IODP Proposal Cover Sheet

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Mediterranean-Atlantic Gateway Exchange

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Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
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Keywords	Paleoclimate, gateway, salt giant, contourites
Area	Either side of Gibraltar Strait

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Abstract

Marine gateways play a critical role in the exchange of water, heat, salt and nutrients between oceans and seas. The advection of dense waters helps drive global thermohaline circulation and, since the ocean is the largest of the rapidly exchanging CO2 reservoirs, this advection also affects atmospheric carbon concentration. Changes in gateway geometry can therefore significantly alter both the pattern of global ocean circulation and associated heat transport and climate, as well as having a profound local impact.

Today, the volume of dense water supplied by Atlantic-Mediterranean exchange through the Gibraltar Strait is amongst the largest in the global ocean. For the past five million years this overflow has generated a saline plume at intermediate depths in the Atlantic that deposits distinctive contouritic sediments in the Gulf of Cadiz and contributes to the formation of North Atlantic Deep Water. This single gateway configuration only developed in the early Pliocene, however. During the Miocene, a wide, open seaway linking the Mediterranean and Atlantic evolved into two narrow corridors: one in northern Morocco; the other in southern Spain. Formation of these corridors permitted Mediterranean salinity to rise and a new, distinct, dense water mass to form and overspill into the Atlantic for the first time. Further restriction and closure of these connections resulted in extreme salinity fluctuations in the Mediterranean, leading to the formation of the Messinian Salinity Crisis salt giant.

IMMAGE is an amphibious drilling proposal designed to recover a complete record of Atlantic-Mediterranean exchange from its Late Miocene inception to its current configuration. This will be achieved by targeting Miocene offshore sediments on either side of the Gibraltar Strait with IODP and recovering Miocene core from the two precursor connections now exposed on land with ICDP. The scientific aims of IMMAGE are to constrain quantitatively the consequences for ocean circulation and global climate of the inception of Atlantic-Mediterranean exchange; to explore the mechanisms for high amplitude environmental change in marginal marine systems and to test physical oceanographic hypotheses for extreme high-density overflow dynamics that do not exist in the world today on this scale.

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Scientific Objectives

The objectives of the IMMAGE research program are:

Objective 1: To document the time at which the Atlantic first started to receive a distinct overflow from the Mediterranean and to evaluate quantitatively its role in Late Miocene global climate and regional environmental change.

Objective 2: To recover a complete record of Atlantic-Mediterranean exchange before, during and after the Messinian Salinity Crisis and to evaluate the causes and consequences of this extreme oceanographic event, locally, regionally and globally.

Objective 3: To test our quantitative understanding of the behavior of ocean plumes during the most extreme exchange in Earth's history.

These objectives require sediments that can only be recovered by undertaking both onshore drilling in Morocco and Spain and offshore drilling in the Alborán Sea and on the Moroccan and Iberian Atlantic margin. The drilling strategy for IMMAGE is therefore amphibious.

IMMAGE's scientific objectives 1 and 2 fall under IODP's science plan for Climate and Ocean Change: Reading the Past, Informing the Future, addressing Challenges 1, 2, 3 and 4 specifically and ICDP's focus on Global Cycles and Environmental Change. Objective 3, however, goes beyond the remit of the science plans of both ICDP and IODP by providing an unparalleled opportunity to test physical oceanographic representations of extreme high-density overflow dynamics. This objective will provide key insights into the role and behavior of all marine gateways and their impact on global climate.

