granites; Kilias et al. 2013). They will traverse thick, near-basin-axis successions at locations likely to contain eruption-generated turbidites and where seismic stratigraphy is well constrained. In order to avoid the very high-energy axis of each basin, our sites are intentionally placed slightly off-axis. As a result we may encounter small hiatuses in deposition associated with onlap surfaces between the six seismic units. While this will reduce the completeness of our stratigraphic record, it will not threaten our objectives. Note that drilling on adjacent bathymetric highs would not sample full sequences of events (as seen on seismic profiles), and would make it impossible to link volcanic stratigraphy to rifting history.

By drilling in both NE basins, we will achieve the fullest sampling of the submarine volcanic record, since each basin taps a different sediment distributary branch of the CSK system. Site 01/02 lies in Anhydros Basin downstream of Kolumbo Volcano and the submarine terminus of the LBA pyroclastic flows (Fig. 2a); it is expected to yield volcaniclastics from Kolumbo eruptions and large Santorini eruptions, but not smaller Santorini eruptions due to flow blocking by the Kolumbo chain. Site 09/10 in Anafi Basin, on the other hand, is expected to sample volcaniclastics from most explosive eruptions of Santorini, but not Kolumbo.

Site 03/04 will penetrate the flank of Kolumbo Volcano to sample its products for correlation with other drill sites. Primary site 03 will sample units K1, K2, K3 and K5 or their thin lateral continuations (Fig. 10c).

Site 11/12 is designed to sample the earlier volcanic history of the CSK field, including eruptions of Christiana, Santorini, and possibly Milos.

Santorini caldera sites 05/06 (northern basin) and 07/08 (southern basin) will sample seismic units S1-S3, test the published correlations between the two caldera basins, and penetrate below S3. Unit S1 probably consists of muds and sands, S2 compacted (and possibly lithified) sandy volcaniclastics, and S3 consolidated coarse blocky tuffs, landslide debris and/or flood gravels. The sub-S3 levels probably consist of blocky, indurated intracaldera tuffs of the LBA eruption. Recent heat flow measurements (Hannington et al. 2017; see Fig.2a for sites) give 506-1496 $mW.m^{-2}$ in the northern caldera basin and 8064 $mW.m^{-2}$ in the southern caldera basin, higher than the 56-63 $mW.m^{-2}$ measured far from the volcanoes in the Anhydros Basin (and consistent with regional values of 60-80 $mW.m^{-2}$;

Kalyoncuoglu et al. 2013). However, no high-temperature hydrothermal system has been recognized in the caldera, only low-temperature hydrothermal areas (60-100 °C on Nea Kameni; 18-20 °C on the caldera floor) and pools of CO_2-rich bottom water (Tassi et al. 2013; Camilli et al. 2015).

Our site prioritization order is: 01/02, 03/04, 11/12 (to obtain a full volcanic history of the area), 05/06, 07/08 (to access Santorini intracaldera fill), and lastly 09/10.

7. Hypotheses to be tested by deep drilling

Objective 1. Arc volcanism in an active rift environment

Leading hypothesis. *The CSK volcanic field has developed from SW to NE with time*

Existing onland and marine seismic data suggest that Christiana is the oldest volcanic centre, Santorini intermediate, and Kolumbo the youngest (Fig. 3a). ***We will test the leading hypothesis*** by using cores from all sites to reconstruct a complete volcanic stratigraphy of the CSK volcanic field since rift inception in the Pliocene, consistent with both onland and marine constraints. Were there earlier, now-buried volcanic centres in the area? How are large eruptions distributed spatially and temporally along the volcanic field? How do eruptive styles at individual centres evolve through time? Using seismic profiles linked to the cores, we will estimate eruptive volumes and fluxes for the different eruptive centres, and for the CSK field as a whole.

Eruption products will be preserved in the rift basins as tephra fallout, but mostly as turbidites channelled down the basin axes from volcanoes upslope (e.g., Schmincke and Sumita 2006). Using criteria for recognising eruption-related turbidites (Table 1), we will correlate primary volcaniclastic beds based on chemical and textural criteria between cores, as well as from core to source volcano using onland (Christiana, Santorini) and drilled (Kolumbo) near-source sequences. Bed-to-bed and seismic unit-to-unit correlation between cores will use major and trace element compositions of juvenile blocks or lapilli, glasses, crystal-hosted glass inclusions (Brandl et al. 2017), and phenocrysts. Pyroclast textures (e.g., vesicle abundances, sizes and shapes) and accidental lithic assemblages will aid in correlation, as will physical properties measured onboard ship. Correlation of volcaniclastics to source volcanoes will exploit established chemical and mineralogical differences between the different volcanic centres (Figs. 3b,c). Tephra fall layers from other circum-

Mediterranean volcanoes will serve as marker beds (Satow et al. 2015). Absolute dates of cored volcanic layers based on (i) published onland ages, (ii) published ages of marine tephra fall layers, and (iii) new radiometric age determinations of suitably fresh drilled pyroclasts (Table 1) will refine the volcanic chronostratigraphy. The result will contribute to existing facies models for explosive volcanoes in marine settings (e.g., Schmincke and Sumita 2006).

Objective 2. The volcano-tectonic connection

Leading hypothesis. *Rifting has exerted a control on spatial and temporal development of volcanism in the CSK volcanic field, with links between major crustal tectonic events and eruption history.*

Studies of Miocene plutons, of fault patterns along the modern-day arc, and of relationships between regional seismicity and caldera unrest at Santorini in 2011-12 all hint at strong relationships between Aegean volcanism and crustal tectonics (Kokkalas and Aydin 2013; Feuillet 2013; Rabillard et al. 2018). ***We will test the leading hypothesis*** by (i) reconstructing the histories of subsidence and tectonics of the Anhydros, Anafi and Christiana Basins from our drill cores and seismic records, (ii) integrating them with our volcanic chronostratigraphy, and (iii) seeking relationships between CSK volcanism and major tectonic events.

We will reconstruct the sedimentary and subsidence histories of the basins using sediment-focussed chronostratigraphic techniques: biostratigraphy, oxygen isotope and sapropel records, magnetostratigraphy, and relative magnetic palaeointensity (Table 1), while noting that high sedimentation rates (order of magnitudes 0.1 mm/y in the rift basins, 1 cm/y in the caldera, and >1 m/y for eruption units; see online form 5) and slumping may complicate use of these methods. Inclusion of the volcanic record will then build a detailed, rift-wide stratigraphy with multiple independent age markers, enabling construction of a Bayesian age model for each basin. Benthic foraminifera from fine-grained sediments (low-energy environments where the likelihood of microfossil reworking is reduced) will provide estimates of paleo-water depth and, via integration with seismic profiles and chronologic data, on time-integrated basin subsidence rates (Pallikarakis et al. 2018). Benthic foraminifera can predict water depths as deep as 850 m with accuracies of ± 50 m in the Mediterranean back to the early Pleistocene (Avnaim-Katav et al. 2016; Milker et al. 2017).

Major rifting events in the basins will be recognized on seismic profiles principally from onlap surfaces (five of which are recognized to date in the Anhydros and Anafi Basins; Fig. 4), and levels of fault termination. The presence of thick seismogenic turbidites (Goldfinger 2011; Polonia et al. 2013; Sumner et al. 2013; Table 1), and/or homogenites (slumping of hemipelagic muds; Beck et al. 2007) in the cores may record large-magnitude seismic events and tsunamis.

By exploiting downhole seismic velocity measurements, we will match our core stratigraphies to seismic profiles and generate a time series of inter-correlated volcanic and tectonic histories of the basins that will be used to seek relationships between volcanism and major tectonic events. When did volcanism start relative to rifting? Do large tectonic events recorded by the five main onlap surfaces in the Anhydros and Anafi Basins, or any prominent seismogenic sedimentary beds, correlate with (i) activation of the different volcanic centres, (ii) changes in eruptive style (e.g., the onset of major explosive activity at Santorini 250,000 years ago) or (iii) particularly large explosive eruptions? In particular, did the change from symmetric (basin units B1-B3) to more asymmetric (B4-B6) rifting NE of Santorini coincide with a change in the rate or type of volcanism at any of the CSK centres? Does the hypothesized younging of volcanism from SW to NE (if confirmed) result from NE-wards propagation of the rift? Can we relate the reconstruction of rift development and volcanism to published histories of Hellenic subduction, slab rollback, and backarc extension (Jolivet et al. 2013)?

We will also investigate how sea level modulates volcanic activity, although this will be challenging. There is already evidence for a sea-level influence on Mediterranean volcanism (McGuire et al. 1997; Sternai et al. 2017), and further work is in progress by C. Satow and colleagues using onland Santorini products and deep-sea tephra records back to 200,000 y. Our proposed drill-core eruption time series will allow us to push these investigations into the Pliocene and exploit existing sea-level curves back to 5 My (Grant et al., 2012, Rohling et al. 2014). Approximate palaeodepth data from benthic foraminifera may help quantify the eustatic and regional-tectonic contributions to sea level variations.

Objective 3. Arc magmatism in a region of extending crust

<u>Leading hypothesis.</u> *Rift-driven crustal thinning influences magma petrogenesis through its effects on magma storage, differentiation and contamination in the crust.*

Magmas of the CSK field have traversed 18-20 km of rifted continental crust, which has influenced their chemical and isotopic evolution (Bailey et al. 2009; Elburg et al. 2013). Primitive basaltic melts rise into the crust, where they evolve to intermediate and silicic compositions through fractional crystallization, crustal melting/assimilation and magma mixing (Cashman et al. 2017). Crustal differentiation pathways vary significantly in the CSK field (Mortazavi and Sparks 2004; Klaver et al. 2016a). Some silicic magmas such as those of Christiana, Santorini (>550 ka) and Kolumbo show evidence (low Y, high Ba/Y, low Dy/Yb; Fig. 3b) of interaction with amphibole-rich regions in the lower crust (amphibole 'sponge' of Davidson et al. 2007), whereas others (Santorini <550 ka) lack such evidence and differentiate by fractional crystallisation of anhydrous minerals (Francalanci et al. 2005). The factors governing formation of an amphibole sponge, or lack of it, are debated (Smith 2014; Klaver et al. 2018). At the CSK volcanic field variations in the stability of amphibole cannot be attributed to differences in the major element compositions or water contents of the primary magmas, so external factors may be responsible. It is likely that the structure of the rifted crust governs the polybaric ascent history of the CSK magmas, with evolving faults, density interfaces and rheological transitions (Jolivet et al. 2013) controlling levels of magma storage and differentiation (Flaherty et al. 2018) as observed in the exhumed Miocene magmatic complexes of the Aegean (Rabillard et al. 2018).

Estimates from rift cross sections (Nomkou et al. 2018) suggest 10-20% of horizontal extension since the late Pliocene, corresponding to 2-4 km of crustal thinning. This progressive rifting and thinning of the continental crust beneath and around the CSK volcanoes ***allows us to test the leading hypothesis***. Most of the volcaniclastics in our basin drill holes will probably be from explosive eruptions of intermediate or silicic magmas. We will investigate magma genesis using major, trace and multi-isotopic data on suitably fresh rocks. Volatile contents of crystal-hosted melt inclusions, and mineral-barometry techniques, will be used to quantify magma storage depths during ascent prior to eruption (Table 1). These data will constrain how mantle source characteristics and heterogeneity (Bailey et al. 2009; Klaver et al. 2016b), degree of magma contamination by the crust, and the role of lower crustal amphibole have varied in space and time since the Pliocene across the volcanic field.

Objective 4. Unravelling an iconic caldera-forming eruption

Leading hypothesis. *The LBA caldera-forming eruption of Santorini was the largest of the Holocene worldwide and shed large volumes of tsunami-generating pyroclastic flows into the sea, forming marine deposits up to 80 m thick.*

The Late-Bronze-Age eruption of Santorini has attracted attention for many decades (Friedrich 2009), and the onland products have been studied in detail (Sparks and Wilson 1990; Druitt 2014). More recently seismic studies have imaged the LBA products both outside (Sigurdsson et al. 2006) and inside (Johnston et al. 2015) the caldera, although their firm identification on seismic profiles is problematic due to the many other eruptions and tuffs with which they can be confused. Full understanding of this famous eruption awaits deep drilling.

The eruption began with phases of plinian fallout and violent phreatomagmatic explosions, followed by outpouring of hot pyroclastic flows into the sea. The eruption caused collapse of the present-day caldera, but whether collapse took place during or after the eruption is not known (Sparks and Wilson 1990). Tsunamis that impacted the coasts of the eastern Mediterranean and northern Crete (Bruins et al. 2008) may have been generated by the entry of pyroclastic flows into the sea (Nomikou et al. 2016a). Impacts of these waves on ports, shipping and trade are implicated in weakening the Minoan civilization on Crete prior to its collapse (Bruins et al. 2008).

LBA tuffs laid down outside the caldera are inferred from seismic profiles to be up to 80 m thick and have an estimated volume of ~ 60 km^3 (DRE: dense-rock equivalent; Sigurdsson et al. 2006). Moreover, a further 18-26 km^3 DRE of tuffs may lie buried inside the caldera, yielding a total DRE volume of 78 to 86 km^3 that would make the LBA eruption the largest of the last 10,000 y worldwide (Johnston et al. 2014). However these estimates have large associated uncertainties due to assumptions in interpreting the seismic sections.

Drilling will enable us ***to test the leading hypothesis*** by coring the LBA deposits both outside and inside the caldera (Fig. 2a), and by ground-truthing the seismic profiles using down-hole measurements of seismic velocities. Conventional gravity coring is not sufficient for this purpose, as the LBA deposits are far too thick. Outside the caldera, drilling will penetrate the LBA submarine pyroclastic flows at sites 03/04 and 11/12, and test the published seismic interpretation. This will in turn enable refined volume estimates for the flows, feeding into models of tsunami impact on the Bronze-Age Aegean world (Novikova et al. 2011). Textural and palaeomagnetic (thermal remnant magnetism; Table 1) analysis of the flow deposits will characterise the transformation of (hot) subaerially erupted pyroclastic flows into (cold) debris flows, then turbidity currents, upon entry into the sea (Schmincke and Sumita 2006; Kutterolf et al. 2014).

Inside Santorini caldera, we will drill to 360 mbsf in the northern caldera basin (site 05/06) and to 400 mbsf in the southern basin (site 07/08)(the respective limits of seismic imagery). Seismic units S1 (cliff mass wasting), S2 (Kameni volcaniclastics) and S3 (possible flood deposit) within the caldera have a combined thickness of 185 m at site 05 and 218 m at site 07 (Figs. 7d-f; online Form 5), so our anticipated drilling will penetrate the top 175 m (north) and 182 m (south) of the sub-S3 units thought to be intracaldera LBA tuffs. Johnston et al. (2015) estimate from onland geological evidence that the intracaldera LBA tuffs may exceed 500 m in thickness, so it is unlikely that drilling will reach pre-LBA levels. By drilling into the LBE tuffs in the caldera we will be able to estimate their minimum volume, which we can then combine with volume estimates for LBA deposits onland and offshore (outside of the caldera) to make a new, much more precise (minimum) estimate of the erupted volume.

We will also identify the deposits from different eruptive phases within in the caldera fill, and correlate them using textural and chemical criteria with the well studied onland sequences (Druitt 2014). The relative thicknesses of pyroclastic flow deposits inside and outside the caldera will tell us whether the caldera collapsed during or after the eruption (Sparks and Wilson 1990; Druitt 2014): pyroclastic flows can pond to great depths inside calderas if collapse takes place during eruption, but not if it occurs afterwards (Lipman 1984).

By drilling both caldera basins, and exploiting our dense seismic reflection coverage, we will gain access to the 3D architecture of the entire caldera fill and the relative roles of downfaulting and downsagging in LBA caldera collapse (Acocella 2007). Why is the northern basin 100 m deeper than the southern one, with thicker S1 but thinner S3? Did the northern caldera basin already exist prior to the LBA eruption, as proposed (Athanassis et al. 2016)?

Drilling will also give new information on the cylindrical low-density seismic anomaly that extends from 400 to 3000 mbsf beneath the northern caldera basin (Hooft et al. 2019). We cannot drill into this deep structure, and will not be able to determine its origin. However, by characterising the layers above it we will place constraints on its stratigraphic and structural relationships with the shallow (<400 m) intracaldera fill. Since the axis of the anomaly coincides with the focus of uplift in 2011-12 (Fig. 7b,c), we may also get a better understanding of the mechanisms of caldera unrest.

Finally, we will test the hypothesis of Nomikou et al. (2016a) that the LBA caldera underwent catastrophic flooding by the sea soon after its formation. While Johnson et al. (2015) interpreted unit S3 as the uppermost layer of LBA intracaldera tuff, Nomikou et al. (2016a) reasoned that it may be the post-LBA flood deposit: most likely very high-energy, coarsely grained fluvial gravels overlying a major scour surface, and perhaps intercalated with landslides from the caldera cliffs.

Objective 5. Volcanic hazards from submarine silicic eruptions

Leading hypothesis. *Shallow-marine explosive eruptions of water-rich silicic magmas driven mainly by magmatic degassing, and with dispersion by fallout and density currents, have occurred repeatedly in the neighbourhood of Santorini.*

A potential future hazard at Santorini is a submarine eruption of Kameni or Kolumbo Volcanoes, similar to that of 1650 but probably not as large. Better understanding of the dynamics of such eruptions will allow us to improve risk mitigation strategies in this highly populated and densely visited part of the Eastern Mediterranean (Vougioukalakis et al. 2016).

Three quarters of global volcanism occurs under the sea but the dynamics of submarine eruptions is poorly understood, particularly those of water-rich silicic magmas at island arcs (White et al. 2015, Carey et al. 2018). Possible tephra production mechanisms in the submarine realm include explosive fragmentation by bubble growth (magmatic explosive eruption), explosive fragmentation by water-magma interaction (phreatomagmatic explosive eruption), and autoclastic fragmentation (effusive eruption and hyaloclastite formation). The exact mechanisms likely depend on magma composition, magma volatile content, magma flux, and water depth (Rotella et al. 2015).

Studies of the products of the 1650 eruption of Kolumbo show that the eruption was driven mainly by primary degassing of the water-rich silicic magma, but with a component of phreatomagmatic fragmentation, and that the deposits were emplaced by a combination of subaerial plumes, submarine plumes, and density currents (Cantner et al. 2014; Fuller et al. 2018). Drilling at site 03/04 will enable us to traverse the products of at least three earlier explosive eruptions of Kolumbo (seismic units K1, K2, K3) and, via combined petrological, chemical and textural studies (Table 1), compare and contrast these earlier submarine eruptions to that of 1650, ***test the leading hypothesis***, and arrive at a general model for this rarely accessible type of submarine volcanism. Use of textural criteria for magmatic versus phreatomagmatic fragmentation (Table 1) will allow us to better understand the interplay of these processes as the Kolumbo cone grew by successive eruptions, with implications for tsunami genesis (Ulvrova et al. 2016).

Inside Santorini caldera, (sites 05/06 and 07/08) seismic unit S2 will provide access to a time series of postcaldera volcanism since the birth of Kameni after the LBA eruption, to its emergence in 197 BCE. Using similar methods as at Kolumbo, we will reconstruct the history of eruption style (magmatic explosive, phreatomagmatic explosive, and/or effusive) during the growth of Kameni from 400 m water depth to the surface (sea level has changed <1 m since 3600 y). Has Kameni always been effusive, or has it had explosive submarine phases like Kolumbo that would need to be accounted for in hazard assessments? If so, did Kameni underwater eruptions exhibit the same dynamics as those of Kolumbo, given that both edifices erupt silicic magma?

The Kameni time series is also of petrological interest, since it records the onset of a new caldera cycle following the LBA eruption (Pyle and Eliot 2006). It is rare to have such a petrological record of postcaldera volcanism at an arc caldera, the magmatic transition *and* the long subsequent evolution of the new intracaldera volcano seldom being both preserved. Onland Kameni dacitic magmas and their mafic enclaves form a geochemical series that is lower in incompatible elements (e.g., K, Rb, La) than the LBA magma that preceded it, and represent the arrival of a new, unrelated magma batch from depth following the LBA eruption (Huijsmans et al. 1988; Zellmer and Turner 2007). What compositions were the first Kameni magmas to erupt, and how have they evolved over the subsequent 3600 y? When did the changeover from residual LBA-type to Kameni-type magma take place, with what implications for post-eruptive solidification of the LBA magma reservoir? Do barometric techniques such as the volatile contents of crystal-hosted melt inclusions (Druitt et al. 2016) record changes in magma storage depth over the lifetime of Kameni Volcano? What are the implications for the mechanisms of postcaldera volcanism at Santorini and elsewhere?

8. Methods

We propose a drilling strategy of APC to refusal for all holes, followed by XCB and RCB drilling, where necessary, providing the required flexibility to drill volcanogenic sediments. At least three holes per site are proposed to maximise recovery, especially in coarser volcaniclastics. Based on shallow gravity coring, foreseen recovery rates with APC in the basins are 90-100% at <100 m, and (assuming similar, but more consolidated, lithologies) 50-70% at >100 m. However, three parallel holes, using different drilling technologies, will provide nearly 100% recovery when using spliced cores. This includes the possibility to core intervals while drilling ahead to fill stratigraphic gaps identified in the other holes. Inside the caldera we anticipate reduced recovery for all drilling techniques, especially RCB. Nevertheless, two holes for the first 100 m and 20-50 % recovery for deeper RCB will give us enough information to address our scientific goals. High anticipated sedimentation rates (order of magnitudes 0.1 mm/y in the rift basins, 1 cm/y in the caldera, and >1 m/y during large eruptions; see online form 5) at all sites will compensate for any poor recovery.

All cores will require description of lithological, structural, geochemical, palaeo-environmental and physical parameters acquired by standard IODP procedures in the core flow (see JOIDES Resolution Standard Measurement Guidelines). Procedures will include macroscopic, microscopic, and compositional properties (e.g. texture, mineralogy, diagenesis, cementation, density, porosity, magnetic susceptibility, etc …) of the cored material. Standard petrophysical and lithological logging data are requested (see online form 1) using the Triple Combo and FMS-Sonic tools extended by the Vertical Seismic Imager to collect active seismic data for integration of borehole and surface seismic data.

Drilling must take place between late autumn and early spring to avoid dense tourist shipping and high winds. A risk for hole stability at some sites will be encountering bouldery deposits from nearby basin margins (sites 01/02, 09/10), near-source volcanic ejecta (03/04), or coarse-grained intracaldera tuffs (05/06, 07/08), although we have chosen the sites to minimise this risk. Given the proximity of site 05/06 to the focus of deep intrusion in 2011-12, encountering excess fluid pore pressures is a possibility there. All proposed sites lie within Greek territorial waters.

Primary drill sites outside the caldera will each need 10 to 12 operational days, including 1-2 days of logging and 8 to 11 days of drilling. Drilling inside the caldera will NOT require casing and we expect ~4 days of drilling at both sites followed by 1 day of logging.

Operational days on primary sites sum to 55.1 days, and the total expedition duration (including 0.9 days of transit time and 5 days port call) amounts to 61 days for a drilling sequence CSK-09, CSK-01, CSK-03, CSK-11, CSK-05, CSK-07.

9. Site characterisation data

The dense network of multichannel and single channel seismic reflection profiles from collaborating groups and publications have been interpreted in detail in Santorini caldera (based on the volcanic history recorded onland; Johnston et al. 2015), and in the basins NE of Santorini (Sigurdsson et al. 2006; Hübscher et al. 2015; Nomikou et al. 2016a, 2016b, 2018), but only partly in the Christiana Basin (Tsampouraki-Kraounaki et al. 2018) where we plan to collect new data (see below). Fault distributions and throws have been mapped NE of Santorini (Nomikou et al. 2016b; Hooft et al. 2017), and TWT isopach maps have been constructed for each rift (Figs. 7d-f). High-resolution multibeam bathymetry is available inside and outside of Santorini caldera (Nomikou et al. 2014; 2016a; Hooft et al. 2017), as are isolated heat-flow measurements (Hannington et al. 2017). We adopt a velocity model (SSDB and online Form 5) based on multichannel seismic profiles. These velocities are lower than those based on tomography (Fig. 8b,c), but are probably more accurate at shallow depths. During the PROTEUS cruise 2015 3.5 kHz sub-bottom profiling, gravity and magnetic data were recorded.

Seven (03, 04A, 04B, 05, 06, 09, 10) of our proposed drilling sites are located at intersections of MCS profiles, and two (07, 08) are each at the intersection of a SCS profile and a MCS profile. The other three sites (01, 02, 11) each lie on a single MCS profile and site 12 lies on a single SCS profile; we have tried relocating these onto the intersections of other seismic profiles, but the intersections are not suitable for drilling because the full seismic stratigraphy is not recognizable. Following discussions with the watchdogs, a proposal to collect additional cross profiles was submitted to German Research Vessels in February of 2019 (PI: J. Karstens). This cruise will collect (i) new MCS profiles NE of Santorini to enable placing of all drill sites on cross points and improve interpretations of seismic stratigraphy, and (ii) new MCS profiles throughout the Christiana Basin, placing our drilling sites on cross points and refining the interpretations of Tsampouraki-Kraounaki et al. (2018). Once these new data have been interpreted it is possible that some core sites may shift slightly, but without changing the science objectives or strategies. We will also refine our velocity model using the diffraction-extraction technique (Schwarz and Gajewski 2017). A proposal for reprocessing of MCS and SCS data has been submitted to the German Science Foundation.