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

Proposed Sites (Total proposed sites: 8; pri: 3; alt: 5; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
ALM-01A (Primary)	37.4317 -9.5767	1567	990	0	990	To recover a thick, shallow Late Miocene succession which contains distal Mediterranean overflow deposits. The main contribution of this site is that it captures the evolution of the equilibrium depth of the plume and hence tests quantitative constraints on the behavior of dense overflows (Objective 3). In addition, the high resolution (precessional) record we will recover at this site is a key component of the complete record of Mediterranean-Atlantic exchange during the Late Miocene-Pliocene (Objectives 1 and 2).
ALM-02A (Alternate)	36.8359 -9.7481	2265	1630	10	1640	To recover a thick, shallow Late Miocene succession which contains distal Mediterranean overflow deposits. The main contribution of this site is that it captures the evolution of the equilibrium depth of the plume and hence tests quantitative constraints on the behavior of dense overflows (Objective 3). In addition, the high resolution (precessional) record we will recover at this site is a key component of the complete record of Mediterranean-Atlantic exchange during the Late Miocene-Pliocene (Objectives 1 and 2).
MOM-01A (Primary)	35.240956 -6.747839	555	1460	10	1470	This site targets a complete late Miocene succession in the pathway of Mediterranean overflow linking the onshore record at RIF-01A with the distal site ALM-01A. The aim is to obtain a high-resolution (precessional) record of Miocene Mediterranean overflow. This record provides critical information for all three objectives.
MOM-02A (Alternate)	35.107278 -6.818264	712	997	10	1007	This site targets a complete late Miocene succession in the pathway of Mediterranean overflow linking the onshore record at RIF-01A with the distal site ALM-01A. The aim is to obtain a high-resolution (precessional) record of Miocene Mediterranean overflow. This record provides critical information for all three objectives.
GUB-01A (Alternate)	36.5256 -7.6059	637	911	10	921	This site targets a complete late Miocene succession in the pathway of Mediterranean overflow. The aim is to obtain a high-resolution (precessional) record of Miocene Mediterranean overflow at an intermediate site between the onshore records (RIF-01A and BET-01A) and the distal record (ALM-01A). This record makes a critical contribution to all three objectives
WAB-03A (Primary)	36.312544 -4.571213	800	1700	0	1700	This site targets one of the few thick late Messinian sedimentary successions in the Alboran Basin. The record recovered from this location will provide key constraints on the chemistry and physical properties of Mediterranean overflow during the Late Miocene. This is critical for all three objectives.
EAB-02A (Alternate)	35.75518251 -2.43956525	845	1277	0	1277	This site targets one of the few thick late Messinian sedimentary successions in the Alboran Basin. The record recovered from this location will provide key constraints on the chemistry and physical properties of Mediterranean overflow during the Late Miocene. This is critical for all three objectives. The site is located on the Spanish side of the Moroccan-Spanish territorial boundary, very close to the other alternate site EAB-03A.
EAB-03A (Alternate)	35.750427 -2.431305	838	1277	0	1277	This site targets one of the few thick late Messinian sedimentary successions in the Alboran Basin. The record recovered from this location will provide key constraints on the chemistry and physical properties of Mediterranean overflow during the Late Miocene. This is critical for all three objectives. The site is located on the Moroccan side of the Moroccan-Spanish territorial boundary, very close to the other alternate site EAB-02A.