A data base of more than 50 K-Ar, ^{39}Ar-^{40}Ar and ^{14}C dates, and over 1000 whole rock major and trace element analyses (with a subset analysed for radiogenic and stable isotopes) are available for onland volcanic rocks from the CSK centres, particularly Santorini. Glass major and trace element analyses from onland products and from marine ash cores back to 200,000 y are also available.

10. Outreach

The stunning volcanic scenery, famous caldera-forming eruption, unique Late Bronze-Age archaeological site, and developed infrastructure at Santorini offer plentiful opportunities for IODP-related outreach/education initiatives involving online streaming, school teachers and pupils, local residents, onboard cruise presentations, and tourist agencies.

11. Two secondary drilling objectives

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

Drilling in the Anhydros and Anafi Basins (sites 01/02 and 09/10) will allow us to pierce the entire basin stratigraphy and reach the basement unconformity (pre-subsidence land surface). This provides the opportunity to reconstruct the environmental histories of the basins from continental to deepening marine, as well as the evolution of the Eastern Mediterranean paleoclimate, since the Pliocene. It will build on ongoing analysis of cores at DSDP site 378 in the Cretan Basin (Hsü et al. 1978), and will enable establishment of a robust sedimentary reconstruction and time framework across the southern Aegean.

Uplift and erosion of the Aegean crust in the Middle to Late Miocene was followed by subsidence and marine transgression in the Pliocene and Quaternary. Seismic profiles at the Aegean margins reveal a gradual subsidence over 400,000 years (Lykousis et al. 2009). Commercial boreholes in the northern Aegean reveal alluvial and lacustrine conditions in the Pliocene and Early Pleistocene prior to marine transgression (Faugeres and Robert, 1976). However, the subsidence history in the southern Aegean is poorly known due to the paucity of offshore studies. We will build a high-resolution biostratigraphic framework for the cores which, along with stable isotope and alkenone profiles, will provide a first-order bed-to-bed age control to be integrated into the chronological model of Objective 1 (Table 2). We will then extract a time series of palaeoenvironmental data from the cores using assemblages of calcareous nannofossils, benthic foraminifera, dinoflagellates, and pollen, refined by stable oxygen and carbon isotopes, total organic carbon, major and trace elements, and organic biomarkers for selected depth intervals (Table 2).

Objective 7. Biological systems reactions to volcanic eruptions and seawater acidification

The deep-marine biosphere hosts a large component of the world's microbial ecosystems, but little is known about them (Parkes et al. 2000; Schippers et al. 2005). Marine microbes have evolved to respond to environmental challenges, resulting in different survival mechanisms, growth strategies and genetic adaptations. Knowing that Santorini caldera harbours highly diverse, metabolically complex microbial communities (Oulas et al. 2016; Christakis et al. 2018), we will use one or more deep cores from inside the caldera (sites 05 to 08) to characterize the living and fossilized sub-seafloor biological communities present. By applying the latest developments in omics and culture-based technologies, we will document the sizes, genetic variabilities and metabolic functions of subsurface ecosystems to 300-400 m depth, and will explore for past anoxic events in the caldera subsurface, extant biological activity, and trace fossils of extinct seafloor life. The cores will offer a potentially continuous record of the impact of repeated eruptions of Kameni Volcano, hydrothermal fluids, and seawater acidification on biological activity, and of subsequent re-colonization of the caldera floor (Danovaro et al. 2017).

Analytical techniques will include cultivation experiments and state-of-the-art molecular techniques to get a full picture of biological structural diversity, functional diversity, and metabolic complexity (Table 2). Special emphasis will be given to the characterization of microbes associated with specific metabolic reactions and the identification of key metabolic processes. Effects of eruption-associated water acidification will be studied using Synchrotron X-ray tomography for 3D reconstructions of calcareous nannofossil coccoliths (Hönisch et al. 2012; Beuvier et al., 2019).

Study of drill cores and pore-fluids will investigate the relationship between subseafloor extant, or fossilized, microbial communities and subseafloor biogeochemical and mineralization processes, particularly the relative importance of Fe released from hydrothermal activity in sustaining subseafloor biomes (Templeton et al., 2011).

Full compliance with the Nagoya Protocol is assured (Table 2).

Table 1. Some methods related to the primary objectives

Criteria for interpretation of turbidites and debris flows (objective 1, 2, 4)	
Primary, eruption-generated turbidite	Homogeneity of juvenile component. Texture similar to onland deposits with lithic and pumice grading. Consistency with onland or upslope eruption stratigraphy. Consistency with onland or upslope eruption lithic assemblage. Use of particle textures to distinguish subaerial from submarine eruption (Schindlbeck et al. 2013).
Secondary, reworked eruption-generated turbidite	Homogeneity of juvenile component. Texture similar to onland deposits with lithic and pumice grading. Possibly more heterogeneity than primary turbidite. Repetition in the sequence. Inconsistency with onland or upslope stratigraphy
Seismogenic (or tsunamigenic) turbidite	Polylithologic. No magmatic component, or multiple populations of magmatic components. Possible presence of fault-scarp-derived lithologies. May overlie onlap surface on seismic profile
Establishment of a chronostratigraphy (objectives 1, 2)	
Biostratigraphy	Microfossil assemblages will be used to construct a biostratigraphic framework, similar to that using the calcareous nanofossils Ceratolithus tricorniculatus and Gephyrocapsa oceanica in DSDP hole 378 of the Cretan Basin.
Radiometric dating	Some primary core volcaniclastic beds will be dated directly by K-Ar or $^{40}Ar/^{39}Ar$ methods on large juvenile clasts (groundmass separates), if sufficiently fresh.
Oxygen isotope stratigraphy	Oxygen isotope stratigraphy of planktonic foraminifera will be established and correlated with the existing 5 My orbitally tuned and millennially resolved eastern Mediterranen ^{18}O stacks (Wang et al. 2010; Grant et al. 2012).
Sapropel stratigraphy	Sapropel occurrences will be matched to astronomically tuned sapropel cycles (Rohling et al. 2015; Grant et al. 2016), the sequences and ages of which are known to within 1000 years in the Mediterranean back to the Pliocene (target curve La2004; Laskar et al. 2004).
Reversal-based magnetostratigraphy	Provided sediments carry a strong natural remanent magnetization, geomagnetic polarity reversal-based magnetostratigraphy (Richter et al. 1998; Papanikolaou et al. 2011; Roberts et al. 2016) would target the Brunhes-Matuyama boundary at 0.78 My, the Jaramillo subchron (1.068 to 0.987 My), and the Olduvai subchron (1.778-1.945 My). All onland eruption products of Santorini are <0.65 My and are normally magnetized.
Relative palaeo-intensity	Relative magnetic paleointensity (RPI) records will be compared with well established global RPI records such as SINT2000 (Valet et al. 2005) and PISO1500 (Channell et al. 2009), validated to 2.0 and 1.5 My, respectively, while being aware of potential complications (Roberts et al. 2013).
Textural characterization (objectives 1, 2, 4, 5)	
Magma fragmentation mechanisms	Particles fragmented by bubble exsolution and growth have highly vesicular textures, whereas those produced by water-melt interaction have surface quench cracking, blocky shapes with stepped fractures or moss-like features (Zimanowski et al. 2015). Crystal and bubble size distributions will allow estimation of histories of magma ascent and bubble nucleation and growth (Giachetti et al. 2010; Rotella et al. 2015).
Turbidite types; tsunami deposits	Combined high-resolution textural (CT-scan) and geochemical (μ-XRF core scanner) characterization of turbidites will allow distinguishing of different types of turbidites . The same method could be applied to primary tsunami deposits (if preserved in the sedimentary record).
Deposit emplacement temperature	If chemical remanence is taken into account, thermal remanent magnetism studies of lithic clasts in submarine mass flow deposits enable estimation of emplacement temperatures (Bardot and McClelland 2000) and distinction close to the shoreline between debris flow (<100 °C) and subaqueous pyroclastic flow (>100 °C) deposits.
Chemical, petrologic and isotopic characterization (objective 4)	
Magma petrogenesis and crustal interaction	Chemical (major and trace elements) data on suitably fresh juvenile samples, with radiogenic (Sr, Nd, Pb, Hf, U-Th) and stable (O) isotopic analyses on selected samples, will enable us to track parental magma composition and degree of crustal assimilation in space and time since the Pliocene using classical geochemical approaches (Francalanci et al. 1995; Vaggelli et al. 2009; Klaver et al. 2016b). The role of deep-crustal amphibole in magma genesis will be tracked by the presence/absence of phenocrystic amphibole, and by trace element signatures of amphibole involvement (low Y, low Dy/Yb; Davidson et al. 2007).
Magma pre-eruptive storage depths	Variations of magma storage depths will be constrained using mineral barometry (Putirka 2008) and the volatile contents of crystal-hosted melt inclusions (Druitt et al. 2016) if suitably unaltered.

Table 2. Some methods and legal protocols related to the secondary objectives

Palaeo-environmental analysis (objective 6)	
Biostratigraphy	Microfossil assemblages, in particular calcareous nanofossils. In DSDP site 378 the base of the marine sequence is dated as Early Pliocene (biozone NN12) on the presence the species *Ceratolithus tricorniculatus*. The sequence extends up to NN19 on the presence of *Gephyrocapsa oceanica*. (Athanasiou et al. 2015; Geraga et al. 2010; Gogou et al. 2016; Triantaphyllou et al. 2009a ; 2009b ; 2014; 2016 ; 2018.)
Calcareous nanofossils	Primary marine productivity; rapid response to variations in sea surface temperature, sea surface salinity, water column stratification, freshwater input, CO_2 variations affecting the carbonate system parameters. The abundance ratio between *Florisphaera profunda* (F) and *Emiliania huxleyi* (E) is used as stratification index. *Helicosphaera* spp. (mainly *H. carteri*) together with *Braarudosphaera begelowii* are used as indicators of salinity decrease. Previous studies of Emiliania huxleyi in the modern Aegean Sea provided strong evidence for seasonal variation in coccolith size, morphology and calcification associated with carbonate system variations. (Triantaphyllou et al. 2016).
Benthic foraminifera	Proxies for deepwater circulation and oxygenation, nutrient fluxes; approx. water palaeo-depth. Dysoxic to oxic bottom waters are characterized by a high abundance of benthic foraminiferal species tolerating surface sediment and/or pore water oxygen depletion (e.g., *Chilostomella mediterranensis, Globobulimina affinis*), and the presence of *Uvigerina mediterranea*, which thrives in oxic mesotrophic-eutrophic environments. (Triantaphyllou et al. 2009b; 2014 ; Avnaim-Katav et al. 2016; Milker et al. 2017).
Dinoflagellates	Qualitative and comparative estimates of paleotemperature, paleosalinity, primary production, nutrient levels, bottom water anoxic/oxic conditions. The temperature index warm/cold (W/C) is derived from the warm-water dinocyst assemblage *Tuberculodinium vancampoae, Tectatodinium pellitum, S.nephroides, I. patulum, I. aculeatum, Pyxidinopsis reticulata, O. israelianum, Spiniferites mirabilis, S. hyperacanthus*, and the cold-water assemblage *N. labyrinthus, P.dalei.* (*Geraga et al. 2010; Triantaphyllou et al. 2009a ; 2016).*
Planktonic foraminifera	Powerful tool for estimation of past sea surface temperatures and salinities; reconstructions of past water masses and circulation using the Modern Analog Technique (MAT). Increased abundance of *Globigerina bulloides*, suggests enhanced productivity in the water column. (Kouli et al. 2012; 2015).
Pollen	Parameters such as terrestrial vegetation cover, humidity, runoff, and sediment influx are defined using Aegean pollen-based indices. Pollen data patterns organized in assemblage zones elucidate the occurrence - alternation of different vegetation types in time, and contribute to estimation of climatic parameters such as humidity (H-index=AP/St where AP: Arboreal taxa excluding *Pinus* and St: Steppic taxa) and relative temperature (T-index = cool temperate/(sum of temperate and Mediterranean taxa). (Rohling et al. 2014; 2015).
Stable oxygen and carbon isotopes	Oxygen isotopes for ^{18}O stratigraphy, sea surface temperatures and salinities. Carbon isotopes for relative contributions of marine/terrigenous organic matter. Negative shifts in foraminiferal $\delta^{18}O$ indicate cooling events. (De Lange et al. 2008; Katsouras et al. 2010; Filippidi et al. 2016).
Total organic carbon (TOC); major and trace elements	Paleo-productivity (e.g., TOC, Ba/Al) and preservation; in the absence of considerable diagenetic alteration in the sediments, enrichments observed in redox-sensitive elements represent initial depositional conditions. (Athanasiou et al. 2017; Gogou et al. 2007; 2016; Triantaphyllou et al. 2016).
Alkenone-derived SSTs and selected lipid biomarkers	Alkenone/Uk37 index-based sea surface temperature (SST) reconstructions are fundamental. Pliocene alkenone-SST record in the E. Mediterranean documents the “warm Pliocene”period (~4.1–3.25 Ma) characterized by mean SST of c. 26 °C. Distinct SST minima at ~3.9 Ma, 3.58 Ma and between 3.34 and 3.31 Ma, correspond to the MIS Gi16, MIS MG12 and MIS M2 global cooling episodes, before onset of the Northern Hemisphere glaciation. (Triantaphyllou et al. 2016).
Biological analysis (objective 7)	
Sampling and processing	Carried out onboard ship using sterile conditions.
Minimize contamination	Use of seawater from pristine offshore locations for drilling mud. Avoiding sewage dumping during drilling. Surface seawater, drilling fluids and onboard wastewater monitored for microbes. Core exteriors cleaned and trimmed; samples taken from interior. (Lever 2013; Hirayama et al. 2015).
Cultivation experiments	Different media, temperatures, aerobic/anaerobic conditions - targeting chemolithoautotrophic and heterotrophic microorganisms in order to isolate the most extreme and active microbes from the deep-subsurface
Molecular techniques	Illumina-based 16S and 18S rRNA gene surveys. 16S is an excellent marker gene for all prokaryotic communities including bacteria and archaea and 18S is the marker gene for microeukaryotic communities
	Metagenomic analysis. Metagenomics is the analysis of all genes of all microorganisms present in a sample and allows identification of dominant metabolic processes. Illumina HiSeq will be used in order to produce thousands of sequencing reads and capture all potential metabolic processes.
	Metatranscriptomic is the analysis of gene expression of all microbes from a sample; we will attempt to isolate RNA which allows the identification of the active communities and processes in the deep subsurface
	Targeted proteomic techniques to get additional insights into metabolic complexity. Extraction and analysis of proteins related to anaerobic degradation of aromatic hydrocarbons with potential implications in bioremediation field. Bioremediation is the process that uses microbes or enzymes to detoxify contaminated environments
Legal issues and the Nagoya protocol	
All participants of the present proposal endorse that access to, and utilization, of genetic resources taken during the project should be consistent with the provisions of the Convention on Biological Diversity (CBD) taking into account their specifications by the Bonn Guidelines on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilization, and, where appropriate, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits arising from their Utilization (NP, not yet in force), as well as with the United Nations Convention on the Law of the Sea (UNCLOS). All biological samples related to Objective 7 will be delivered to IMBBC-HCMR at their laboratories in Heraklion, Crete, where they will be used for research purposes only. A Material Transfer Agreement between the project Coordinator and the IMBBC-HCMR partner will be prepared and signed by both parties, to ensure delivery of samples of marine organisms accessed in the framework of the present IODP project, to the IMBBC-HCMR premises in Heraklion.	

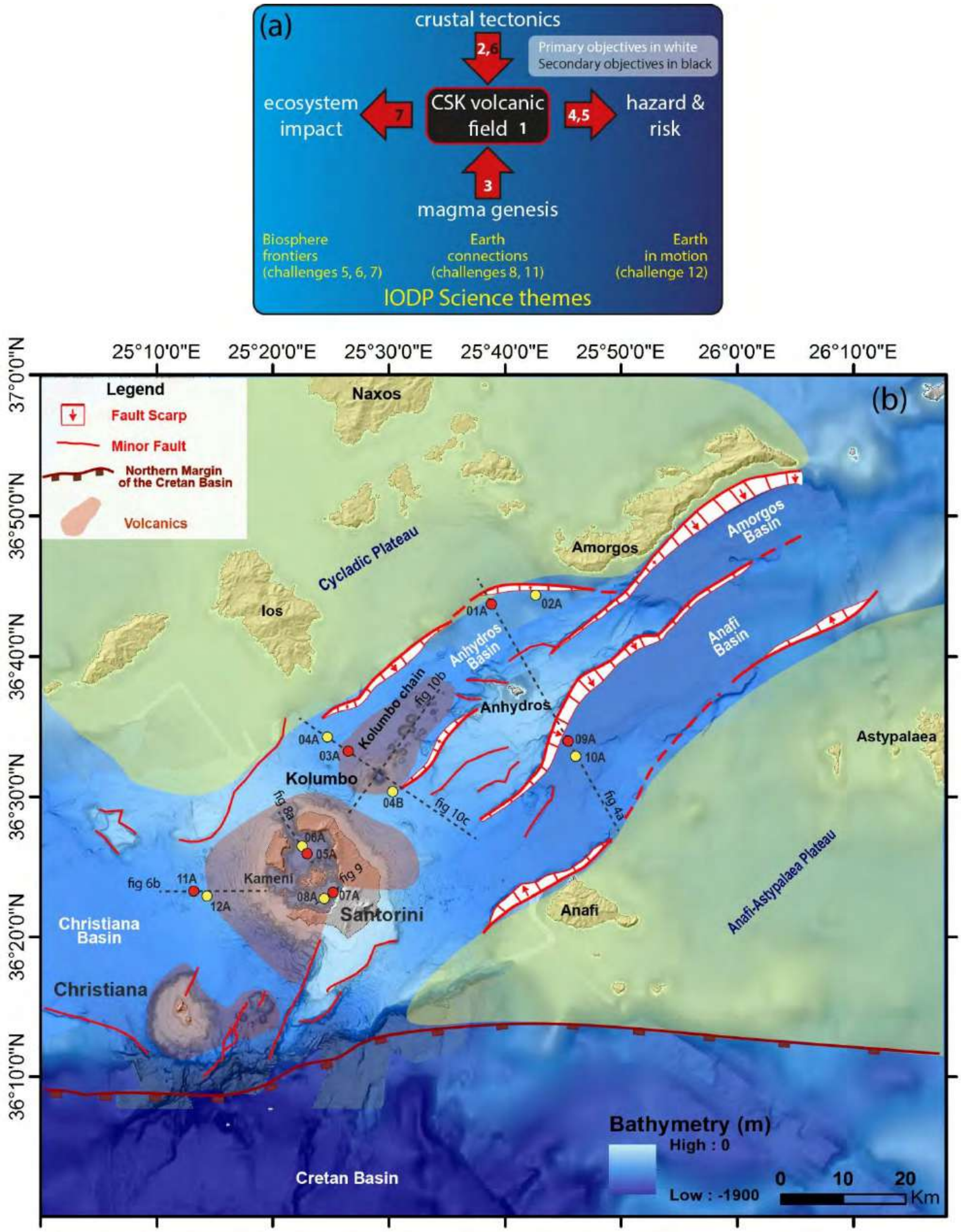
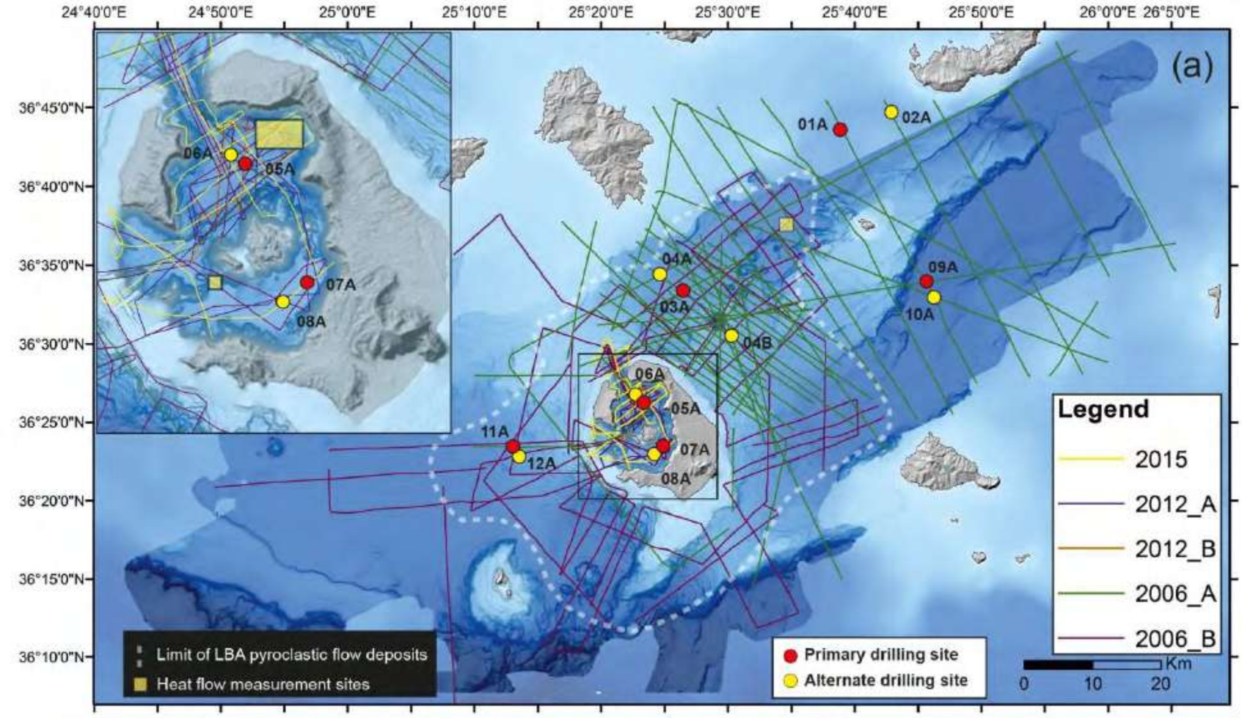


Figure 1. (a) Plan of the drilling proposal, showing inputs (vertical) and outputs (horizontal) of the volcanic system. Numbers on the arrows and rounded square are the seven proposal objectives. The proposal encompasses all three science themes, and six challenges, of the IODP Science Plan. **(b)** Tectonic context of the Christiana-Santorini-Kolumbo volcanic field, showing drill sites (red dots, primary sites; yellow dots, alternate sites) and seismic profiles of the different figures.



Survey (Year)	No. of Profiles	Length (km)	Source	Channels	Streamer length (m)	Dominant frequency	Data holder
2015	13	120	1 Sparker (6 kJoule)	24	100 m	300 Hz	UHH
2012_A	19	82	1 airgun (10 cin)	1	SCS	125 Hz	UA
2012_B	13	38	1 airgun (10 cin)	1	SCS	125 Hz	UA
2006_A	51	1500	1 GI-Gun (45/105cin)	24	600 m	100 Hz	UHH
2006_B	128	990	1 airgun (10 cin)	1	SCS	60 Hz	UA

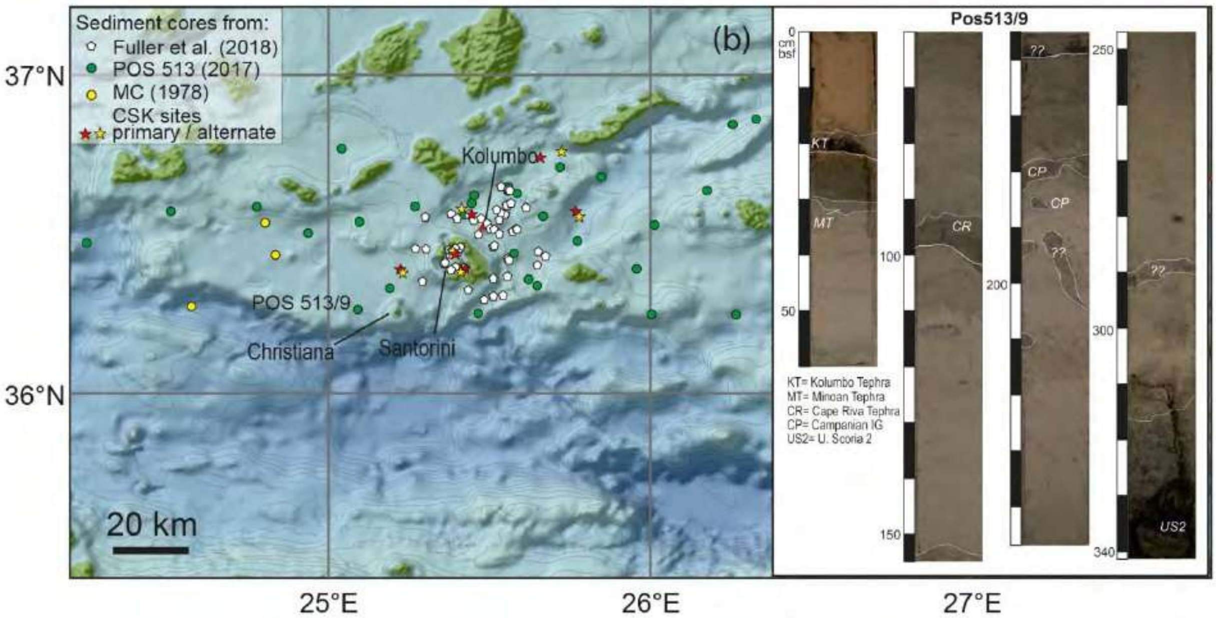
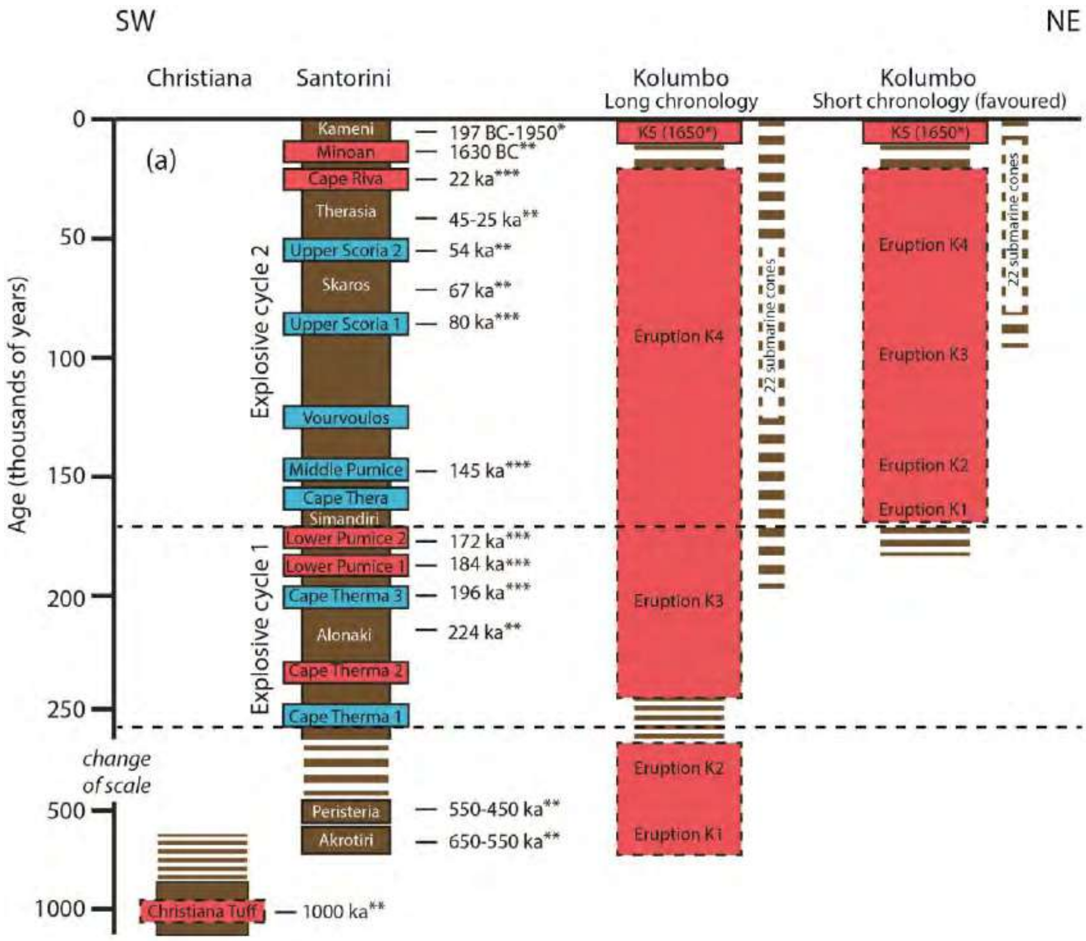
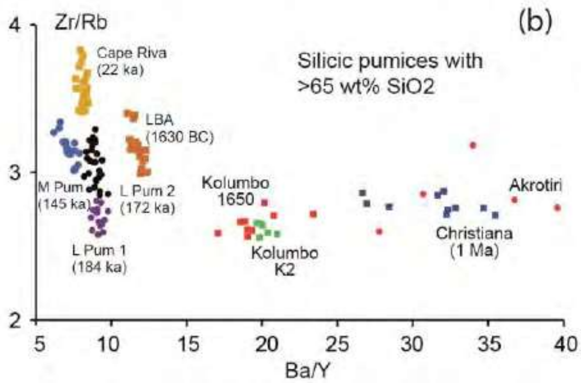


Figure 2. (a) Available seismic lines in and around the CSK volcanic field, with those around and inside of Santorini caldera shown enlarged in the inset. The submarine limit of pyroclastic flows from the Late Bronze Age eruption of Santorini are also shown, as are heat flow measurement sites (from Hannington et al. 2017). The different seismic data sets amount to 2740 km total length. The GI-Gun used for set 2006_A was operated in true-GI mode. Abbreviations: cin: Cubic inch (volume); SCS: Single channel seismics; UA: University of Athens; UHH: University of Hamburg. **(b)** Sites of shallow gravity and box coring carried out to date in the neighbourhood of the CSK volcanic field. The example of a gravity core illustrates the lithologies present in the upper few metres of the marine sediments (unpublished data from Poseidon cruise 513).





(c)

Occurrence of certain characteristic minerals

Phenocryst phase	Christiana	Santorini (550-650 ka)	Santorini (<550 ka)	Kolumbo
Hornblende		■	Trace	■
Cummingtonite	■			
Biotite				■
Quartz			Trace	■
Zircon	■	■		■

Figure 3. (a) Summary of age constraints for the CSK volcanic centres, based on the data of Druitt et al. (1999), Fabbro et al. (2013), Vespa et al. (2006), Hubscher et al. (2015) and Nomikou et al. (2016b). Boxes represent major explosive eruptions (red: silicic magmas; blue: intermediate magmas). The ages are derived from * historical records, ** radiometric dating, or *** correlation with marine tephra layers. Two endmember interpretations of age relationships for the Kolumbo eruption units (K1-K5) are presented, after the analysis of seismic profiles by Hübscher et al. (2015). Several of the 22 Kolumbo chain submarine cones postdate unit K3 on seismic profiles. **(b)** Examples of chemical fingerprinting of silicic pumices from several large eruptions of Christiana, Santorini and Kolumbo, showing that the products could be distinguished chemically in marine successions provided that they are sufficiently fresh. Data from Druitt et al. (1999), Aarburg and Frechen (1999) and Cantner et al. (2014). LBA: Late Bronze Age; L Pum: Lower Pumice; M Pum: Middle Pumice. **(c)** The occurrence of some key minerals in silicic products of the different centres would also aid correlation of primary volcaniclastic beds to source volcano.

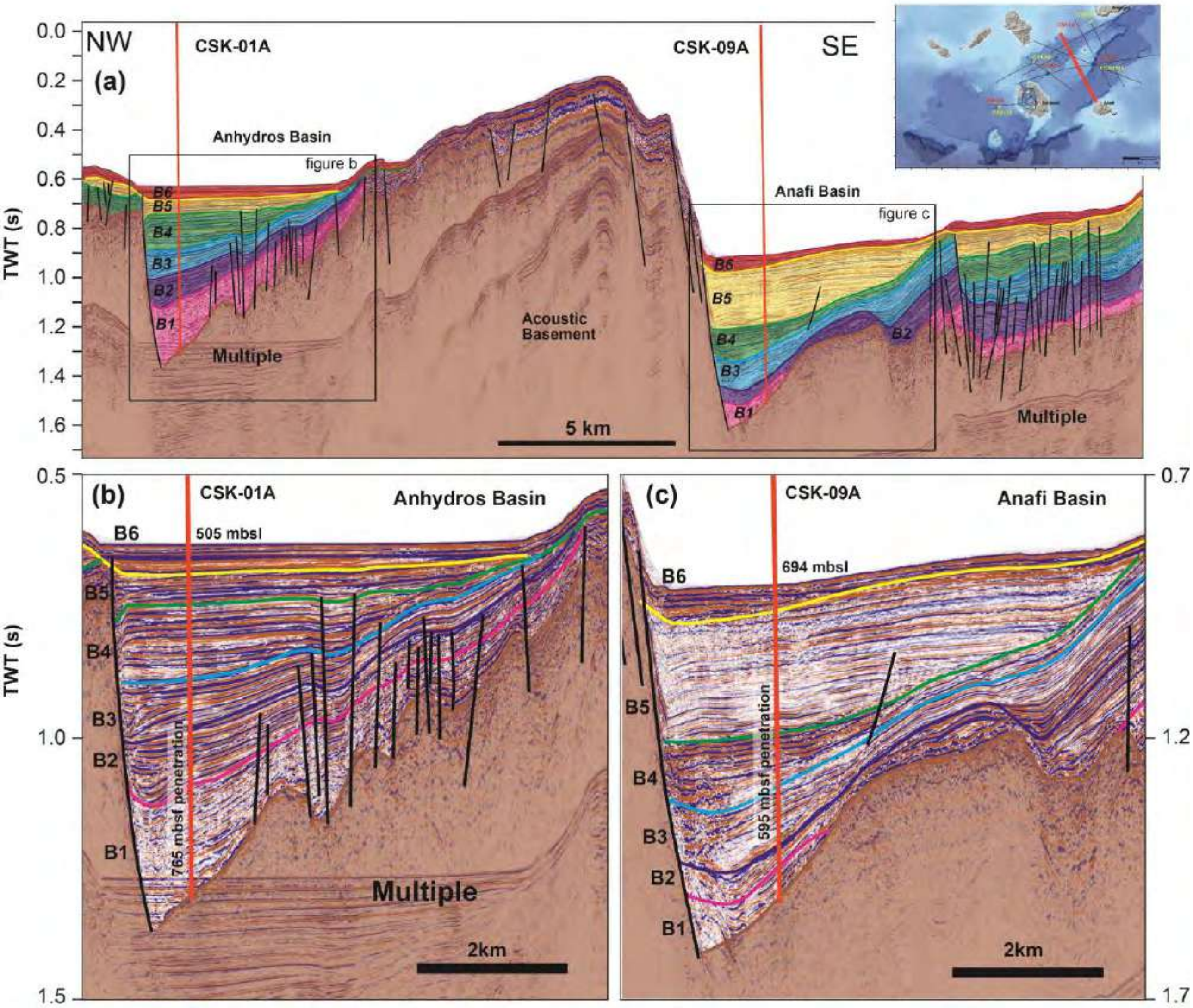


Figure 4. (a) Interpretative multi-channel seismic profile through the Anhydros and Anafi Basins, showing the six seismic-stratigraphic units B1 to B6. The lower three units (B1-B3) record a phase of rather symmetrical extension, and the upper three (B4-B6) record a phase of more asymmetric extension (from Nomikou et al. 2018). The profile location is shown in Figure 1b. This published profile is equivalent to sparker profile HH06-15 shown on the site maps. **(b and c)** Enlargements of the two basins. Primary drill sites CSK-01A in the Anhydros Basin (or nearby alternate site CSK-02A; not on this profile) will penetrate the entire volcano-sedimentary fill to the basement unconformity. The core will provide a record of the full history of the main volcanic centres (Santorini and Kolumbo) upslope of this site, and the sedimentary history of the basin since rift inception. Core CSK-09A in the Anafi Basin (or nearby alternate core CSK-10A; not on this profile) will penetrate the volcano-sedimentary fill to the basement unconformity. The basin fill potentially records the full volcanic history of Santorini (and possibly earlier submarine centres) since rift inception, but probably not of Kolumbo.

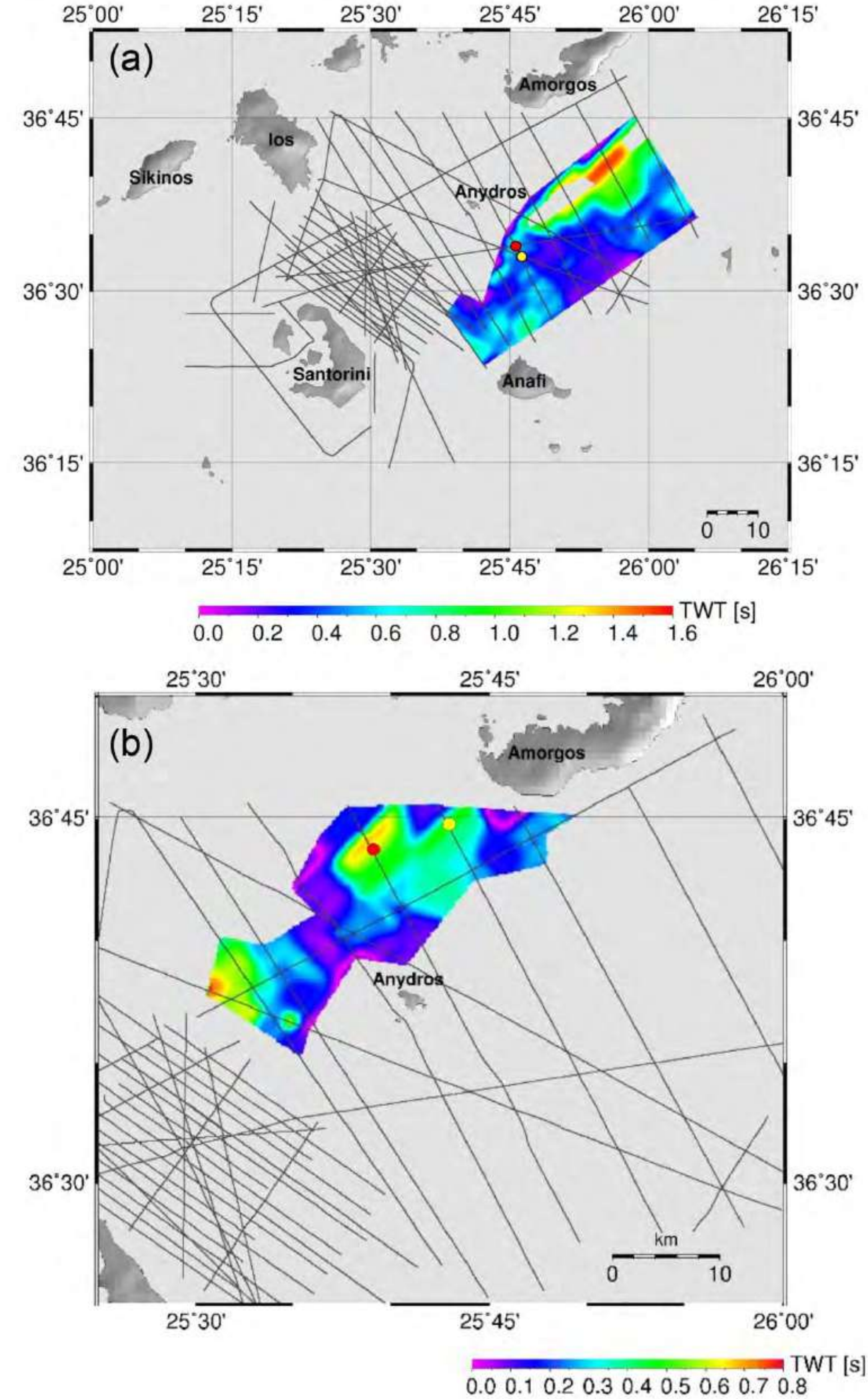


Figure 5. TWT(s) isopach maps of the sediment fills of **(a)** Anhydros and **(b)** Anafi basins. Note the different colour schemes for the two figures. Selected seismic lines are shown.

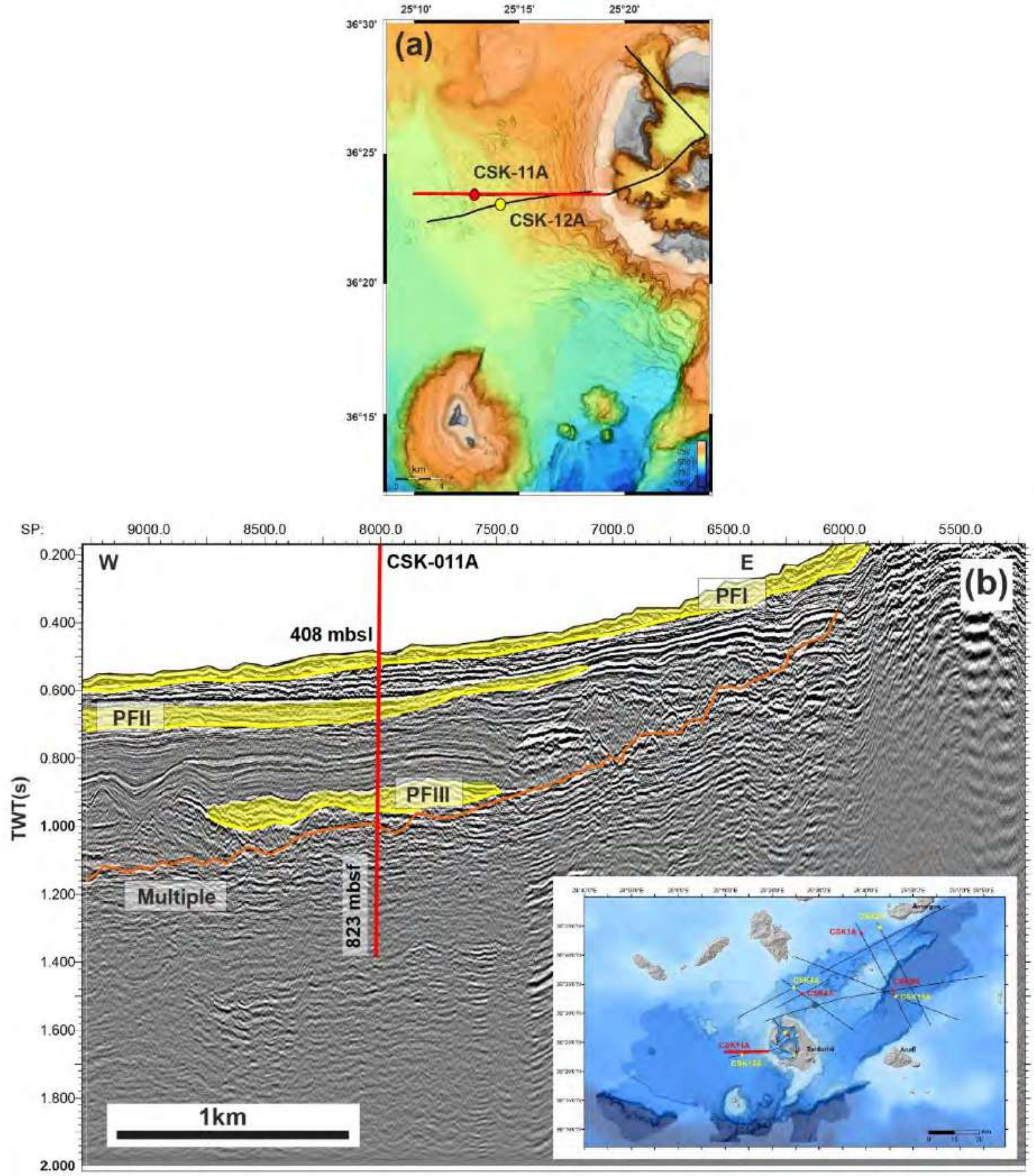


Figure 6. (a) Swath map of the eastern part of the Christiana basin and of the eroded remnants of Christiana Volcano, showing the drill sites and selected seismic lines. The location of the profile is shown in Figure 1b. **(b)** Multi-channel seismic profile. Core CSK-11A in the Christiana Basin (and nearby alternate site CSK-12A; not on this profile) will penetrate the volcano-sedimentary fill of the basin, which potentially records the volcanic histories of Christiana, Santorini and possibly Milos volcanic centres; it will pass through three prominent volcanic units (PF I to PF III) seen on seismic records and interpreted as possible pyroclastic flow deposits, based on the work of Tsampouraki-Kraounaki et al. (2018). Drilling in the Christiana Basin should allow us to access an earlier volcanic history than the basins to the north-east.

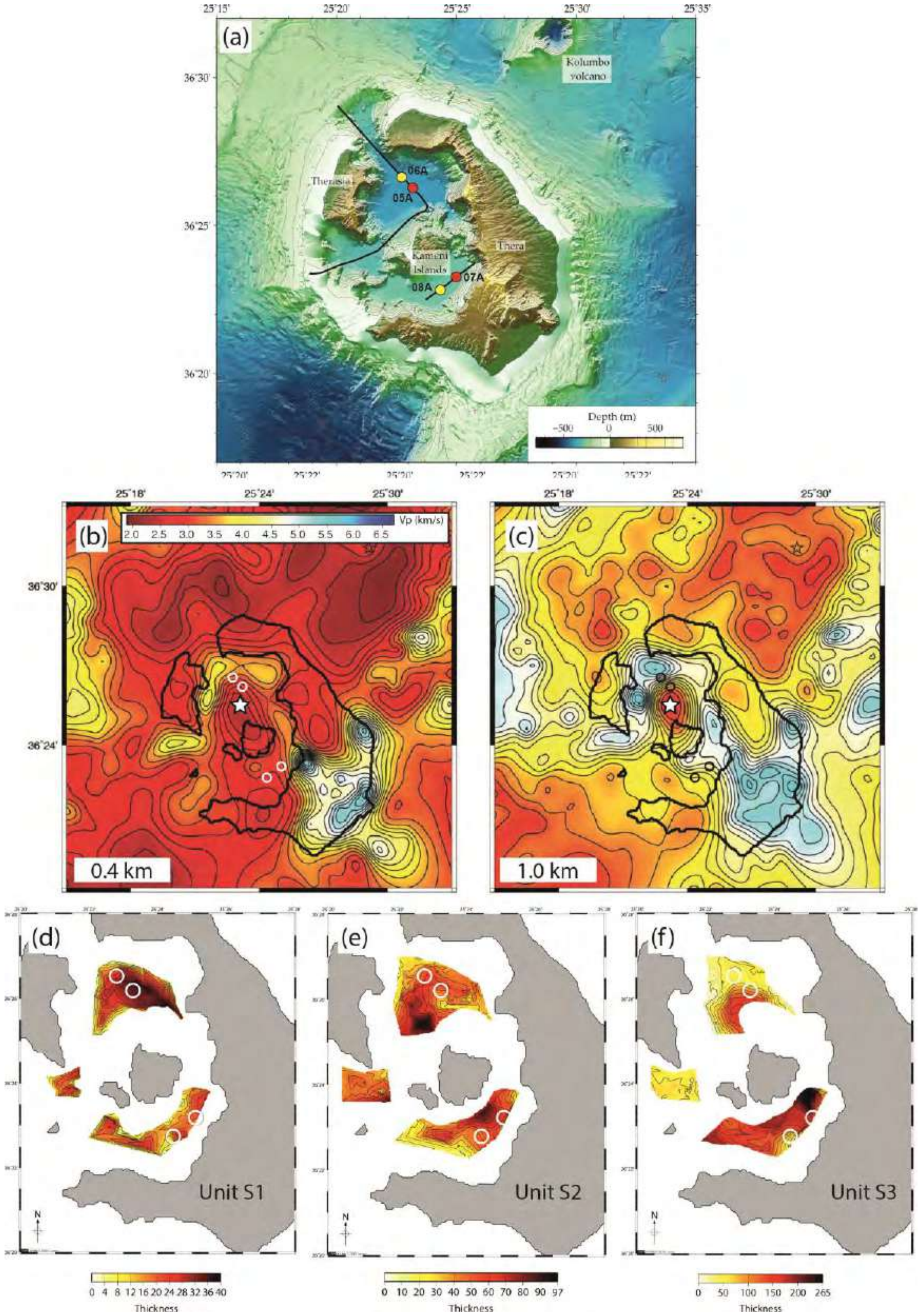


Figure 7. (a) Bathymetric map of Santorini caldera (Nomikou et al. 2016b), showing drill sites and selected seismic lines. **(b-c)** Horizontal sections (depths 0.4 and 1.0 km) through the low-velocity seismic anomaly in Santorini caldera (after Hooft et al. 2019). The anomaly forms a vertical cylinder in 3D extending from 0.4 to 3 km (approx) depth below the caldera floor. The centre of the anomaly coincides with the focus of caldera-floor uplift during the unrest of 2011-2012 (white star; Newman et al. 2012; Parks et al. 2012). The drill sites are shown as circles. **(d-f)** The thicknesses (m) and areas of seismic units S1 (b), S2 (c) and S3 (d) in Santorini caldera, calculated assuming a mean sound velocity of 1900 m s^{-1} (from Johnston et al. 2015). The drill sites are shown as circles.