Contact Information

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Proponent List

First Name	Last Name	Affiliation	Country	Role	Expertise
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Abdella	Ait Salem	Office Natioinal des Hydrocarbures et des Mines, Rabat	Morocco	Other Proponent	Petroleum Geology, seismic interpretation
Nadia	Bahoun	University of Hassan II Casablanca	Morocco	Other Proponent	Biostratigraphy
Domenico	Chiarella	Dept Earth Sciences, Royal Holloway, University of London	United Kingdom	Other Lead	Wireline logs, straits, tidal sediments
Evelina	Dmitrieva	Exploration Technical Services, Repsol, Madrid	Spain	Other Proponent	Seismic and sequence stratigraphy
Damien	Do Couto	Universite de Pierre et Marie Cure, Paris	France	Other Proponent	Seismic interpretation
Gemma	Ercilla	Institute of Marine Sciences, Barcelona	Spain	Other Proponent	Seismic and sequence stratigraphy
Marcus	Gutjahr	GEOMAR, Kiel	Germany	Other Proponent	isotope geochemistry, overturning dynamics
Tim	Herbert	Dept. Earth, Environmental and Planetary Sciences, Brown University	United States	Other Proponent	Paleoceanography, orbital-climatic interactions
Javier	Hernandez-Molina	Royal Holloway, University of London	United Kingdom	Other Lead	Contourites
Frits	Hilgen	Utrecht University	Netherlands	Other Proponent	Astrochronology
Wout	Krijgsman	Utrecht University	Netherlands	Other Proponent	Palaeomagnetism
Sonya	Legg	Princeton University	United States	Other Proponent	Physical oceanography
Paul	Meijer	Utrecht University	Netherlands	Other Proponent	physical paleoceanography, numerical modelling
Michael	Rogerson	University of Hull	United Kingdom	Other Lead	Geochemistry and palaeoceanography
Cristina	Roque	Instituto Português do Mar e da Atmosfera Lisbon	Portugal	Other Proponent	Seismic interpretation
Francisco	Sierro	University of Salamanca	Spain	Other Lead	Planktic foraminfera and palaeoclimate
Zakaria	Yousfi	Office National des Hydrocarbures et des Mines, Rabat	Morocco	Other Proponent	Micropaleontology
Cesar	Rodriguez Ranero	Marine Sciences Institute, Barcelona	Spain	Other Proponent	Tectonics, basin analysis, geophysical imaging
Francisco Jose	Jiménez-Espejo	Granda University	Spain	Other Proponent	Geochemistry and palaeoclimate

Combined IODP and ICDP proponents

First Name	Last Name	Affiliation	Country	Role	Expertise
Rachel	Flecker	School of Geographical Sciences, Bristol University	United Kingdom	Principal Lead and Data Lead	Geochemistry, sedimentology, gateway exchange
Abdella	Ait Salem	Office National des Hydrocarbures et des Mines, Rabat	Morocco	Other Proponent	Seismic interpretation, basin analysis, wellsite geology
Alvaro	Arnaiz	Repsol	Spain	Other Proponent	Seismic interpretation
Nadia	Bahoun	University of Hassan II Casablanca	Morocco	Other Proponent	Micropalaeontology (foraminifera)
Asmae	Benarchid	Office National des Hydrocarbures et des Mines, Rabat	Morocco	Other Proponent	Seismic interpretation, petroleum Geology
Guillermo	Booth Rea	Instituto Andaluz de Ciencias de la Tierra, CSIC-University of Granada	Spain	Other Proponent	Structural geology, tectonics, geomorphology, geodynamics
Domenico	Chiarella	Dept Earth Sciences, Royal Holloway, University of London	United Kingdom	Other Lead	Wireline logs, tidal sedimentology
Damien	Do Couto	Universite de Pierre et Marie Cure, Paris	France	Other Proponent	Seismic interpretation
Hajar	el Talibi	Faculty of Sciences and Techniques of Al-Hoceima - FSTH, University of Mohammed Premier	Morocco	Other Proponent	Geochemistry, sedimentology, basin analysis, sedimentary petrology
Gemma	Ercilla	Institute of Marine Sciences, Barcelona	Spain	Other Proponent	Seismic and sequence stratigraphy
Ferran	Estrada	Institute of Marine Sciences, Barcelona	Spain	Other Proponent	Seismic and sequence stratigraphy
Marcus	Gutjahr	GEOMAR, Kiel	Germany	Other Proponent	Isotope geochemistry, overturning dynamics
Tim	Herbert	Dept. Earth, Environmental and Planetary Sciences, Brown University	United States	Other Proponent	Paleoceanography, orbital-climatic interactions
Javier	Hernandez-Molina	Royal Holloway, University of London	United Kingdom	Other Lead	Contourite sedimentology, seismic interpretation
Frits	Hilgen	Department of Earth Sciences, Faculty of Geosciences, Utrecht University	Netherlands	Other Proponent	Stratigraphy, micropalaeontology, astronomical dating
Francisco Jose	Jiménez-Espejo	Granda University	Spain	Other Proponent	Geochemistry, physical properties, sedimentology
Wout	Krijgsman	Paleomagnetic laboratory "Fort Hoofddijk", Utrecht University	Netherlands	Other Proponent	Paleomagnetism, stratigraphy
Santiago	Ledesma-Mateo	Gas Natural Fenosa	Spain	Other Proponent	Seismic interpretation, petrophysics, stratigraphy
Sonya	Legg	Princeton University	United States	Other Proponent	Physical oceanography
Estefania	Llave	IGME, Instituto Geologico y Minero de España	Spain	Other Proponent	Seismic interpretation, contourites
Amine	Manar	Office National des Hydrocarbures et des Mines, Rabat	Morocco	Other Proponent	Seismic interpretation
Pilar	Mata	Instituto Geológico y Minero de España	Spain	Other Proponent	Physical properties, sedimentary geochemistry, diagenesis
Hugo	Matias	Centro de Recursos Naturais e Ambiente, Instituto Superior Tecnico (University of Lisbon)	Portugal	Other Proponent	Seismic interpretation
Paul	Meijer	Utrecht University	Netherlands	Other Proponent	Physical paleoceanography, numerical modelling
Cesar	Rodriguez Ranero	Marine Sciences Institute, Barcelona	Spain	Other Proponent	Tectonics, basin analysis, geophysical imaging
Maria Isabel	Reguera	Instituto Geológico y Minero de España	Spain	Other Proponent	Micropaleontology, paleoclimatology, paleoceanography
Francisco J	Rodríguez-Tovar	Department of Stratigraphy and Palaeontology, University of Granada	Spain	Other Proponent	Ichnology, palaeoecology, sequence stratigraphy, sedimentary basin analysis
Michael	Rogerson	University of Northumbria	United Kingdom	Other Lead	Geochemistry and palaeoceanography
Cristina	Roque	Instituto Português do Mar e da Atmosfera Lisbon	Portugal	Other Proponent	Seismic interpretation
Francisco	Sierro	University of Salamanca	Spain	Other Lead	Planktic foraminfera and palaeoclimate
Duncan	Wallace	Chariot Oil and Gas	United Kingdom	Other Proponent	Seismic interpretation
Zakaria	Yousfi	Office National des Hydrocarbures et des Mines, Rabat	Morocco	Other Proponent	Micropaleontology (foraminifera)