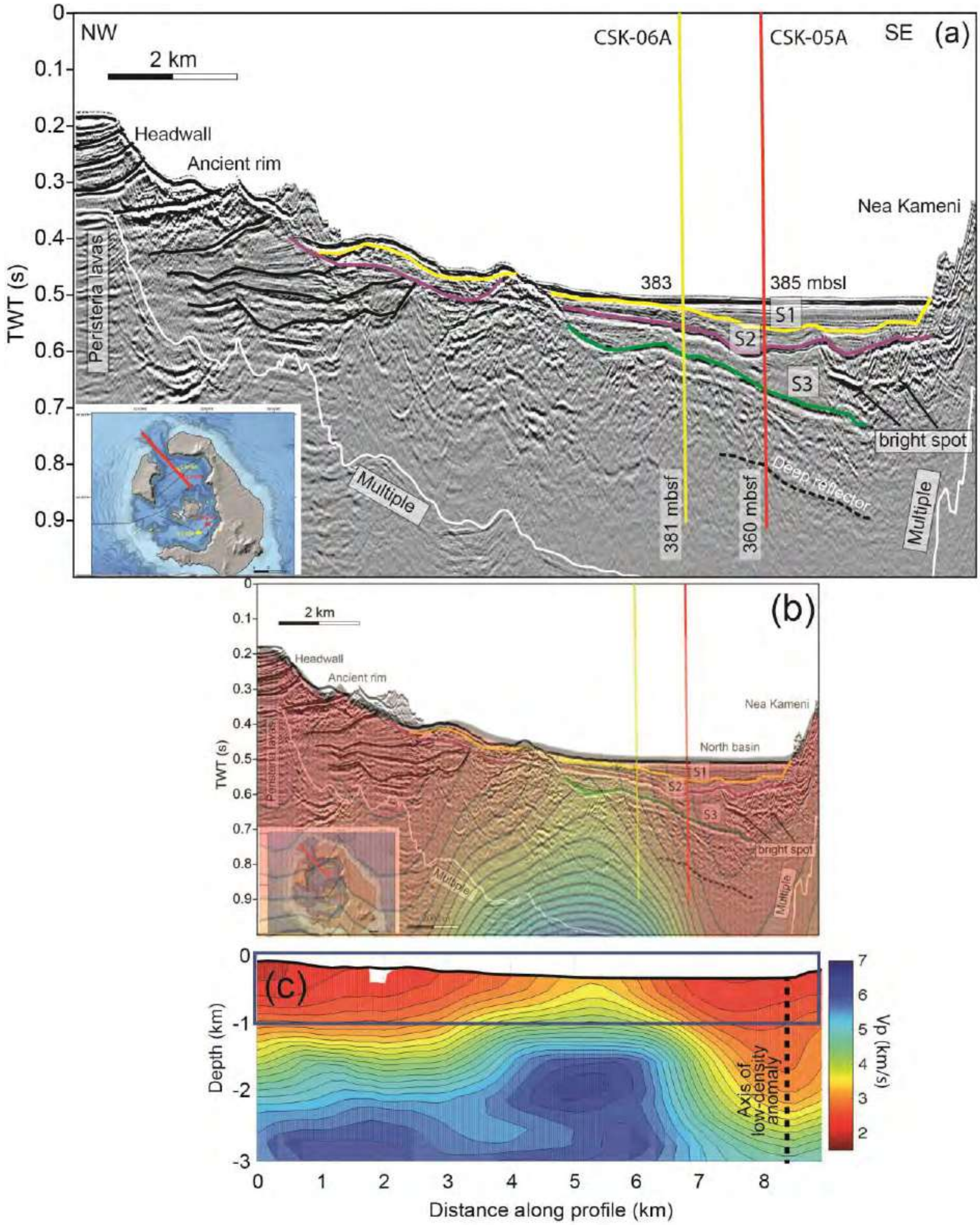


Figure 8. (a) Multi-channel seismic profile NW-SE across the northern basin of Santorini caldera (from Nomikou et al. 2016a). The location of the profile is shown on Figure 1b. Primary core CSK-05A or alternate core CSK-06A will characterise seismic units 1-3 and sample the deep sub-S3 intracaldera fill to test interpretations of the origins of the different units (Johnston et al. 2015). This published profile is equivalent to sparker profile HH15-SP1 on the site maps. **(b)** Velocity data from the PROTEUS seismic tomography experiment overlain on figure a (from Hooft et al. 2019). **(c)** A more vertically extended velocity section, with the depth range of figure b shown by the dark blue box. The dotted line is the axis of the low-velocity cylindrical anomaly. Note that velocities from the tomographic data are higher than those used in the velocity model of this proposal (online form 5), which is based on multi-channel seismic results.

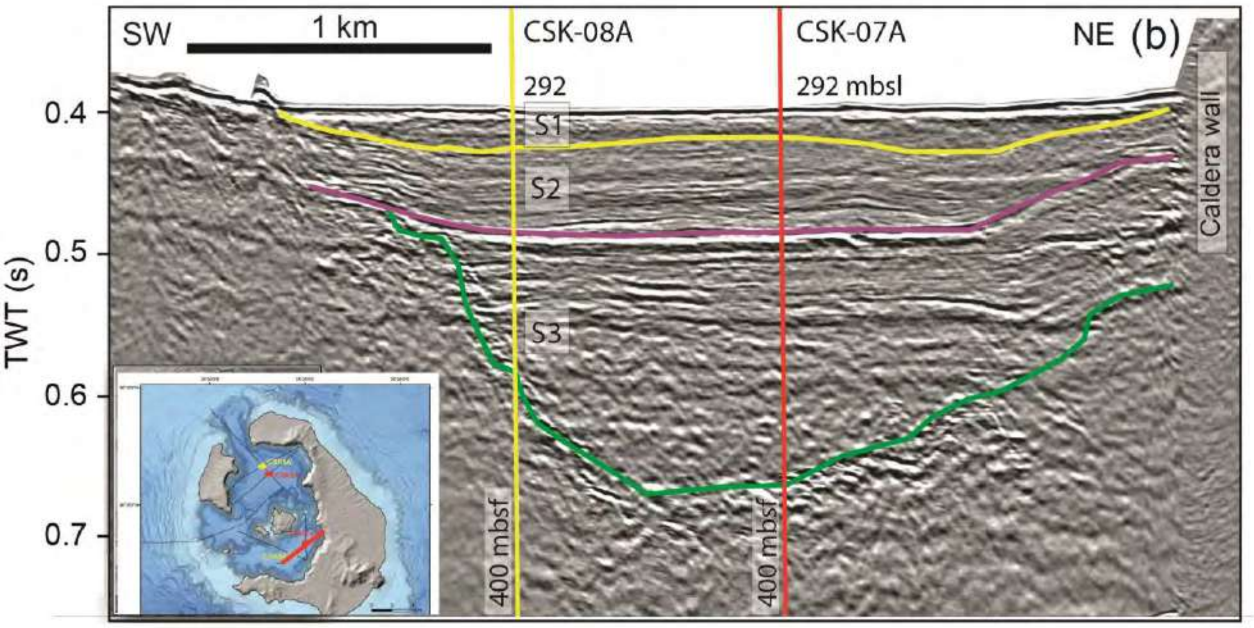


Figure 9. Single channel seismic profile SW-NE across the southern caldera basin of Santorini (from Johnston et al. 2015). The location of the profile is shown on Figure 1b. Core CSK-07A or CSK-08A will characterise units S1 (mass wasting of the cliffs), S2 (volcaniclastics from submarine eruptions of Kameni Volcano) and S3 (probable sediments from caldera flooding), as well as deposits underlying unit S3 (intracaldera tuffs of the Late Bronze-Age eruption). This published profile is equivalent to sparker profile HH15-SP10 of the site maps.

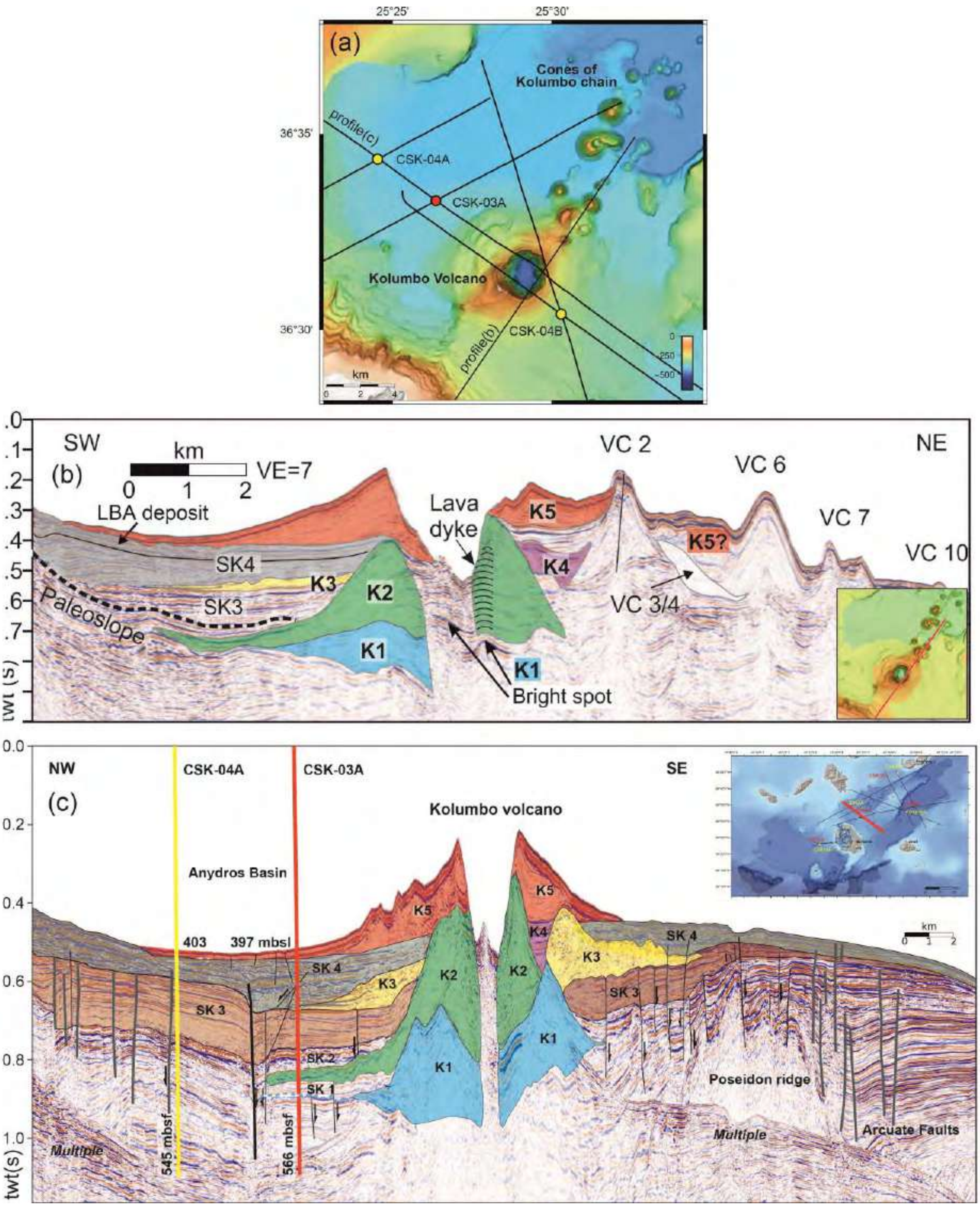


Figure 10. (a) Swath map showing the centres of the Kolumbo chain, the proposed drill sites, and selected seismic profiles. **(b)** NE-SW interpreted multi-channel seismic profile, showing the five eruptive units (K1-K5) of Kolumbo Seamount. VC's are volcanic cones of the Kolumbo chain (from Hübscher et al. 2015). **(c)** NW-SE interpreted multi-channel seismic profile, showing primary drill site CSK-03A and alternate site CSK-04A (also from Hübscher et al. 2015). Primary site CSK-3A will penetrate eruptive units K2, K3 and K5 from Kolumbo and allow them to be intercorrelated with the eruption stratigraphy of Santorini. It is expected to also intersect the thin feather edge of unit K1 (blue dotted line), constraining it stratigraphically as well. The preferred alternate site for this is CSK-4B (off profile). Units SK1 to 4 are volcano-sedimentary packages expected to contain Santorini-derived volcaniclastsics, and would be sampled by alternate site CSK-4A, which is of lower priority than CSK-04B. The profile locations are shown on Figure 1b. The profile in figure c is equivalent to sparker profile HH06-22 of the site maps.

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IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-01A targets the plio-quaternay volcano-sedimentary fill of the Anhydros Basin, to the depth of the Alpine basement. The site lies near the basin axis in a position downstream of Santorini and Kolumbo Volcanoes. The aim is to use the core (and seismic profiles) to reconstruct the volcanic, sedimentary and tectonic histories of the basin, and to access a near-continuous time series of volcanism in the area since rift inception. The hole will transect and characterize all six seismic packages of the Anhydros rift basin (B1 to B6).
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-01A	Area or Location:	Anhydros Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.7293	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.6482	Distance to Land: (km)	10
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	505

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	756	9
	Total Sediment Thickness (m): 756	
		Total Penetration (m): 765
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	Limestone, schist or granite

Coring Plan: (Specify or check)

2 Holes APC/HLAPC to refusal, each followed by XCB to 600 mbsf; drill ahead in Hole C to 575 mbsf with the option of one or two cored intervals of 50 meters in between and afterwards RCB to 765 mbsf; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:	Drilling/Coring: 10.7	Logging: 1.6	Total On-site: 12.3

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-01A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-15 Position: CDP 2746
1b High resolution seismic seismic reflection (crossing)	no	No cross line
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	yes	See Velocity_Table.pdf
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	The 3.5 kHz profiles do not run along the site survey profiles, but image the shallow strata on a regional scale.
7 Swath bathymetry	yes	CSK-bathy.grd, CSK-bathy.pdf
8a Side looking sonar (surface)	yes	
8b Side looking sonar (bottom)	no	
9 Photography or video		
10 Heat Flow		
11a Magnetics	yes	CSK-Mag.grd, CSL-Mag.pdf These grids cover entire study area on a regional scale, covering all sites. There are no site specific grids or maps.
11b Gravity	yes	CSK-Gravity-FreeAir.grd, CSK-Gravity-FreeAir.pdf CSK-Bouguer.grd, CSK-Gravity-FreeAir.pdf These grids cover entire study area on a regional scale, covering all sites. There are no site specific grids or maps.
12 Sediment cores	yes	~5m long gravity core and a box corer (POS513/15 and 21), 7 km from site position showing soft hemipelagic muds with some 1 to 5 cm thick intercalated ash layers; Sedimentation rate ~9 cm/ka.
13 Rock sampling		
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-15.txt
17 Other	no	

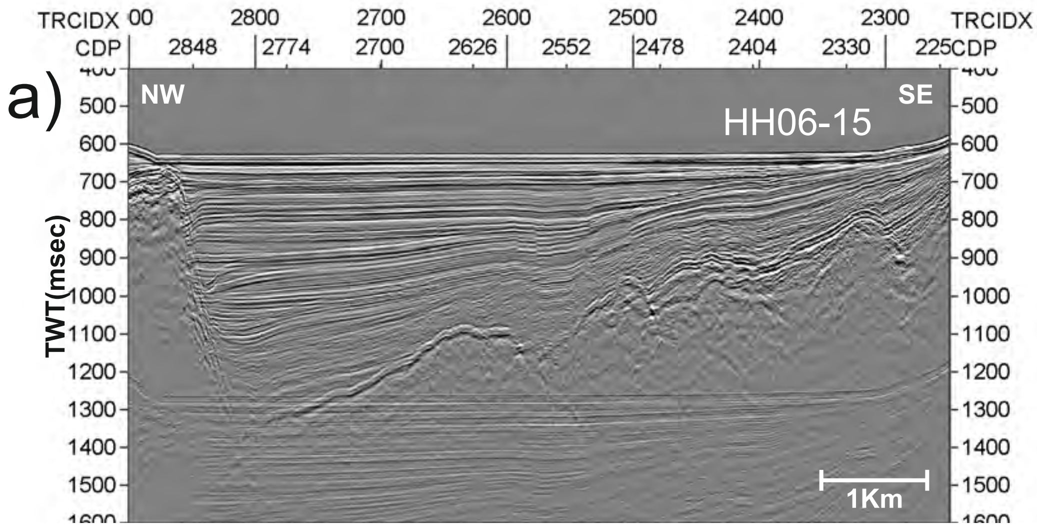
Proposal #: 932 - Full	Site #: CSK-01A	Date Form Submitted: 2019-03-29 20:21:19

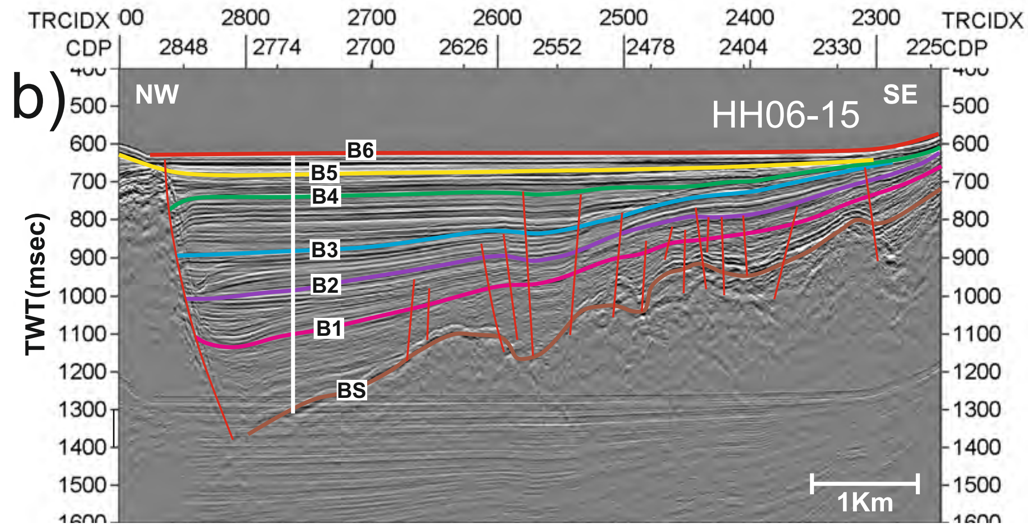
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Two holes (A, B) APC/HLAPC to refusal including 4 temperature measurements, each followed by XCB to 600 mbsf; Hole C: RCB drilling ahead until 575 mbsf with the option of one or two cored intervals of 50 meters in between, RCB to 765 mbsf including 10 m of basement, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	no
5. Are there reasons to expect hydrocarbon accumulations at this site?	no
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	Non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	Target drill depth may be to deep for XCB only

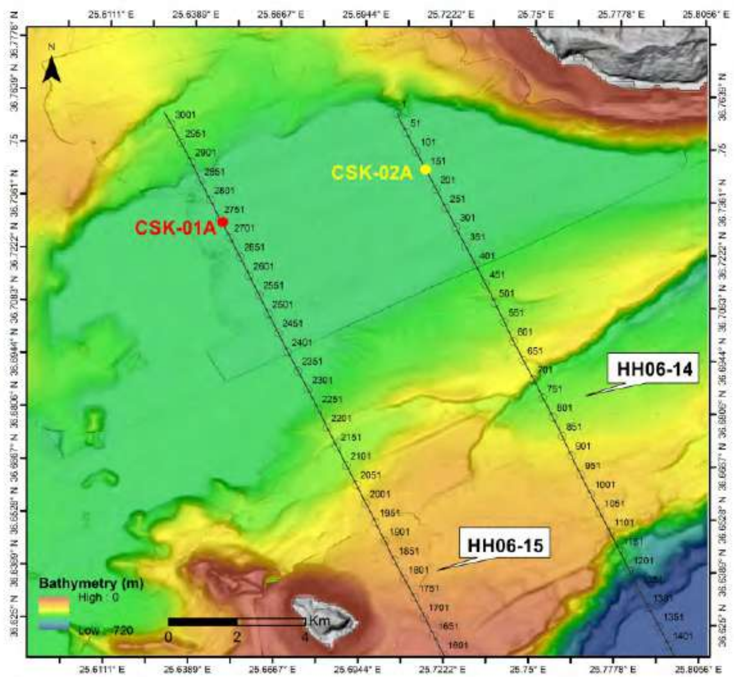
Proposal #: 932 - Full	Site #: CSK-01A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 43	Seismic unit B6: horizontal dipping beds, one stronger reflector at ~20 m	Pleistocene/ Holocene	1.6	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	180	lithology similar like in gravity core; interpretation Nomikou et al. (2016b; 2018)
43 - 95	Seismic unit B5: horizontal dipping beds	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	170	lithology and structures are the same like in first seismic units but stronger compacted; Interpretation after Nomikou et al. (2016b; 2018)
95 - 239	Seismic unit B4: horizontal dipping beds, several stronger reflectors distributed within the unit	Early? Pleistocene	2.0	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	160	More turbiditic deposits but at drill site still horizontal layering; interpretation after Nomikou et al. (2016b; 2018)
239 - 349	Seismic unit B3: subhorizontal dipping beds, several stronger reflectors distributed within the unit	Early Pleistocene/ Pliocene	2.1	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	150	Inclination in bedding indicate either initial fill off the rifted basin or tectonic activity; interpretation after Nomikou et al. (2016b; 2018)
349 - 488	Seismic unit B2: subhorizontal dipping beds, several stronger reflectors distributed within the unit; chaotic layering in the lower part?	early Pleistocene?/ Pliocene	2.4	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift	120	Inclination in bedding indicate either initial fill off the rifted basin or tectonic activity; chaotic layer may indicate slumping and mass flows; interpretation after Nomikou et al. (2016b; 2018)
488 - 756	Seismic unit B1: subhorizontal dipping beds on basement unconformity	Pliocene	2.6	MTD´s, sands and gravel, turbidites, hemipelagic muds, volcaniclastics	submarine to continental; initial filling of a rift basin	110	initial filling sequence of the rift with mixed volcaniclastic and continental material; interpretation after Nomikou et al. (2016b; 2018)
756 - 765	continental basement	Mesozoic	3.0	limestone, schists, granites	continental basement	??	Interpretation after Nomikou et al. (2016b; 2018)

CSK-01A







CSK-01A: HH06-15, CDP 2746 (a and b)

Files to be uploaded to SSDB:
Location map: CSK-01A_location.pdf
SEGY-data: HH06-15.sgy
Navigation data:HH06-15.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf

Site Information:
Coordinates: 36.7293/25.6482
Water depth: 505m
Penetration: 765m

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-02A targets the plio-quaternay volcano-sedimentary fill of the Anhydros Basin, to the depth of the Alpine basement. The site lies near the basin axis in a position downstream of Santorini and Kolumbo Volcanoes. The aim is to use the core (and seismic profiles) to reconstruct the volcanic, sedimentary and tectonic histories of the basin, and to access a near-continuous time series of volcanism in the area since rift inception. The hole will transect and characterize all six seismic packages of the Anhydros rift basin (B1 to B6).
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-02A	Area or Location:	Anhydros Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.7438	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.7146	Distance to Land: (km)	6
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	511

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	437	10
	Total Sediment Thickness (m): 437	
		Total Penetration (m): 447
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	Limestone, schist or granite

Coring Plan: (Specify or check)

3 Holes APC/HLAPC to refusal, each followed by XCB to 447 mbsf including 10 meters into basement or until refusal; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
8.5	1.3	9.8

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					

Sensitive marine habitat (e.g., reefs, vents):

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-02A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-14 Position: CDP 150
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	~5m long gravity core and a box corer (POS513/15 and 21), 4 km from site position showing soft hemipelagic muds with some 1 to 5 cm thick intercalated ash layers; Sedimentation rate ~9 cm/ka.
13 Rock sampling		
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-16.txt
17 Other	no	

Proposal #: 932 - Full	Site #: CSK-02A	Date Form Submitted: 2019-03-29 20:21:19

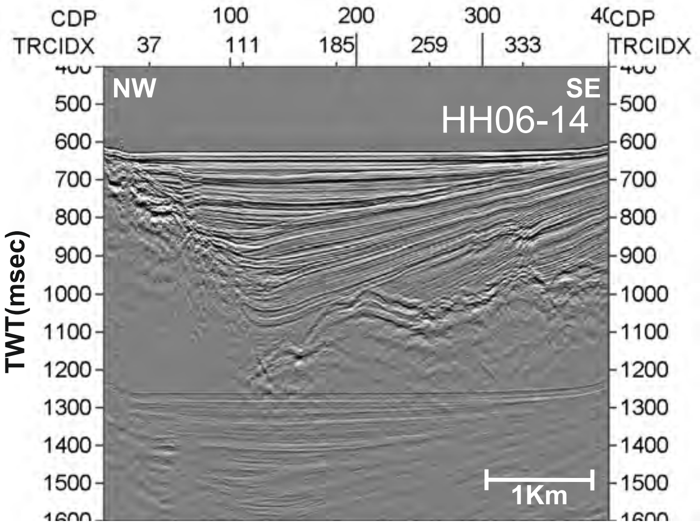
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Tripple APC/HLAPC (Holes A, B, C) to refusal including 4 temperature measurements, each followed by XCB to 447 mbsf including 10 meters of basement or until refusal, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	

Proposal #: 932 - Full	Site #: CSK-02A	Date Form Submitted: 2019-03-29 20:21:19

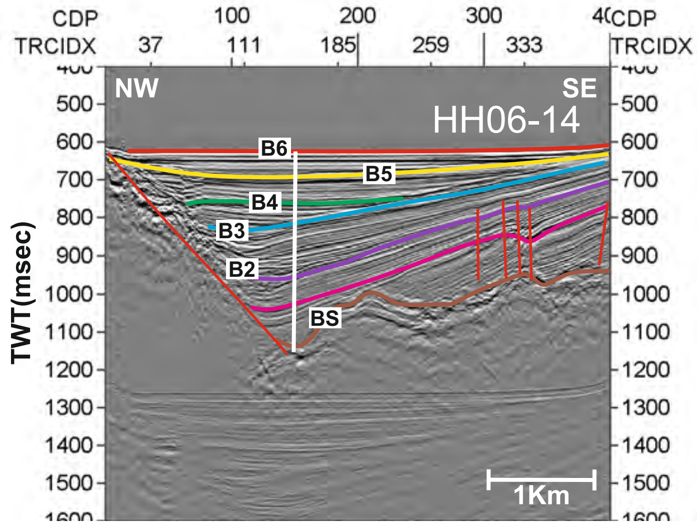
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 51	Seismic unit B6: horizontal dipping beds, one stronger reflector at ~30 m	Pleistocene/ Holocene	1.6	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	120	lithology similar like in gravity core; interpretation after Nomikou et al. (2016b; 2018)
51 - 116	Seismic unit B5: horizontal dipping beds	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift	110	lithology and structures are the same like in first seismic units but stronger compacted; interpretation after Nomikou et al. (2016b; 2018)
116 - 152	seismic unit B4 with horizontal dipping beds, several stronger reflectors distributed within the unit	Early? Pleistocene	2.0	hemipelagic muds, volcaniclstics, turbidites	filled submarine rift-basin	100	More turbiditic deposits but at drill site still horizontal layering; interpretation after Nomikou et al. (2016b; 2018)
152 - 291	seismic unit B3 with subhorizontal dipping beds, several stronger reflectors distributed within the unit	Early Pleistocene/ Pliocene	2.1	hemipelagic muds, volcaniclstics, turbidites	filled submarine rift-basin	90	Inclination in bedding indicate either initial fill off the rifted basin or tectonic activity; interpretation after Nomikou et al. (2016b; 2018)
291 - 375	seismic unit B2	Early Pleistocene?/ Pliocene	2.4	hemipelagic muds, volcaniclastics	filled submarine rift-basin	80	Interpretation after Nomikou et al. (2016b; 2018)
375 - 437	Seismic unit B1	Pliocene	2.6	hemipelagic muds, volcaniclastics	submarine to continental; initial filling of a rift basin	70	Interpretation after Nomikou et al. (2016b; 2018)
437 - 447	continental basement	Mesozoic	3.0	Limestones, schists, granites	Basement	??	Interpretation after Nomikou et al. (2016b; 2018)

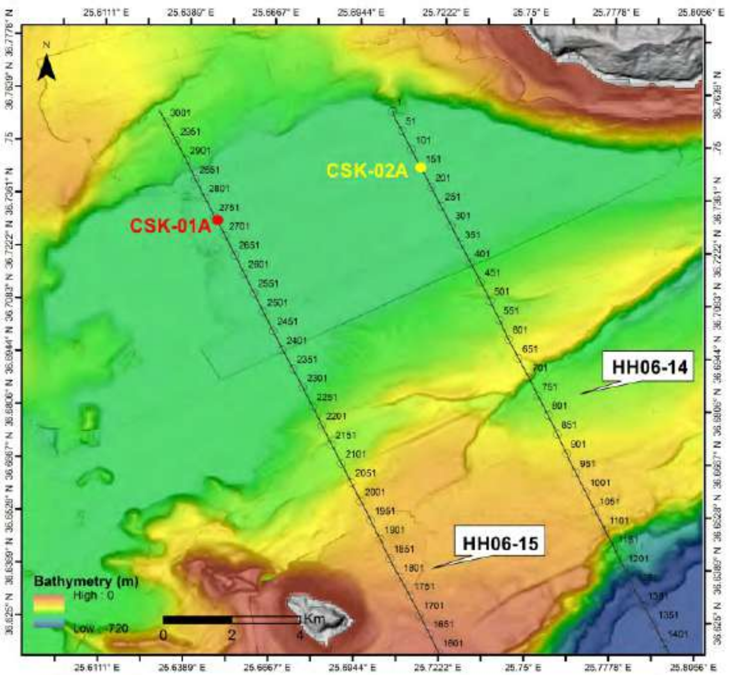
CSK-02A

a



b)





CSK-02A: HH06-14, CDP 150 (a and b)

Files to be uploaded to SSDB:
Location map: CSK-02A_location.pdf
SEGY-data : HH06-14.sgy
Navigation data: HH06-14.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf

Site Information:
Coordinates: 36.7438/25.7146
Water depth: 511m
Penetration: 447m

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-03A lies in the Anhydros Basin on the NW submarine flank of Kolumbo Volcano. The aim is to penetrate four seismically recognized volcanic eruption units from Kolumbo (K2, K3, K5 and the thin lateral continuation of K1), as well as many eruption units from Santorini. This will enable characterisation of the products of the Kolumbo eruptions, as well as construction of a coherent stratigraphy for Santorini and Kolumbo together.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-03A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 36.5549
Longitude:	Deg: 25.4398
Coordinate System:	WGS 84
Priority of Site:	Primary: ✓ Alternate: ☐

Area or Location:	Anhydros Basin, Aegean Sea, Greece
Jurisdiction:	Greek territorial waters
Distance to Land: (km)	9
Water Depth (m):	397

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	566	0
	Total Sediment Thickness (m): 566	
		Total Penetration (m): 566
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	

Coring Plan:
(Specify or check)

3 Holes APC/HLAPC to refusal, each followed by XCB to 566 mbsf including 10 meters into basement or until refusal; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
8.2	1.3	9.5

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

Sensitive marine habitat (e.g., reefs, vents):

Preferred weather window: Late autumn, winter or early spring

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-03A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-22 Position: CDP 614
1b High resolution seismic seismic reflection (crossing)	yes	Line: HH06-34 Position: CDP 760
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)		Data and info see Site CSK-01A
8b Side looking sonar (bottom)		
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	3 potential gravity cores nearby: POS513/57 1.6 km away showing 20 cm of muddy surface sediments and stuck in >30 cm fine to coarse ash volcaniclastics (63µ to 1 cm grain sizes); POS513/17 in 4 km distance showing 30 cm of muddy surface sediments and stuck in >50 cm fine grained volcaniclastics (<0.5 cm grain sizes); POS513/16 showing 20 cm of muddy surface sediments and stuck in 80 cm fine-grained volcaniclastics (<1mm grain size); Sedimentation rate ~9 cm/ka in muddy sediments, and event sedimentation for volcaniclastics.
13 Rock sampling		
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-22.txt, HH06-34.txt
17 Other	no	

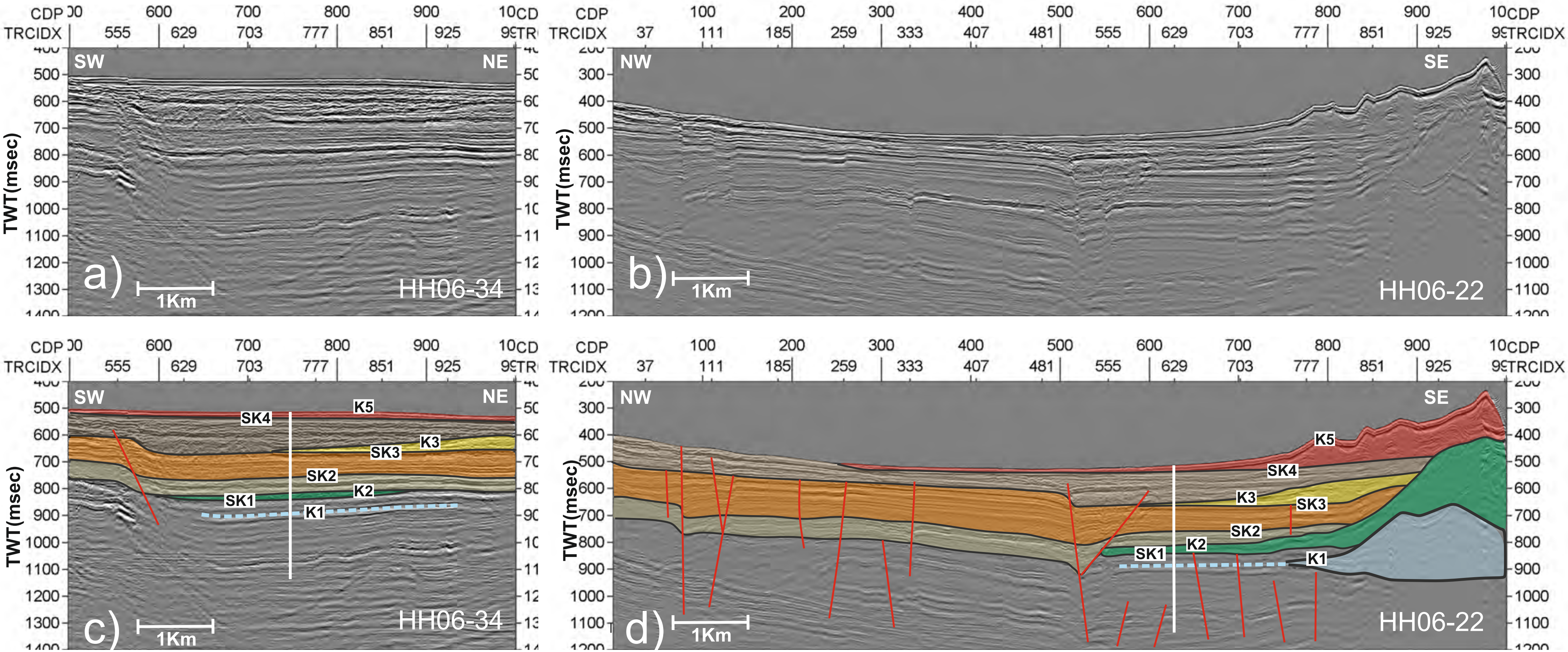
Proposal #: 932 - Full	Site #: CSK-03A	Date Form Submitted: 2019-03-29 20:21:19

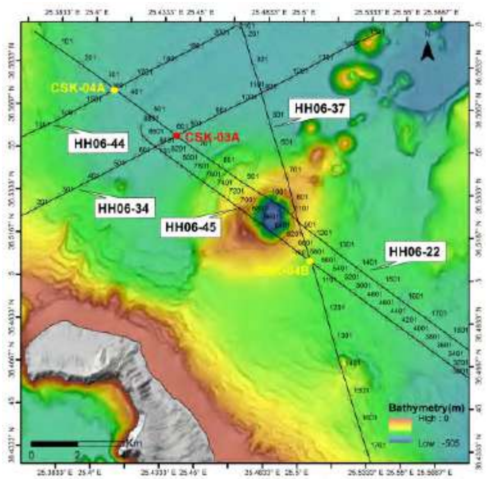
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Tripple APC/HLAPC (Holes A, B, C) to refusal including 4 temperature measurements, each followed by XCB to 566 mbsf, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	Target drill depth may be to deep for XCB only and fine to coarse volcaniclastic in the top 10 meters may be be difficult to penetrate

Proposal #: 932 - Full	Site #: CSK-03A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 20	Seismic unit K5: AD 1650 eruption of Kolumbo	AD 1650	1.65	Volcaniclastics (pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
20 - 118	Seismic unit SK4; Volcaniclastics (including debris flows) from Santorini, and marine sedimentation	Holocene/ Upper Pleistocene	1.7	hemipelagic muds, volcaniclastics, turbidites, MTD´s	filled submarine rift-basin	130	Interpretation of Hubscher et al. (2015)
118 - 129	Seismic unit K3: eruption of Kolumbo	Pleistocene	1.75	volcaniclastics (probably pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
129 - 212	Seismic unit SK3: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	120	Interpretation of Hubscher et al. (2015)
212 - 266	Seismic unit SK2: Volcaniclastics from Santorini (incuding mass flows) and marine sedimentation	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	110	Interpretation of Hubscher et al. (2015)
266 - 288	Seismic unit K2: eruption of Kolumbo	Pleistocene	1.85	volcaniclastics (probably pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
288 - 311	Seismic unit SK1: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene	1.9	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	100	Interpretation of Hubscher et al. (2015)
311 - 320	Seismic unit K1: eruption of Kolumbo (intercalated within SK1)	Pleistocene	1.95	Volcaniclastics (probably pumiceous)	filled submarine rift-basin	>1,000,000	Presence of unit K1 extrapolated on seismic profiles and assumed to be <10 m thick; interpretation of Hubscher et al. (2015)
320 - 566	Seismic unit pre-K1: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene/ Pliocene?	1900	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	80	Interpretation of Hubscher et al. (2015)

CSK-03A





CSK-03A: HH06-34, CDP 760 (a and c); HH06-22, CDP 614 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-03A_location.pdf
SEGY-data data: HH06-34.sgy, HH06-22.sgy
Navigation data: HH06-34.txt, HH06-22.txt
Bathymetry:CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile.

Site information:
Coordinates: 36.5549/25.4398
Water depth: 397m
Penetration: 566m

IODP Site Forms

932 - Full

Form 1 – General Site Information

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-04A lies in the Anhydros Basin on the NW submarine flank of Kolumbo Seamount Volcano. The aim is to penetrate seismically recognized volcanic eruption units from Kolumbo, as well as many units from Santorini. This will enable characterisation of the products of the Kolumbo eruptions, as well as construction of a coherent stratigraphy for Santorini and Kolumbo together. However this site only clearly transects one Kolumbo eruption unit (K5), and has been replaced since the pre-proposal by site CSK-04B, which is better placed for our objectives.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-04A	Area or Location:	Anhydros Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.5728	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.4092	Distance to Land: (km)	10
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	403

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	545	0
	Total Sediment Thickness (m) 545	
		Total Penetration (m): 545
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	

Coring Plan: (Specify or check)

3 Holes APC/HLAPC to refusal, each followed by XCB to 545 mbsf including 10 meters into basement or until refusal; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		
WL	☑	Magnetic Susceptibility	☑	Other tools:
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:	Drilling/Coring: 8.2	Logging: 1.3	Total On-site: 9.5

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping

Generated: 2019-03-29T20:29:11+00:00

Proposal #: 932 - Full	Site #: CSK-04A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-22 Position: CDP 345
1b High resolution seismic seismic reflection (crossing)	yes	Line: HH06-44a Position: CDP 1626
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	yes	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	~3.5m long gravity core and a box corer (POS513/19), 7 km from site position showing hemipelagic muds with some 1 to 20 cm thick intercalated ash layers (max grain size= 2 mm); Sedimentation rate ~6 cm/ka .
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-22.txt, HH06.44a.txt
17 Other	no	

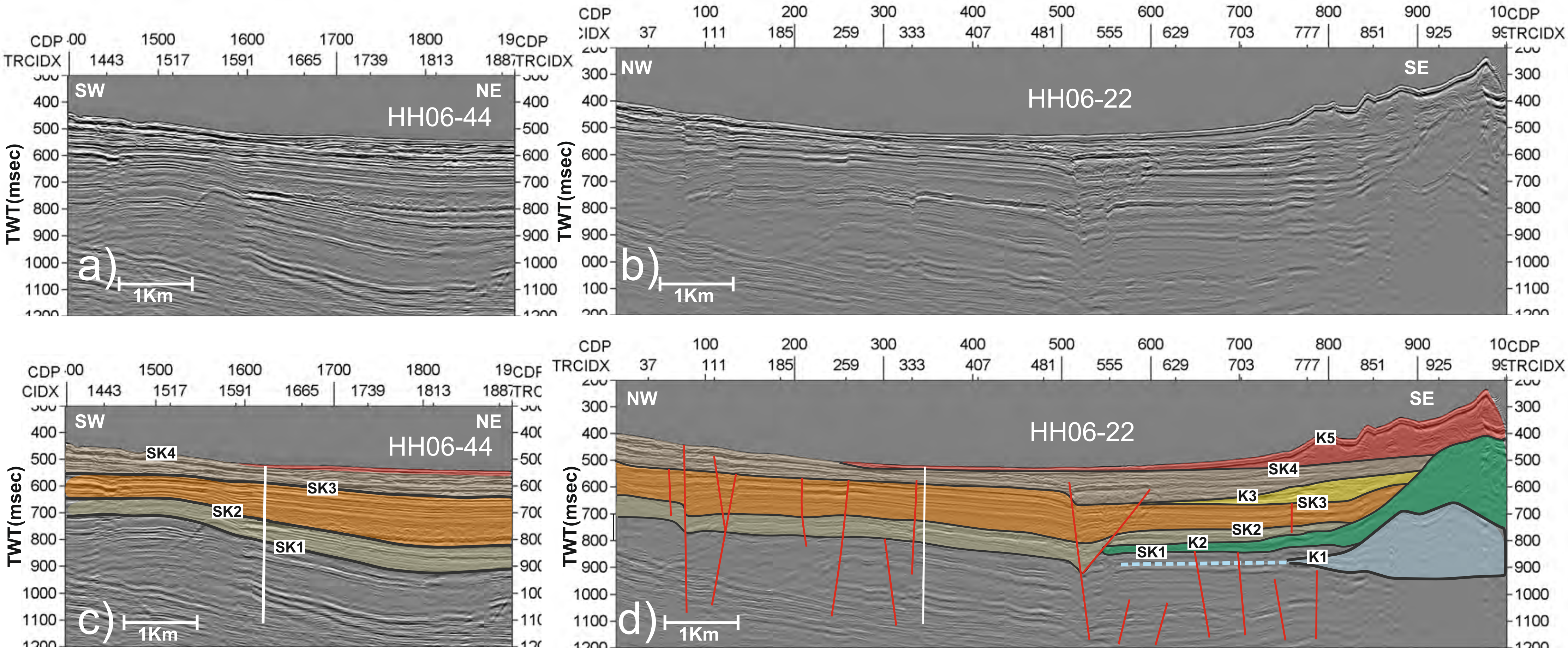
Proposal #: 932 - Full	Site #: CSK-04A	Date Form Submitted: 2019-03-29 20:21:19

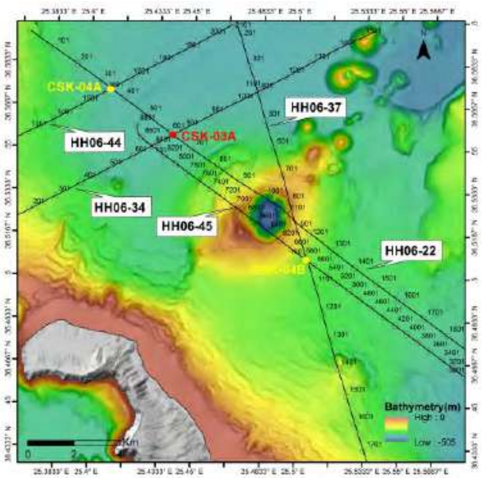
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Tripple APC/HLAPC (Holes A, B, C) to refusal including 4 temperature measurements, each followed by XCB to 545 mbsf; log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	Target drill depth may be to deep for XCB only and fine to coarse volcaniclastic in the top 10 meters may be be difficult to penetrate

Proposal #: 932 - Full	Site #: CSK-04A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 8	Seismic unit K5: AD 1650 eruption of Kolumbo	0.0036	1.65	Volcaniclastics (pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
8 - 56	Seismic unit SK4: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Holocene/ Upper Pleistocene	1.7	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	130	Interpretation of Hubscher et al. (2015)
56 - 184	Seismic unit SK3: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	120	Interpretation of Hubscher et al. (2015)
184 - 254	Seismic unit SK2: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	110	Interpretation of Hubscher et al. (2015)
254 - 545	Seismic unit SK1: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene/ Pliocene?	1.9	hemipelagic miuds, volcaniclastics, turbidites, MTDs	filled submarine rift-basin	100	Interpretation of Hubscher et al. (2015)

CSK-04A





CSK-04A: HH06-44, CDP 1626 (a and c); HH06-22, CDP 345 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-04A_location.pdf
SEGY-data data: HH06-34.sgy, HH06-22.sgy
Navigation data: HH06-34.txt, HH06-22.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile

Site information:
Coordinates:36.5728/25.4092
Water depth: 403m
Penetration: 545m

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-04B lies in the Anhydros Basin on the SE submarine flank of Kolumbo Seamount Volcano. The aim is to penetrate seismically recognized volcanic eruption units from Kolumbo (K1, K3, K5), as well as many units from Santorini. This will enable characterisation of the products of the Kolumbo eruptions, as well as construction of a coherent stratigraphy for Santorini and Kolumbo together. This site replaces CSK-04A (pre-proposal alternate) as the favoured alternate to site 03A, since CSK-04A only transects one Kolumbo eruption unit whereas CSK-04B samples three.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini.

Section B: General Site Information

Site Name:	CSK-04B	Area or Location:	Anhydros Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.5068	Jurisdiction:	Greek territorial water
Longitude:	Deg: 25.5053	Distance to Land: (km)	8
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	300

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	730	0
	Total Sediment Thickness (m): 730	
		Total Penetration (m): 730
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	

Coring Plan: (Specify or check)

2 Holes APC/HLAPC to refusal, each followed by XCB to 600 mbsf; drill ahead in Hole C to 550 mbsf with the option of one or two cored RCB intervals of 50 meters in between and afterwards RCB to 730 mbsf; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
10.4	1.5	11.9

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping

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Proposal #: 932 - Full	Site #: CSK-04B	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-37 Position: CDP 1009
1b High resolution seismic seismic reflection (crossing)		Line: HH06-45short Position: CDP 5727
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-37.txt, HH06-45short.txt
17 Other	no	

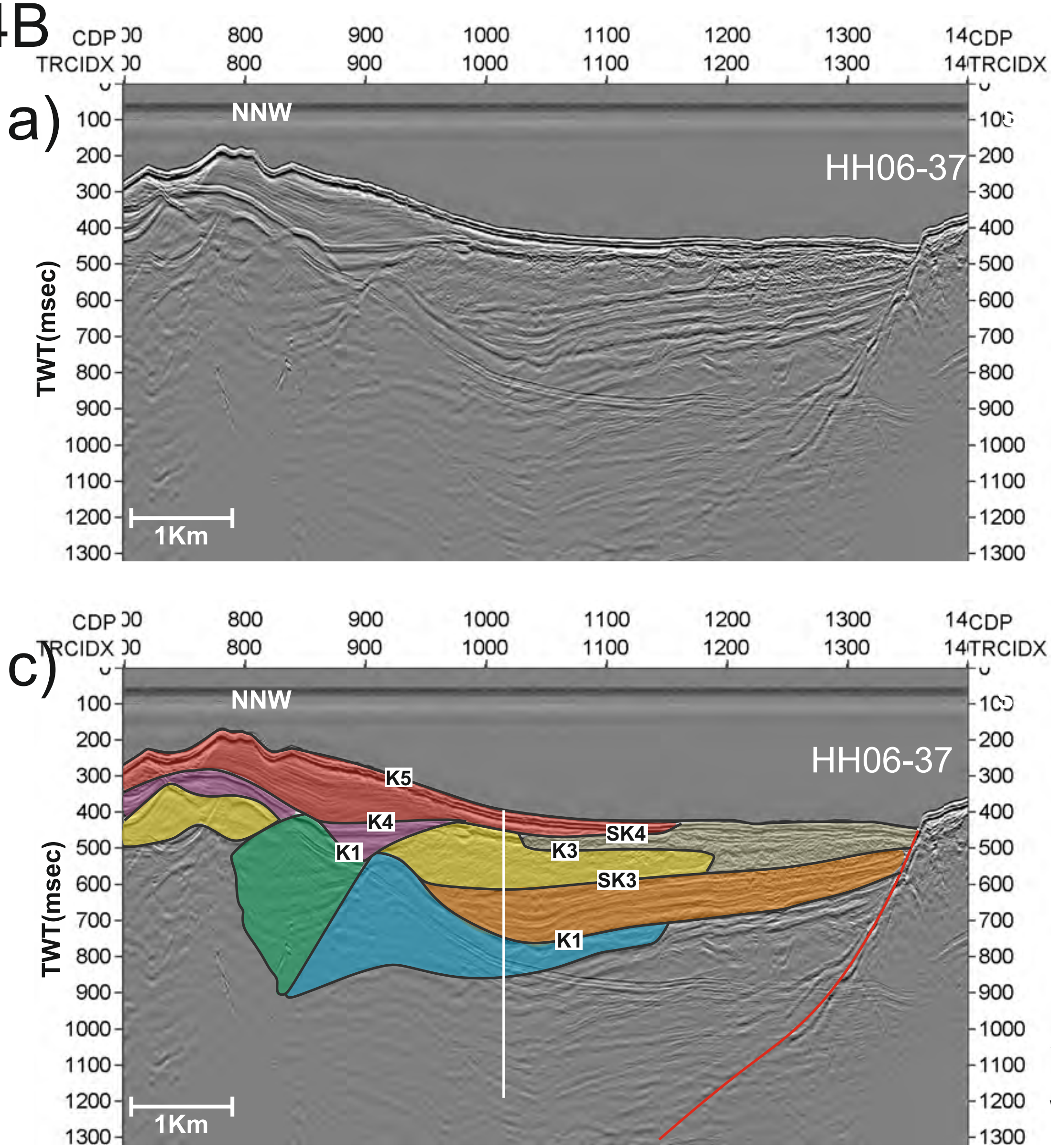
Proposal #: 932 - Full	Site #: CSK-04B	Date Form Submitted: 2019-03-29 20:21:19

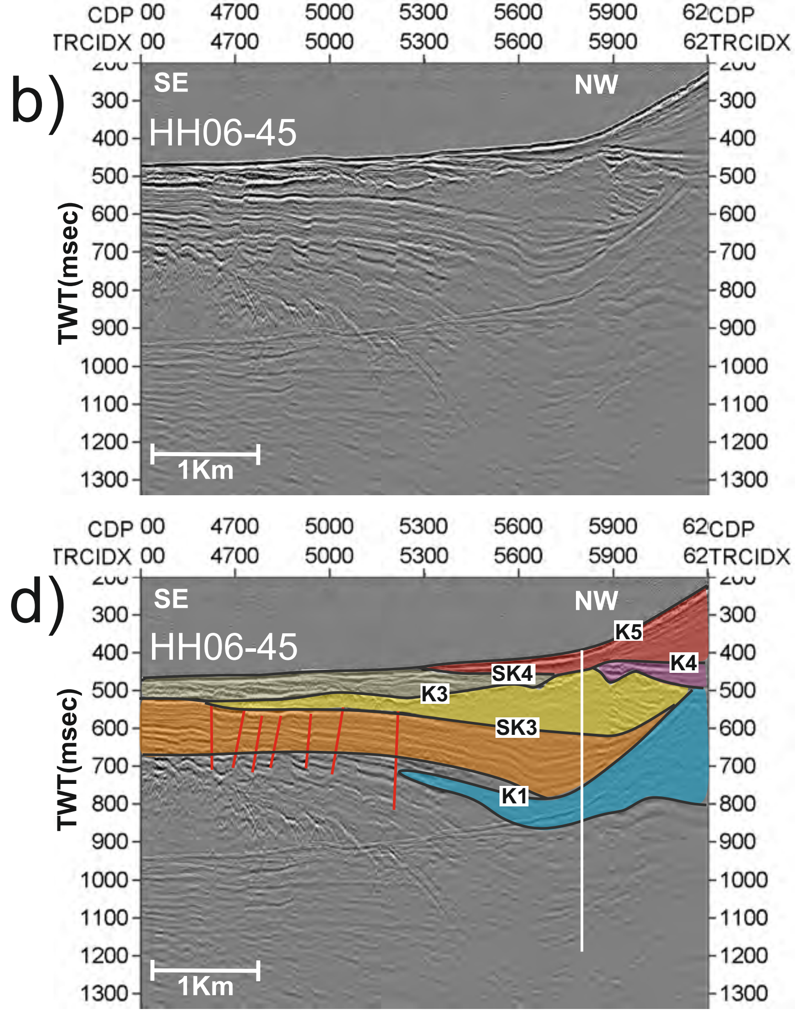
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Two holes (A, B) APC/HLAPC to refusal including 4 temperature measurements, each followed by XCB to 600 mbsf; Hole C: RCB drilling ahead until 550 mbsf with the option of one or two cored intervals of 50 meters in between, RCB to 730 mbsf, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	fine to coarse volcaniclastic in the top 10 meters may be be difficult to penetrate

Proposal #: 932 - Full	Site #: CSK-04B	Date Form Submitted: 2019-03-29 20:21:19

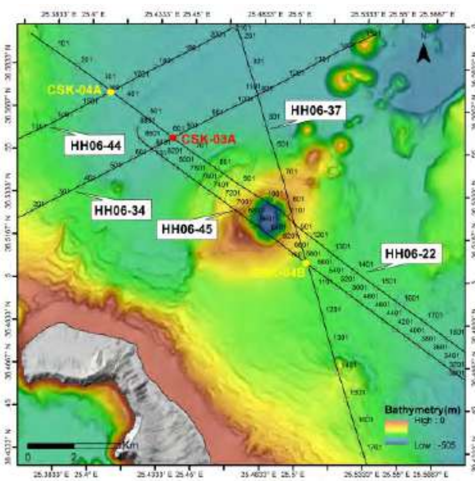
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 43	Seismic unit K5: AD 1650 eruption of Kolumbo	AD 1650	1.65	Volcaniclastics (pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
43 - 190	Seismic unit K3	Pleistocene	1.75	Volcaniclastics (probably pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
190 - 318	Seismic unit SK3: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTDs	filled submarine rift-basin	120	Interpretation of Hubscher et al. (2015)
318 - 405	Seismic unit K1: eruption of Kolumbo	Pleistocene	1.95	Volcaniclastics (probably pumiceous)	filled submarine rift-basin	>1,000,000	Interpretation of Hubscher et al. (2015)
405 - 730	Pre-K1 levels of basin sediment fill: Volcaniclastics from Santorini (including mass flows) and marine sedimentation	Pleistocene/ Pliocene	1.9	hemipelagic muds, volcaniclastics, turbidites, MTDs	filled submarine rift-basin	80	Interpretation of Hubscher et al. (2015)

CSK-04B





Site Information:
Coordinates:36.5068/25.5053
Water depth: 300m
Penetration: 730m



CSK-04B: HH06-37, CDP 1009 (a and c); HH06-45, CDP 5727 (b and d)
Files to be uploaded to SSDB:
Location map: CSK-04B_location.pdf
SEGY-data data: HH06-37.sgy, HH06-45.sgy
Navigation data: HH06-37.txt, HH06-45.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd
CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip,
contains 3.5kHz profiles,
do not run along site survey profile

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-05A is sited in the northern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them and confirm (or not) published hypotheses, as well as to penetrate below unit S3 (probably intracaldera tuff of the LBA eruption). The hole is located north of a low-velocity seismic anomaly detected by the PROTEUS seismic tomography experiments and centered on the focus of caldera floor uplift during the unrest period of 2011-12.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini. Onland drilling on Kameni islands to 200 m depth in 1987-88.

Section B: General Site Information

Site Name:	CSK-05A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 36.4355
Longitude:	Deg: 25.3805
Coordinate System:	WGS 84
Priority of Site:	Primary: ✓ Alternate: ☐

Area or Location:	Santorini caldera (northern basin), Aegean Sea, Greece
Jurisdiction:	Greek territorial waters
Distance to Land: (km)	2
Water Depth (m):	385

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	360	0
	Total Sediment Thickness (m): 360	
		Total Penetration (m): 360
General Lithologies:	Coarse intracaldera sediments, breccias, landslides, lavas, muds	

Coring Plan: (Specify or check)

2 Holes APC/HLAPC/XCB to refusal; drill ahead in Hole C to 150 mbsf and RCB to 360 mbsf; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
4.3	0.9	5.2

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping. Multiple cruise liners in the summer months. No bright spots indicative of gas to the 400 mbsf on available seismic profiles.

Proposal #: 932 - Full	Site #: CSK-05A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH15-SP5 Position: CDP 973
1b High resolution seismic seismic reflection (crossing)	yes	Line: HH15-SP1 Position: CDP 820
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	Mostly Box corer from 2006 R/V Aegeao expedition of variable length up to 1 m. Mixture of hemipelagic muds and volcaniclastics
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH15-SP1.txt, HH-15-SP5.txt
17 Other	no	

IODP Site Forms

Form 4 - Environmental Protection

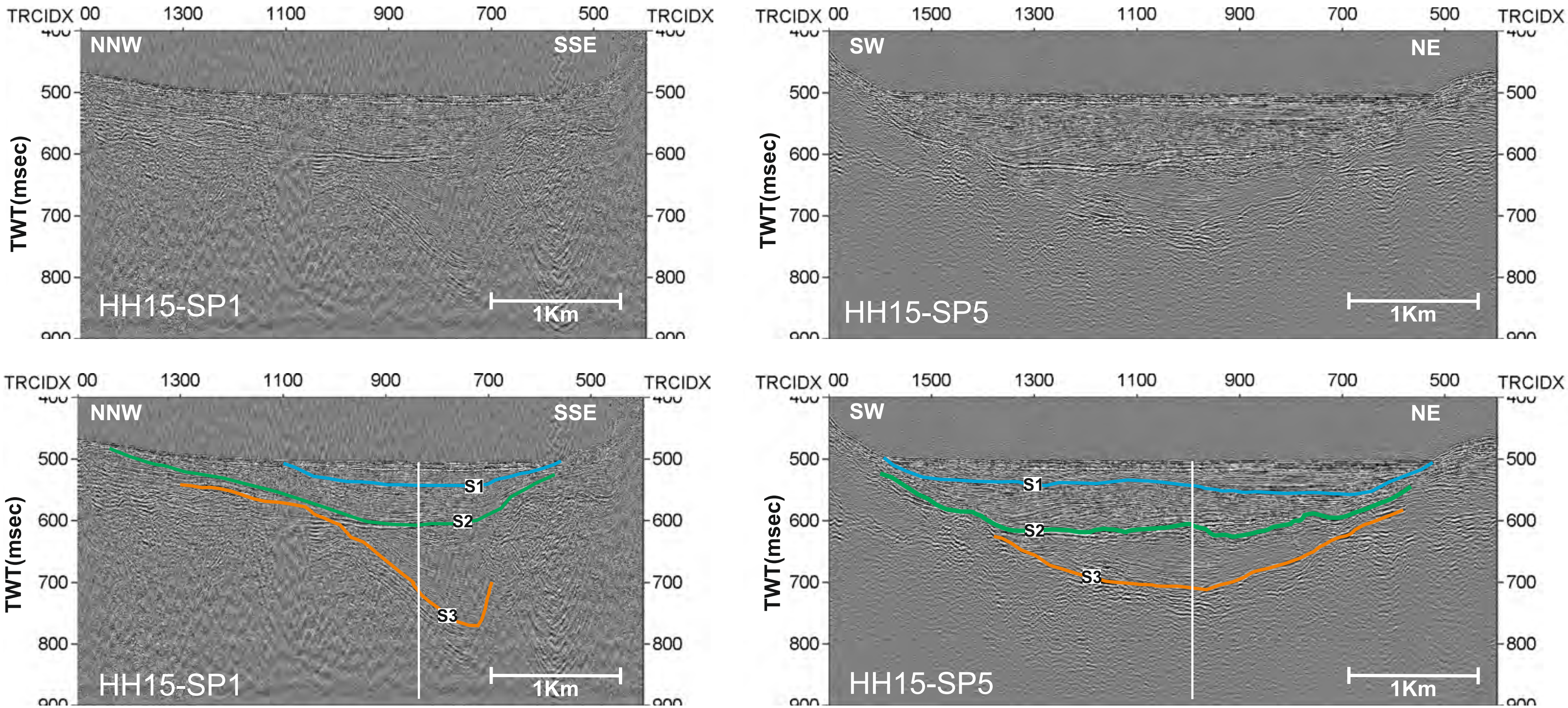
Proposal #: 932 - Full	Site #: CSK-05A	Date Form Submitted: 2019-03-29 20:21:19

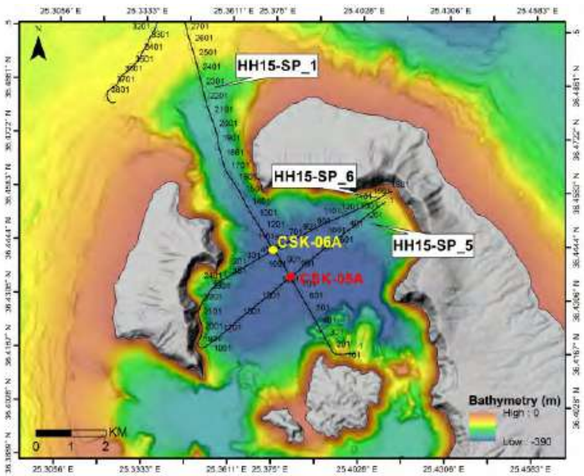
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Two holes (A, B) APC/HLAPC/XCB to refusal including 4 temperature measurements, Hole C: RCB drilling ahead until 150 mbsf, RCB to 360 mbsf; log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	heavy ship traffic in the Caldera but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	coarse clastics and lava blocks

Proposal #: 932 - Full	Site #: CSK-05A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 30	Seismic unit S1; subaerial eruptions and mass wasting of caldera cliffs	<0.0020	1.6	volcaniclastics, turbidites, debris flows, muds	Intra caldera fill	15,000	Interpretation from Johnston et al. (2015)
30 - 88	Seismic unit S2; mainly submarine eruptions of Kameni Volcano	0.0036 to 0.0020	1.8	volcaniclastics, muds	Intra-caldera fill	35,000	Interpretation from Johnston et al. (2015)
88 - 186	Seismic unit S3: end of LBA eruption; caldera flooding	0.0036	1.9	coarse gravels, tuffs, debris avalanches, debris flows	Intra-caldera fill	>1,000,000	Interpretation from Johnston et al. (2015) and Nomikou et al. (2016a)
186 - 360	Pre-S3: Late Bronze Age eruption (top of intracaldera tuffs)	3600 years	2.0	Blocky unwelded tuffs, with possible welded layers and lavas	Intra-caldera fill	>1,000,000	Interpretation of Johnston et al. (2015) and Nomikou et al. (2016a)

CSK-05A





CSK-05A: HH15-SP1, CDP 820 (a and c); HH15-SP5, CDP 973 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-05A_location.pdf
SEGY-data data: HH15-SP1.sgy; HH15-SP5.sgy
Navigation data: HH15-SP1.txt, HH15-SP5.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile

Site Information:
Coordinates: 36.4355/25.3805
Water depth: 385m
Penetration: 360m

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-06A is sited in the northern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them and confirm (or not) published hypotheses, as well as to penetrate below unit S3 (probably intracaldera tuff of the LBA eruption).
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini. Onland drilling on Kameni islands to 200 m depth in 1987-88.

Section B: General Site Information

Site Name:	CSK-06A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 36.4424
Longitude:	Deg: 25.3751
Coordinate System:	WGS 84
Priority of Site:	Primary: ☐ Alternate: ☑

Area or Location:	Santorini caldera (northern basin), Aegean Sea, Greece
Jurisdiction:	Greek territorial waters
Distance to Land: (km)	2
Water Depth (m):	383

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	381	0
	Total Sediment Thickness (m) 381	
		Total Penetration (m): 381
General Lithologies:	Coarse intracaldera sediments, breccias, landslides, lavas, muds	

Coring Plan: (Specify or check)

2 Holes APC/HLAPC/XCB to refusal; drill ahead in Hole C to 150 mbsf and RCB to 381 mbsf; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
4.6	0.9	5.5

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping. Multiple cruise liners in the summer months. No bright spots indicative of gas to the 400 mbsf on available seismic profiles

Proposal #: 932 - Full	Site #: CSK-06A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH15-SP6 Position: CDP 527
1b High resolution seismic seismic reflection (crossing)	yes	Line: HH15-SP1 Position: CDP 1049
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	Mostly Box corer from 2006 R/V Aegeao expedition of variable length up to 1 m. Mixture of hemipelagic muds and volcaniclastics
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH15-SP1.txt, HH15-SP6.txt
17 Other	no	

IODP Site Forms

Form 4 - Environmental Protection

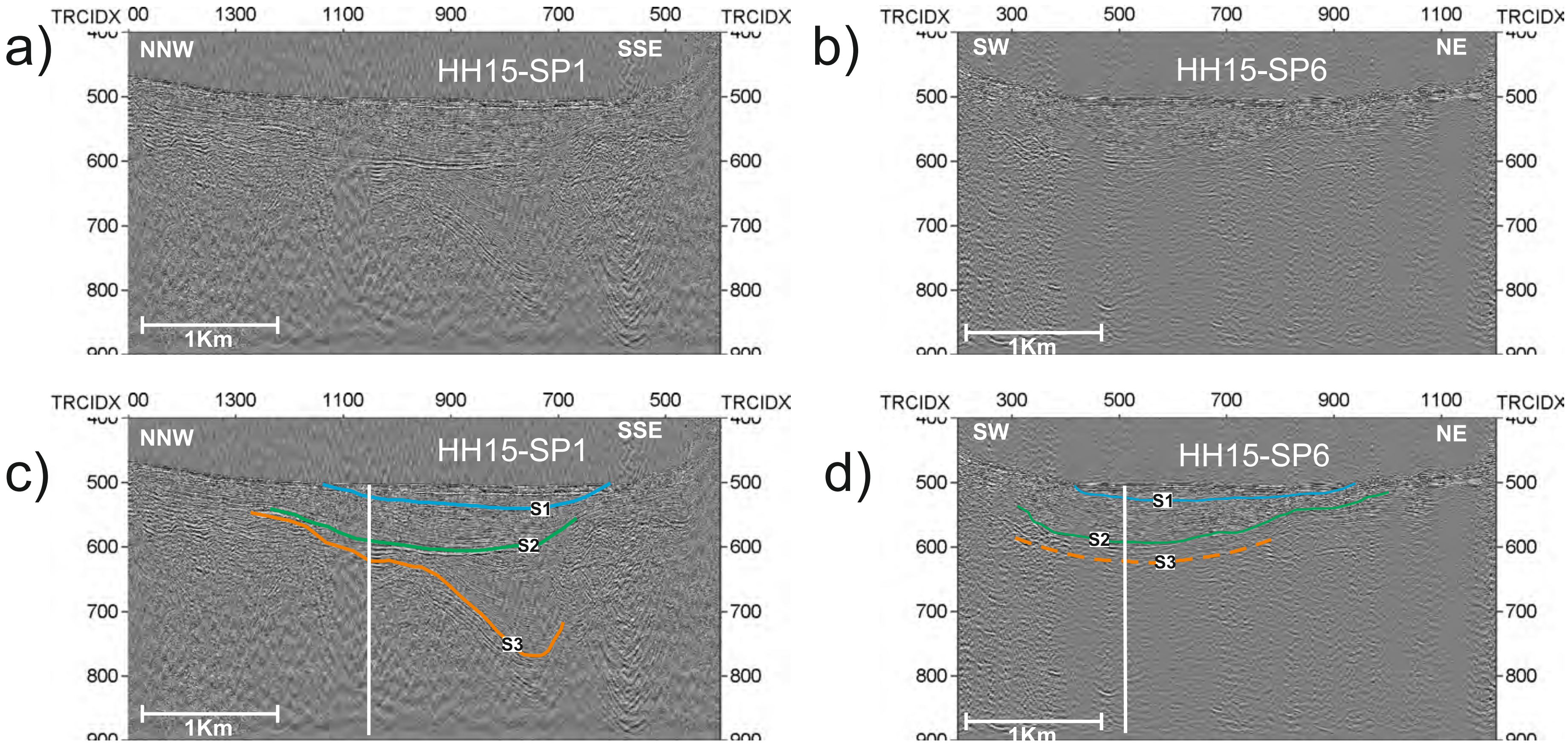
Proposal #: 932 - Full	Site #: CSK-06A	Date Form Submitted: 2019-03-29 20:21:19

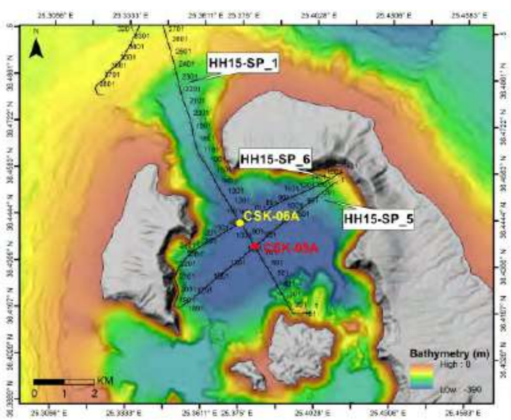
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Two holes (A, B) APC/HLAPC/XCB to refusal including 4 temperature measurements, Hole C: RCB drilling ahead until 150 mbsf, RCB to 360 mbsf; log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	heavy ship traffic in the Caldera but but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	coarse clastics and lava blocks

Proposal #: 932 - Full	Site #: CSK-06A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 14	Seismic unit S1: Subaerial eruptions and mass wasting off the caldera cliffs	<0.0020	1.6	volcaniclastics, turbidites, debris flows, muds	Intra caldera fill	7000	Interpretation from Johnston et al. (2015)
14 - 76	Seismic unit S2: mainly submarine eruptions of Kameni Volcano	0.0036 to 0.0020	1.8	volcaniclastics, muds	Intra-caldera fill	38,000	Interpretation from Johnston et al. (2015)
76 - 104	Seismic unit S3: end of LBA eruption; caldera flooding	0.0036	1.9	Coarse gravels, tuffs, debris avalanches, debris flows	Intra-caldera fill	>1,000,000	Interpretation from Johnston et al. (2015) and Nomikou et al. (2016a)
104 - 381	Pre-S3: Late Bronze Age eruption (top of intracaldera tuffs)	3600	2.0	Blocky unwelded tuffs, with possible welded layers and lavas	Intra-caldera fill	>1,000,000	Interpretation of Johnston et al. (2015) and Nomikou et al. (2016a)

CSK-06A





CSK-06A: HH15-SP1, CDP 1049 (a and c); HH15-SP6, CDP 527 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-06A_location.pdf
SEGY-data data: HH15-SP1.sgy; HH15-SP6.sgy
Navigation data: HH15-SP1.txt, HH15-SP6.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile

Site Information:
Coordinates: 36.4424/25.3751
Water depth: 382m
Penetration: 381m

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-07A is sited in the southern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them, as well as to penetrate below unit S3 (probable intracaldera tuff of the LBA eruption). This site is complementary to sites CSK-05A/06A in the northern caldera basin, as together they will provide a complete understanding of the caldera fill and collapse history.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini. Onland drilling on Kameni islands to 200 m depth in 1987-88.

Section B: General Site Information

Site Name:	CSK-07A	Area or Location:	Santorini caldera (southern basin), Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.3890	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.4171	Distance to Land: (km)	1
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	292

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Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	400	0
	Total Sediment Thickness (m) 400	
		Total Penetration (m): 400
General Lithologies:	Coarse intracaldera sediments, breccias, landslides, lavas, muds	

Coring Plan: (Specify or check)

2 Holes APC/HLAPC/XCB to refusal, followed by drill ahead to 175 mbsf and RCB to 400 mbsf, wireline logging in RCB Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:		
Drilling/Coring: 4.4	Logging: 1	Total On-site: 5.4

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping. Multiple cruise liners in the summer months. No bright spots indicative of gas on seismic profiles.

Proposal #: 932 - Full	Site #: CSK-07A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH15-SP_10 Position: CDP 415
1b High resolution seismic seismic reflection (crossing)	yes	Line: SBL20060504_052810 Position: SP 236
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	Mostly Box corer from 2006 R/V Aegeao expedition of variable length up to 1 m. Mixture of hemipelagic muds and volcaniclastics
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	SBL20060429_150514.txt, SBL20060504_052810.txt
17 Other	no	

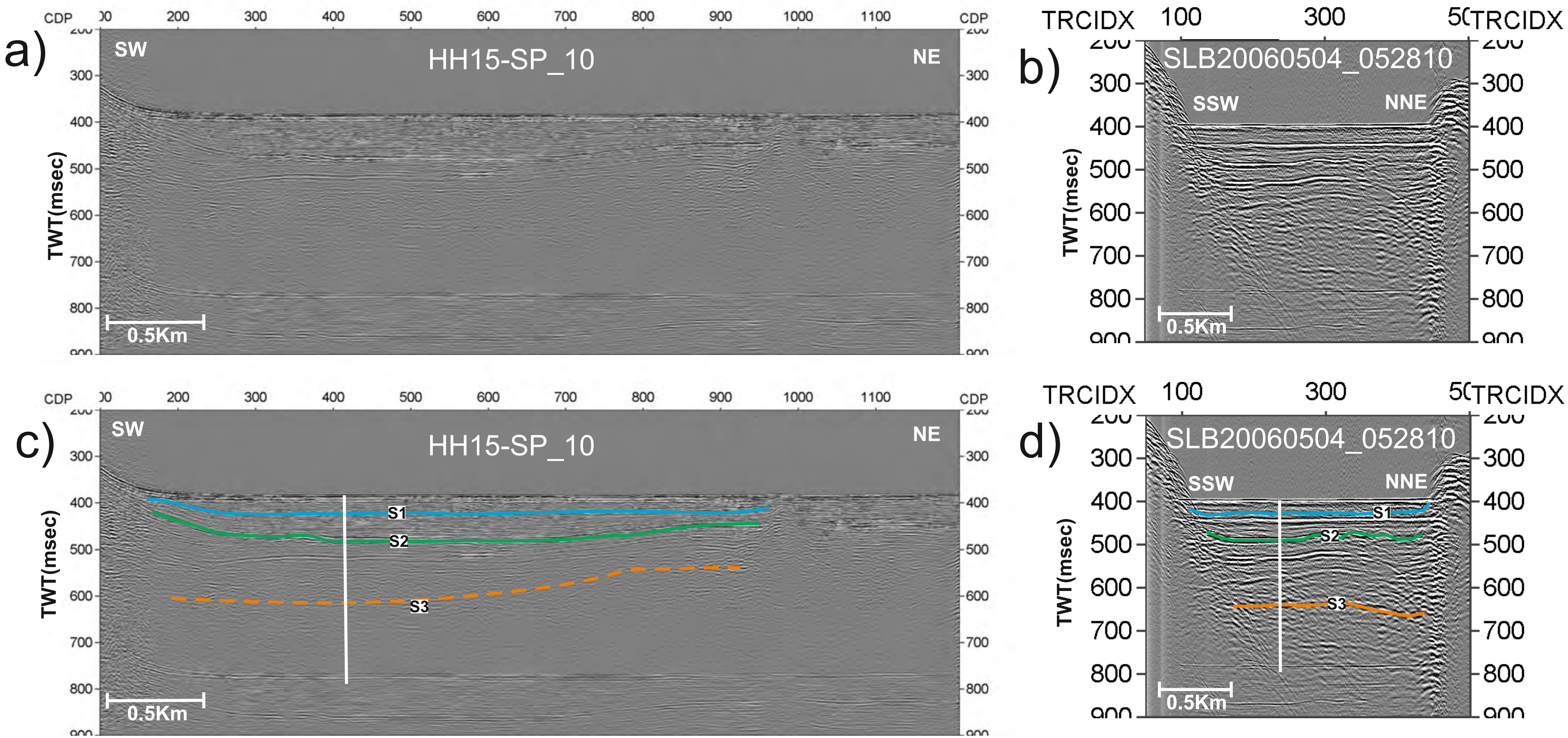
Proposal #: 932 - Full	Site #: CSK-07A	Date Form Submitted: 2019-03-29 20:21:19

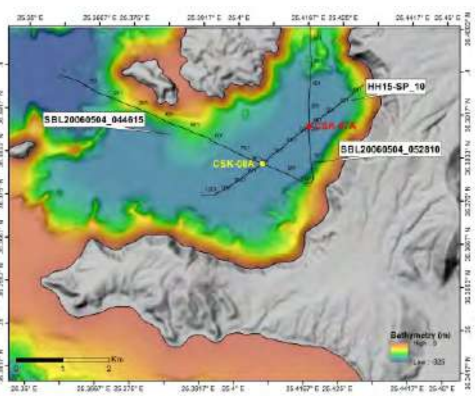
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Double APC/HLAPC/XCB to refusal; followed by drill ahead to 175 mbsf and RCB coring to 400 mbsf, log as shown in on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	heavy ship traffic in the Caldera but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	coarse clastics and lava blocks

Proposal #: 932 - Full	Site #: CSK-07A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 20	Seismic unit S1: subaerial eruptions and mass wasting of the caldera cliffs	<0.0020	1.6	volcaniclastics, turbidites, debris flows, muds	intra caldera fill	10,000	Interpretation from Johnston et al. (2015)
20 - 77	Seismic unit S2: mainly submarine eruptions of Kameni Volcano	0.0036 to 0.0020	1.8	volcaniclastics, muds	Intra-caldera fill	36,000	Interpretation from Johnston et al. (2015)
77 - 218	Seismic unit S3: end of LBA eruption; caldera flooding	0.0036	1.9	Coarse gravels, tuffs, debris avalanches, debris flows	Intra-caldera fill	>1,000,000	Interpretation from Johnston et al. (2015) and Nomikou et al. (2016a)
218 - 400	Sub-S3: Late Bronze Age eruption (top of intracaldera tuffs)	0.0036	2.0	Blocky unwelded tuffs, with possible welded layers and lavas	Intra-caldera fill	>1,000,000	Interpretation of Johnston et al. (2015)

CSK-07A





CSK-07A: HH015-SP_10, CDP 415 (a and c)
SLB20060504_052810, SP 236 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-07A_location.pdf
SEGY-data data: HH15-SP_10.sgy, SLB20060504_052810.sgy
Navigation data: HH15-SP_10.txt, SBL20060504_052810.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Site Information:
Coordinates: 36.3890/25.4171
Water depth:292m
Penetration: 400m

Additional data available:
Magnetic: CSK_Magnetic.grd, CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-08A is sited in the southern basin of Santorini caldera. The aim is to penetrate intracaldera seismic units S1, S2, and S3 in order to characterise them, as well as to penetrate below unit S3 (probable intracaldera tuff of the LBA eruption). This site is complementary to sites CSK-05A/06A in the northern caldera basin, as together they will provide a complete understanding of the caldera fill and collapse history.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini. Onland drilling on Kameni islands to 200 m depth in 1987-88.

Section B: General Site Information

Site Name:	CSK-08A	Area or Location:	Santorini caldera (southern basin), Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.3816	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.4061	Distance to Land: (km)	1
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	293

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	400	0
	Total Sediment Thickness (m) 400	
		Total Penetration (m): 400
General Lithologies:	Coarse intracaldera sediments, breccias, landslides, lavas, muds	

Coring Plan:
(Specify or check)

2 Holes APC/HLAPC/XCB to refusal, followed by drill ahead to 175 mbsf and RCB to 400 mbsf, wireline logging in RCB Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 4.4 Logging: 1 Total On-site: 5.4

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐
CO_2	☐				

Sensitive marine habitat (e.g., reefs, vents)

Preferred weather window: Late autumn, winter or early spring

Other: High winds, dense tourist shipping. Multiple cruise liners in the summer months. No bright spots indicative of gas on seismic profiles.

Proposal #: 932 - Full	Site #: CSK-08A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH15-SP10 Position: CDP 772
1b High resolution seismic seismic reflection (crossing)	yes	Line: SBL20060504_044615 Position: SP 803
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Data and info see Site CSK-01A
7 Swath bathymetry	yes	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	Mostly Box corer from 2006 R/V Aegeao expedition of variable length up to 1 m. Mixture of hemipelagic muds and volcaniclastics
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH15-SP10.txt, SBL20060504_044615.txt
17 Other	no	

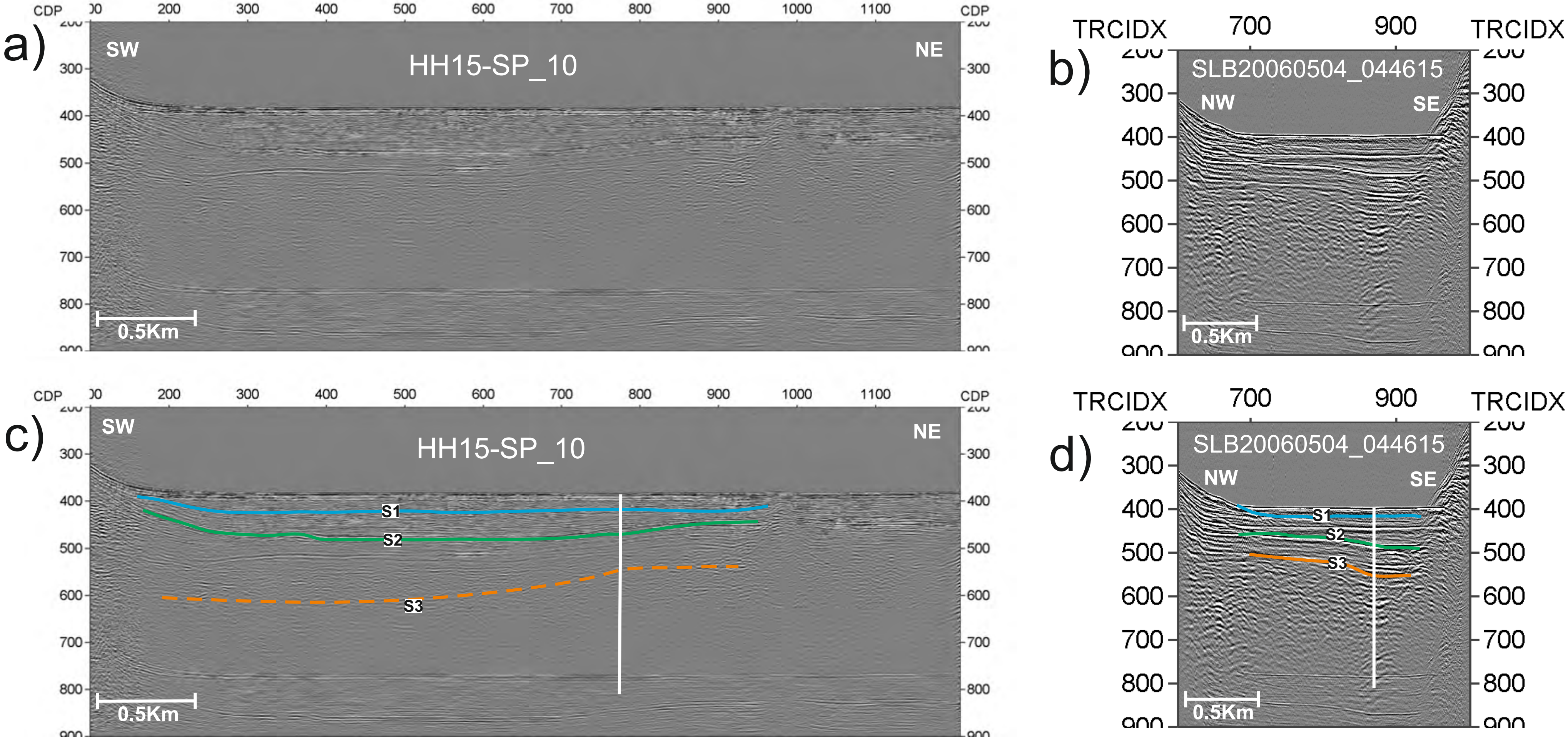
Proposal #: 932 - Full	Site #: CSK-08A	Date Form Submitted: 2019-03-29 20:21:19

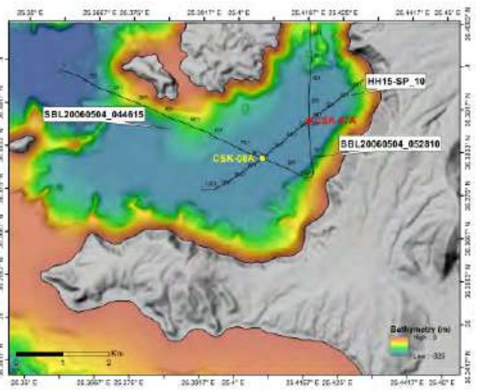
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Double APC/HLAPC/XCB to refusal; followed by drill ahead to 175 mbsf and RCB to 300 mbsf, log as shown in on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	heavy ship traffic in the Caldera but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	coarse clastics and lava blocks

Proposal #: 932 - Full	Site #: CSK-08A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 16	Seismic unit S1: subaerial eruptions and mass wasting of the caldera cliffs	<0.0020	1.6	volcaniclastics, turbidites, debris flows, muds	intra caldera fill	8000	Interpretation from Johnston et al. (2015)
16 - 75	Sesimic unit S2: mainly submarine eruptions of Kameni Volcano	0.0036 to 0.0020	1.8	volcaniclastics, muds	Intra-caldera fill	36,000	Interpretation of Johnston et al. (2015)
75 - 142	Seismic unit S3: End of LBA eruption; caldera flooding	0.0036	1.9	Coarse gravels, tuffs, debris avalanches, debris flows	Intra-caldera fill	>1,000,000	Interpretation from Johnston et al. (2015)
142 - 400	Pre-S3: Late Bronze Age eruption (top of intracaldera tuff)	0.0036	2.0	Blocky unwelded tuffs, with possible welded layers or lavas	Intra-caldera fill	>1,000,000	Interpretation of Johnston et al. (2015) and Nomikou et al. (2016a)

CSK-08A





CSK-08A: HH15-SP_10, CDP 773 (a and c)
SLB20060504_044615, SP 803 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-08A_location.pdf
SEGY-data data: HH15-SP_10.sgy, SLB20060504_044615.sgy
Navigation data: HH15-SP_10.txt, SLB20060504_044615.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Site Information:
Coordinates: 36.3816/25.4061
Water depth: 293m
Penetration: 400m

Additional data available:
Magnetic: CSK_Magnetic.grd,
CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip,
contains 3.5kHz profiles,
do not run site
survey profile

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-09A is sited in the Anafi Basin. The aim is to penetrate the entire volcano-sedimentary fill of this basin as far as the Alpine basement. The basin potentially records the full volcanic history of Santorini (and any older centres) since rift inception, but not of Kolumbo Volcano. The hole will reconstruct the subsidence and sedimentary history of this basin, to compare with that of the Anhydros Basin. It will transect all six seismic units present in the basin (B1 to B6).
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-09A	Area or Location:	Anafi Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.5656	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.7613	Distance to Land: (km)	9
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	694

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	585	10
	Total Sediment Thickness (m): 585	
		Total Penetration (m): 595
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	Limestone, schist or granite

Coring Plan: (Specify or check)

3 Holes APC/HLAPC to refusal, each followed by XCB to 595 mbsf including 10 meters into basement or until refusal, wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☐ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
9.5	1.3	10.8

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-09A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-15 Position: CDP 1067
1b High resolution seismic seismic reflection (crossing)	yes	Line: HH06-09 Position: CDP 3403
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	~2m long gravity core (POS513/20), 9 km from site position showing soft hemipelagic muds with carbonate clasts, some cm thick intercalated ash layers and two dm-scaled tephra layers unto coarse ash and fine lapilli (up to 1 cm); Sedimentation rate ~9 cm/ka.
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-15.txt, HH06-09.txt
17 Other	no	

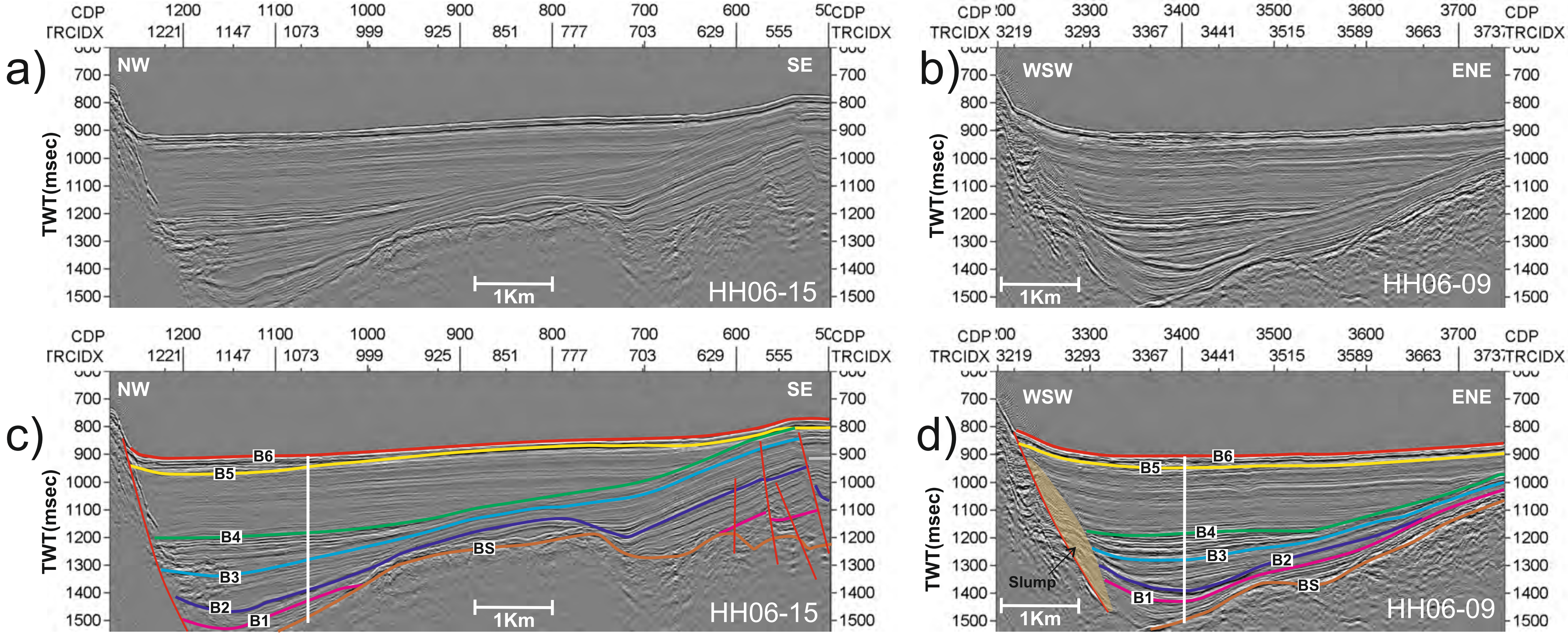
Proposal #: 932 - Full	Site #: CSK-09A	Date Form Submitted: 2019-03-29 20:21:19

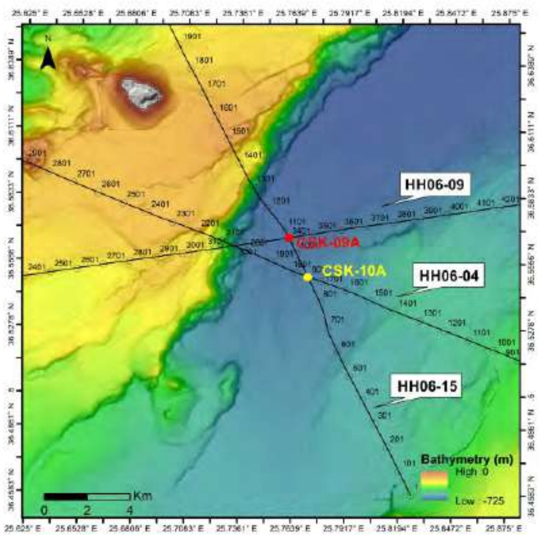
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Tripple APC/HLAPC (Holes A, B, C) to refusal including 4 temperature measurements, each followed by XCB to 595 mbsf including 10 meters of basement or until refusal, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	no
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	

Proposal #: 932 - Full	Site #: CSK-09A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 34	Seismic unit B6: horizontal dipping beds and unconformity into B5	Pleistocene/ Holocene	1.6	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	140	lithology similar like in gravity core; interpretation after Nomikou et al. (2018)
34 - 248	Seismic unit B5: subhorizontal dipping beds, several stronger reflectors distributed within the unit; chaotic layering in the upper part?	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	130	chaotic layering implicate kind of mass transport deposits and high sedimentation rate due to tectonics?; interpretation after Nomikou et al. (2018)
248 - 346	Seismic unit B4 with subhorizontal dipping beds, several stronger reflectors distributed within the unit	Early? Pleistocene	2.0	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	120	More turbiditic deposits and subhorizontal layering, tectonics? Interpretation Nomikou et al. (2018)
346 - 461	Seismic unit B3. Subhorizontal bedding, chaotic layer, MTD? Unconformity onto steep layered unit B2.	Early Pleistocene/ Pliocene	2.1	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	120	Chaotic layering implicates mass transport deposits and high sedimentation rate due to tectonics? Interpretation Nomikou et al. (2018)
461 - 507	Seismic unit B2	early Pleistocene?/ Pliocene	2.4	turbidites, hemipelagics, volcaniclastics, MTD´s	filled submarine rift-basin	120	steep bedding assumes tectonics after initial fill. Interpretation Nomikou et al. (2018)
507 - 585	Seismic unit B1; unconformity into continental basement	Pliocene	2.6	MTD´s, sands and gravel, turbidites, hemipelagic muds, volcaniclastics	submarine to continental; initial filling of a rift basin	110	initial filling sequence of the rift with mixed volcaniclastic and continental material. Interpretation Nomikou et al. (2018)
585 - 595	continental basement	Mesozoic	3.0	limestone, shists, granites	continental basement	??	

CSK-09A





CSK-09A: HH06-15, CDP 1067 (a and c); HH06-09, CDP 3403 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-09A-10a_location.pdf
SEGY-data data: HH06-15.sgy, HH06-09.sgy
Navigation data: HH06-15.txt, HH06-09.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile

Site Information:
Coordinates: 36.5656/25.7613
Water depth: 694m
Penetration: 595m

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-10A is sited in the Anafi Basin. The aim is to penetrate the entire volcano-sedimentary fill of this basin as far as the Alpine basement. The basin potentially records the full volcanic history of Santorini (and any older centres) since rift inception, but not of Kolumbo Volcano. The hole will reconstruct the subsidence and sedimentary history of this basin, to compare with that of the Anhydros Basin. It will transect the topmost five of the six seismic units present in the basin (B2 to B6).
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-10A	Area or Location:	Anafi Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.5494	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.7714	Distance to Land: (km)	10
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	672

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	368	9
	Total Sediment Thickness (m): 368	
		Total Penetration (m): 377
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	Limestone, schist or granite

Coring Plan: (Specify or check)

3 Holes APC/HLAPC to refusal, each followed by XCB to 377 mbsf including 10 meters into basement or until refusal, wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC [x] XCB [x] RCB [ ] Re-entry [ ] PCS [ ]

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	[x]	Magnetic Susceptibility	[x]	
Porosity	[x]	Borehole Temperature	[x]	
Density	[x]	Formation Image (Acoustic)	[ ]	
Gamma Ray	[x]	VSP (walkaway)	[ ]	
Resistivity	[x]	LWD	[ ]	
Sonic (Δt)	[x]			
Formation Image (Res)	[x]			
VSP (zero offset)	[x]			
Formation Temperature & Pressure	[ ]			

Other Measurements:

Estimated Days: Drilling/Coring: 6.4 | Logging: 1 | Total On-site: 7.4

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/Weather:

						Preferred weather window
Shallow Gas	[ ]	Complicated Seabed Condition	[ ]	Hydrothermal Activity	[ ]	Late autumn, winter or early spring
Hydrocarbon	[ ]	Soft Seabed	[ ]	Landslide and Turbidity Current	[ ]	
Shallow Water Flow	[ ]	Currents	[ ]	Gas Hydrate	[ ]	
Abnormal Pressure	[ ]	Fracture Zone	[ ]	Diapir and Mud Volcano	[ ]	
Man-made Objects (e.g., sea-floor cables, dump sites)	[ ]	Fault	[ ]	High Temperature	[ ]	
H_2S	[ ]	High Dip Angle	[ ]	Ice Conditions	[ ]	
CO_2	[ ]					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-10A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-15 Position: CDP 906
1b High resolution seismic seismic reflection (crossing)	yes	Line: HH06-04 Position: CDP 1755
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)		
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	~2m long gravity core (POS513/20), 8 km from site position showing soft hemipelagic muds with carbonate clasts, some cm thick intercalated ash layers and two dm-scaled tephra layers unto coarse ash and fine lapilli (up to 1 cm); Sedimentation rate ~9 cm/ka.
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-04.txt, HH06-04.txt
17 Other	no	

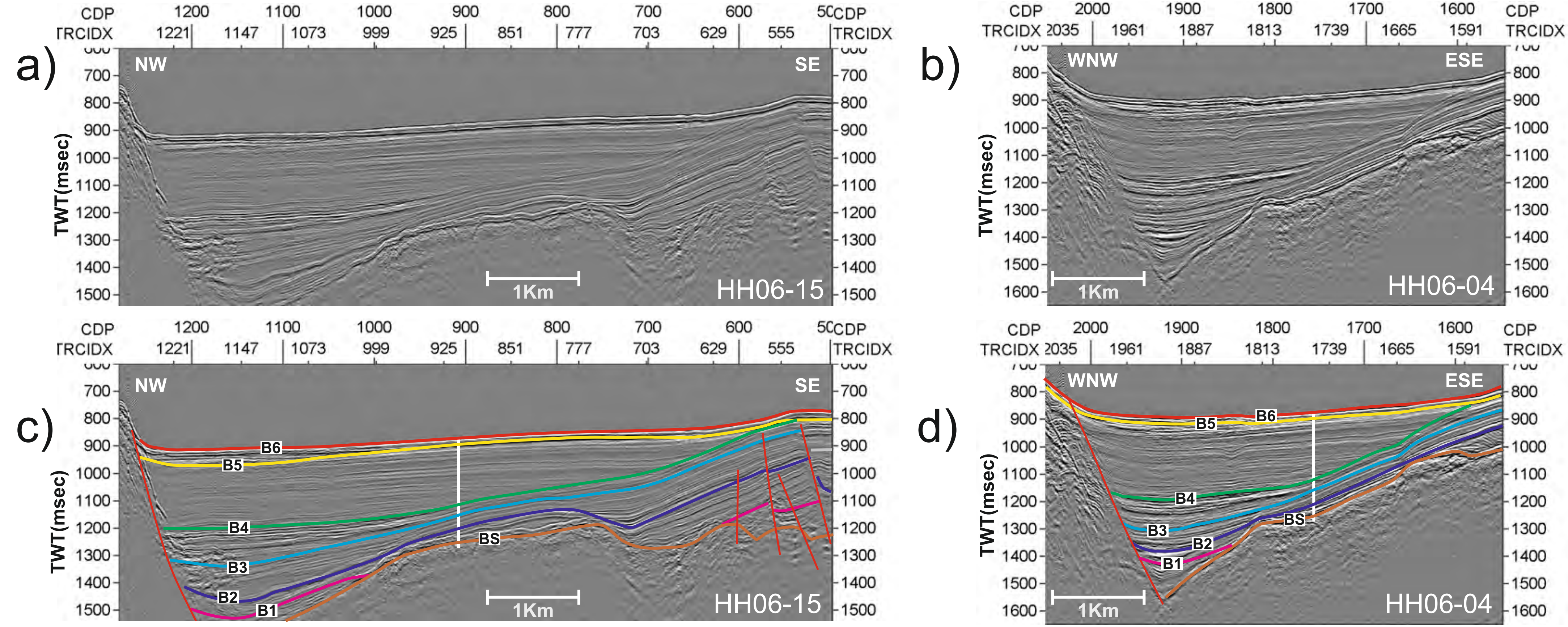
Proposal #: 932 - Full	Site #: CSK-10A	Date Form Submitted: 2019-03-29 20:21:19

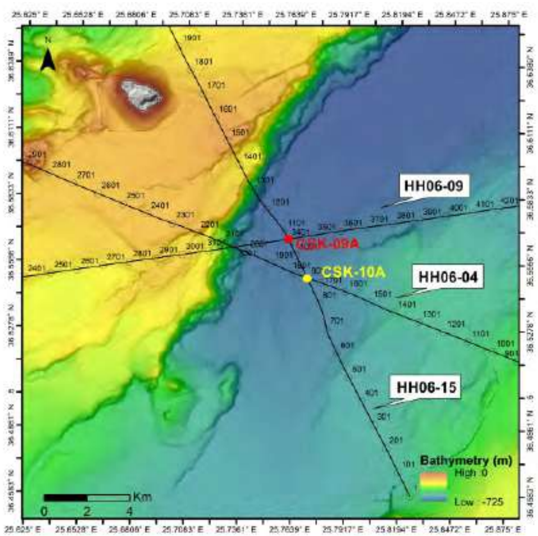
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Tripple APC/HLAPC (Holes A, B, C) to refusal including 4 temperature measurements, each followed by XCB to 377 mbsf including 10 meters of basement or until refusal, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	

Proposal #: 932 - Full	Site #: CSK-10A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 19	Seismic unit B6: horizontal dipping beds and unconformity into B5	Pleistocene/ Holocene	1.6	hemipelagic muds, volcaniclastics, turbidites	filled submarine rift-basin	110	lithology similar like in gravity core; interpretation Nomikou et al. (2018)
19 - 217	Seismic unit B5: subhorizontal dipping beds, several stronger reflectors distributed within the unit; chaotic layering in the upper part?	Pleistocene	1.8	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	100	Interpretation Nomikou et al. (2018)
217 - 255	Seismic unit B4: subhorizontal dipping beds, several stronger reflectors distributed within the unit	Early? Pleistocene	2.0	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	90	Interpretation Nomikou et al. (2018)
255 - 308	Seismic unit B3: subhorizontal bedding, chaotic layer, MTD?, unconformity into steep layered B2	Early Pleistocene/ Pliocene	2.1	hemipelagic muds, volcaniclastics, turbidites, MTD´s?	filled submarine rift-basin	80	Interpretation Nomikou et al. (2018)
308 - 368	Seismic unit B2; unconformity with basement (unit B1 absent)	early Pleistocene?/ Pliocene	2.4	turbidites, hemipelagics, volcaniclastics, MTD´s	filled submarine rift-basin	70	Interpretation Nomikou et al. (2018)
368 - 377	continental basement	Mesozoic	3.0	limestone, shists, granites	continental basement	??	Interpretation Nomikou et al. (2018)

CSK-10A





CSK-10A: HH06-15, CDP 906 (a and c); HH06-04, CDP 1755 (b and d)

Files to be uploaded to SSDB:
Location map: CSK-09A-10A_location.pdf
SEGY-data data: HH06-15.sgy, HH06-04.sgy
Navigation data: HH06-15.txt, HH06-04.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile

Site Information:
Coordinates: 36.5494/25.7714
Water depth: 672m
Penetration: 377m

IODP Site Forms

932 - Full

Form 1 – General Site Information

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-11A is sited in the Christiana Basin. This basin is deeper than the Anhydros and Anafi Basins, and is located SW of Santorini. Its volcano-sedimentary fill potentially records the earlier volcanic history of the CSK volcanic field (including the products of Christiana and early Santorini), as well as younger Santorini and possibly Milos Volcano. The hole will pass through three prominent volcanic units (PFI to PFIII) seen on seismic records. This site may move slightly following planned acquisition of new seismic data in the Christiana basin.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-11A	Area or Location:	Christiana Basin, Aegean Sea, Greece
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.3897	Jurisdiction:	Greek territorial waters
Longitude:	Deg: 25.2142	Distance to Land: (km)	10
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	408

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	823	0
	Total Sediment Thickness (m): 823	
		Total Penetration (m): 823
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	

Coring Plan: (Specify or check)

2 Holes APC/HLAPC to refusal, each followed by XCB to 600 mbsf; drill ahead in Hole C to 575 mbsf with the option of one or two cored RCB intervals of 50 meters in between and afterwards RCB to 823 mbsf; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days: Drilling/Coring: 10.2 | Logging: 1.7 | Total On-site: 11.9

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-11A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: HH06-50 Position: CDP 8000
1b High resolution seismic seismic reflection (crossing)	no	Not availble yet
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	no	~1m and ~3.5m long gravity cores (POS513/60 and 9), 7 km and 17 km from site position showing a) coarse or hardened volcaniclastics after 1 meter of soft hemipelagic muds (Minoan eruption deposits) and b) homogenous hemipelagic muds with some 1 to 20 cm thick intercalated ash layers (max grain size= 2 mm) ; Sedimentation rate ~6 cm/ka in core POS513/9.
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	HH06-50.txt
17 Other	no	

Proposal #: 932 - Full	Site #: CSK-11A	Date Form Submitted: 2019-03-29 20:21:19

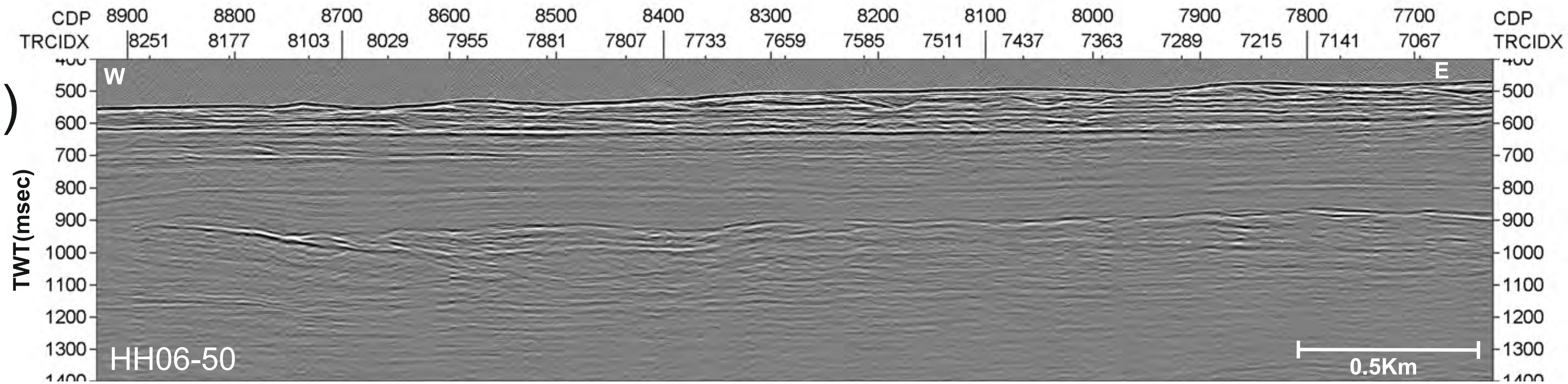
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Two holes (A, B) APC/HLAPC to refusal including 4 temperature measurements, each followed by XCB to 600 mbsf; Hole C: RCB drilling ahead until 575 mbsf with the option of one or two cored intervals of 50 meters in between, afterwards RCB to 823 mbsf, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	coarser volcaniclastics from major eruptions

Proposal #: 932 - Full	Site #: CSK-11A	Date Form Submitted: 2019-03-29 20:21:19

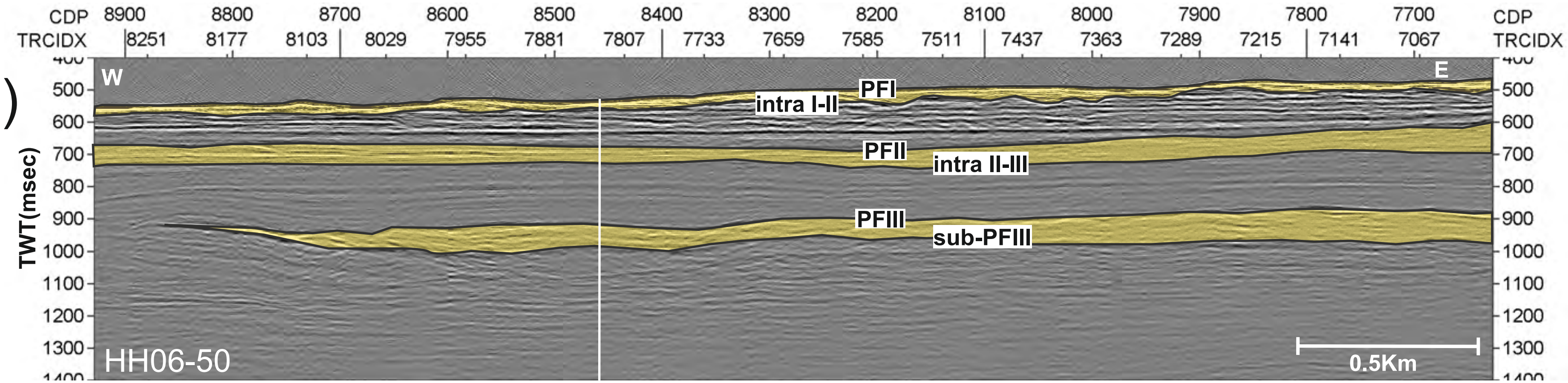
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 22	Late Bronze Age eruption, submarine pyroclastic flow deposit (PF I)	0.0036	1.6	Pumiceous tuffs, debris flows and thin overlying surface muds	filled marine basin	>1,000,000	Based on interpretation of Tsampouraki-Kraounaki et al. (2018)
22 - 121	Marine sedimentation between pyroclastic flows PF I and PF II	Pleistocene	1.65	hemipelagic muds, volcaniclastics, turbidites	filled marine basin	130	Based on interpretation of Tsampouraki-Kraounaki et al. (2018). Detailed interpretation awaits new planned seismic acquisition
121 - 168	Seismic unit PF II, probable pyroclastic flow deposit from Santorini	Pleistocene; possibly 0.42 My	1.8	Pumiceous tuffs, debris flows	filled marine basin	>1,000,000	Based on interpretation of Tsampouraki-Kraounaki et al. (2018). Detailed interpretation awaits new planned seismic acquisition
168 - 344	Marine sedimentation between seismic units PF II and PF III, with volcaniclastics from Christiana, Santorini	Pleistocene/ Pliocene?	1.85	hemipelagic muds, volcaniclastics, turbidites	filled marine basin	100	Based on interpretation of Tsampouraki-Kraounaki et al. (2018). Detailed interpretation awaits new planned seismic acquisition
344 - 409	Possible pyroclastic flow deposit (PF III)	Pleistocene/ Pliocene	1.9	Pumiceous tuffs, debris flows?	filled marine basin	>1,000,000	Detailed interpretation awaits new planned seismic acquisition. This unit may not be (too deep) the same as PF III of Tsampouraki-Kraounaki et al. (2018)
409 - 823	Marine sedimentation prior to seismic unit PF III	Pliocene	2.0	hemipelagic muds, volcaniclastics, turbidites	filled marine basin	80	Detailed interpretation awaits new planned seismic acquisition.

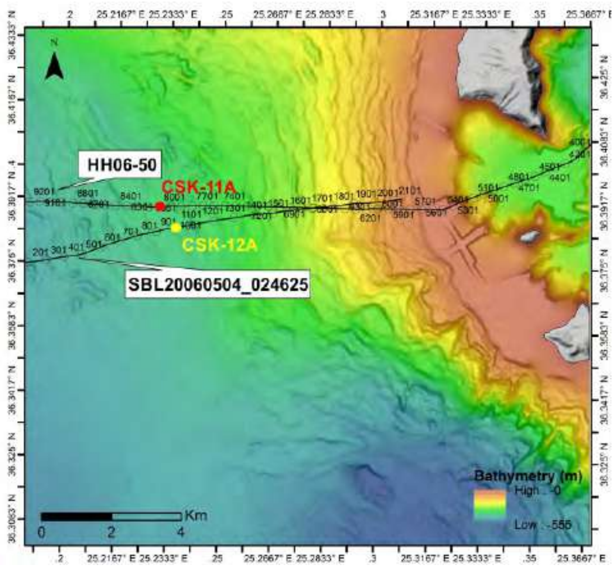
CSK-11A

a)



b)





CSK-11A: HH06-50, CDP 8458 (a and b)

Files to be uploaded to SSDB:
Location map: CSK-11A_location.pdf
SEGY-data data: HH06-50.sgy
Navigation data: HH06-50.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Site Information:
Coordinates: 36.3897/25.2142
Water depth: 408m
Penetration: 823m

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile.

IODP Site Forms

Form 1 – General Site Information

932 - Full

Section A: Proposal Information

Proposal Title	Volcanism and tectonics in an island-arc rift environment (VolTecArc): Christiana-Santorini-Kolumbo marine volcanic field, Greece
Date Form Submitted	2019-03-29 20:21:19
Site-Specific Objectives with Priority (Must include general objectives in proposal)	CSK-12A is sited in the Christiana Basin. This basin is deeper than the Anhydros and Anafi Basins, and is located SW of Santorini. Its volcano-sedimentary fill potentially records the earlier volcanic history of the CSK volcanic field (including the products of Christiana and early Santorini), as well as younger Santorini and possibly Milos Volcano. The hole will pass through three prominent volcanic units (PFI to PFIII) seen on seismic records. This site may move slightly following planned acquisition of new seismic data in the Christiana basin.
List Previous Drilling in Area	DSDP hole 378 was drilled in 1975 in the Cretan basin 60 km SSW of Santorini

Section B: General Site Information

Site Name:	CSK-12A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 36.3842
Longitude:	Deg: 25.2352
Coordinate System:	WGS 84
Priority of Site:	Primary: ☐ Alternate: ☑

Area or Location:	Christiana Basin, Aegean Sea, Greece
Jurisdiction:	Greek territorial waters
Distance to Land: (km)	10
Water Depth (m):	367

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	836	0
	Total Sediment Thickness (m): 836	
		Total Penetration (m): 836
General Lithologies:	Muds, volcaniclastics, debris flows, turbidites	

Coring Plan: (Specify or check)

2 Holes APC/HLAPC to refusal, each followed by XCB to 600 mbsf; drill ahead in Hole C to 575 mbsf with the option of one or two cored RCB intervals of 50 meters in between and afterwards RCB to 836 mbsf; wireline logging in Hole C (Tripple Combo, FMS Sonic, VSI)

APC ☑ XCB ☑ RCB ☑ Re-entry ☐ PCS ☐

Wireline Logging Plan:

Standard Measurements		Special Tools		Other tools:
WL	☑	Magnetic Susceptibility	☑	
Porosity	☑	Borehole Temperature	☑	
Density	☑	Formation Image (Acoustic)	☐	
Gamma Ray	☑	VSP (walkaway)	☐	
Resistivity	☑	LWD	☐	
Sonic (Δt)	☑			
Formation Image (Res)	☑			
VSP (zero offset)	☑			
Formation Temperature & Pressure	☐			

Other Measurements:

Estimated Days:	Drilling/Coring: 10.2	Logging: 1.7	Total On-site: 11.9

Observatory Plan: *Longterm Borehole Observation Plan/Re-entry Plan*

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	Late autumn, winter or early spring
Hydrocarbon	☐	Soft Seabed	☐	Landslide and Turbidity Current	☐	
Shallow Water Flow	☐	Currents	☐	Gas Hydrate	☐	
Abnormal Pressure	☐	Fracture Zone	☐	Diapir and Mud Volcano	☐	
Man-made Objects (e.g., sea-floor cables, dump sites)	☐	Fault	☐	High Temperature	☐	
H_2S	☐	High Dip Angle	☐	Ice Conditions	☐	
CO_2	☐					
Sensitive marine habitat (e.g., reefs, vents)						

Other: High winds, dense tourist shipping

Proposal #: 932 - Full	Site #: CSK-12A	Date Form Submitted: 2019-03-29 20:21:19

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	yes	Line: SBL20060504_024625 Position: SP 1000
1b High resolution seismic seismic reflection (crossing)		
2a Deep penetration seismic reflection (primary)	no	
2b Deep penetration seismic reflection (crossing)	no	
3 Seismic Velocity	no	Data and info see Site CSK-01A
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	Data and info see Site CSK-01A
7 Swath bathymetry	no	Data and info see Site CSK-01A
8a Side looking sonar (surface)	no	Data and info see Site CSK-01A
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	Data and info see Site CSK-01A
11b Gravity	no	Data and info see Site CSK-01A
12 Sediment cores	yes	~1m and ~3.5m long gravity cores (POS513/60 and 9), 7 km and 17 km from site position showing a) coarse or hardened volcaniclastics after 1 meter of soft hemipelagic muds (Minoan eruption deposits) and b) homogenous hemipelagic muds with some 1 to 20 cm thick intercalated ash layers (max grain size= 2 mm) ; Sedimentation rate ~6 cm/ka in core POS513/9.
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	SBL20060504_024625.txt
17 Other	no	

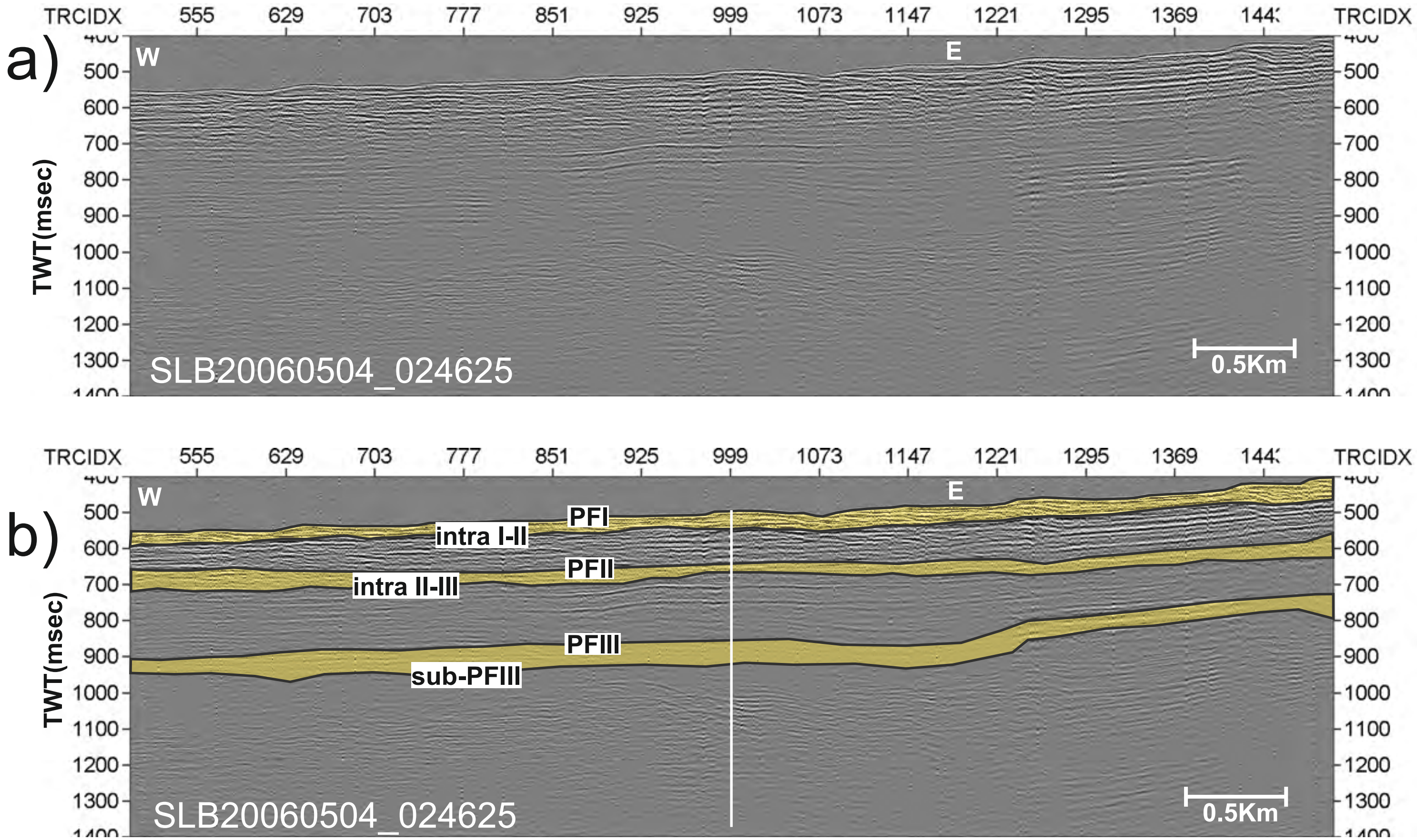
Proposal #: 932 - Full	Site #: CSK-12A	Date Form Submitted: 2019-03-29 20:21:19

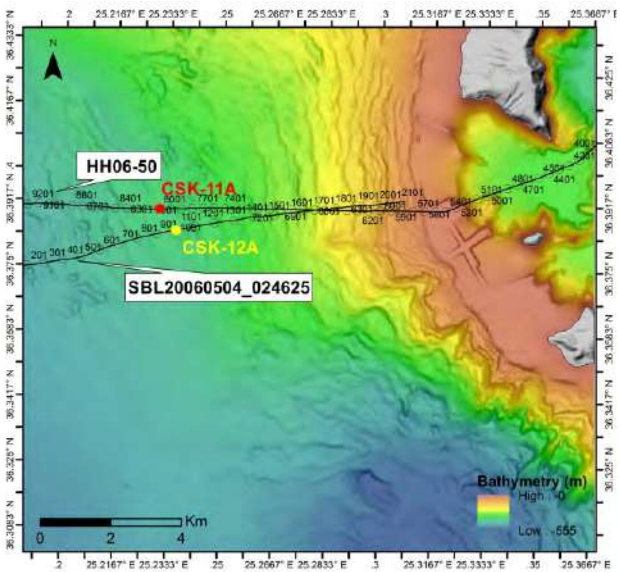
Pollution & Safety Hazard	Comment
1. Summary of operations at site	Two holes (A, B) APC/HLAPC to refusal including 4 temperature measurements, each followed by XCB to 600 mbsf; Hole C: RCB drilling ahead until 575 mbsf with the option of one or two cored intervals of 50 meters in between, afterwards RCB to 836 mbsf, log as shown on form 1
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	non
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	non
4. Indications of gas hydrates at this location	non
5. Are there reasons to expect hydrocarbon accumulations at this site?	non
6. What "special" precautions will be taken during drilling?	non
7. What abandonment procedures need to be followed?	non
8. Natural or manmade hazards which may affect ship's operations	sailing traffic may be existent but minimized during autumn to early spring
9. Summary: What do you consider the major risks in drilling at this site?	coarser volcaniclastics from major eruptions

Proposal #: 932 - Full	Site #: CSK-12A	Date Form Submitted: 2019-03-29 20:21:19

Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 43	Late Bronze Age eruption, submarine pyroclastic flow deposit	0.0036	1.6	Pumiceous tuff, debris flows and thin overlying surface muds	filled marine basin	>1,000,000	Based on interpretation of Tsampouraki-Kraounaki et al. (2018).
43 - 122	Marine sedimentation between pyroclastic flows PFI and PFII	Pleistocene	1.65	hemipelagic muds, volcaniclastics, turbidites	filled marine basin	130	Based on interpretation of Tsampouraki-Kraounaki et al. (2018).
122 - 144	Seismic unit PFII, probable pyroclastic flow from Santorini	0.42 My?	1.8	Pumiceous tuff, debris flow	filled marine basin	>1,000,000	Based on interpretation of Tsampouraki-Kraounaki et al. (2018).
144 - 320	Marine sedimentation between pyroclastic flows PFII and PFIII	Pleistocene/ Pliocene?	1.85	hemipelagic muds, volcaniclastics, turbidites	filled marine basin	100	Based on interpretation of Tsampouraki-Kraounaki et al. (2018).
320 - 382	Possible pyroclastic flow deposit (PF III)	Pleistocene/ Pliocene	1.9	Pumiceous tuffs, debris flows?	rifted marine basin	>1,000,000	Detailed interpretation awaits new planned seismic acquisition. This unit may not be (too deep) the same as PF III of Tsampouraki-Kraounaki et al. (2018)
382 - 836	Marine sedimentation prior to seismic unit PF III	Pliocene	2.0	hemipelagic muds, volcaniclastics, turbidites	rifted marine basin	80	Detailed interpretation awaits new planned seismic acquisition.

CSK-12A





CSK-12A: SLB20060504_024625, Trace 1000 (a and b)

Files to be uploaded to SSDB:
Location map: CSK-12A_location.pdf
SEGY-data data: SLB20060504_024625.sgy
Navigation data: SLB20060504_024625.txt
Bathymetry: CSK_Bathymetry.grd, CSK_Bathymetry.pdf
Backscatter: CSK_Backscatter.grd, CSK_Backscatter.pdf
Gravity-FreeAir: CSK_Gravity_FreeAir.grd, CSK_Gravity_FreeAir.pdf
Gravity-Bouguer: CSK_Gravity_Bouguer.grf,CSK_Gravity_Bouguer.pdf

Additional data available:
Magnetic: CSK_Magnetic.grd,CSK_Magnetic.pdf
3.5kHz: Sediment_Profiler.zip, contains 3.5kHz profiles, do not run along site survey profile.

Site Information:
Coordinates: 36.3842/25.2352
Water depth: 367m
Penetration: 836m