1. Scientific Context

The premise underpinning this amphibious drilling proposal is that by recovering the Late Miocene sedimentary record of the mid-latitude Atlantic-Mediterranean marine exchange from its inception to its present-day configuration, we can quantify a first order teleconnection linking the low-latitude North African monsoonal system with the high-latitudes, evaluate its role in triggering the onset of Northern hemisphere glaciation and test a key physical oceanography hypothesis.

Paleoclimate research is often driven by the need to validate various types of "climate model" under boundary conditions different from those of the last 150 years for which an instrumental record of climate is available (Stocker 2014). Quantifying past changes in temperature, momentum and flux in the ocean and atmosphere is therefore a key target for geological research. However, the small size of climate change signals relative to climate proxy measurement uncertainty means this is challenging to achieve (Rohling 2007). A high signal to noise ratio typically requires amplification of the climate variable and in the ocean, this is most commonly found in marginal marine basins where exchange with the open ocean is limited so it cannot buffer and diminish the signal of environmental change (Grant, et al. 2017). Unfortunately, limited exchange also makes it difficult to use the enhanced marginal basin record to extrapolate to global-scale oceanographic change (Kaminski, et al. 2002). Marine gateways linking the basin to the open ocean represent a "sweet spot" where, on one side climatic changes are amplified in the adjoining marginal basin, while on the other, their impact on globally-meaningful changes in the open ocean can be directly assessed. In addition, the geometric and hydraulic restriction of the gateway itself places physical limitations on the freedom of the system to change (Nelson, et al. 1999). This focuses the deposition of the sedimentological archive of exchange into a small, well-defined geographical area, making it possible to constrain quantitatively responses to exchange that impact global climate (Rogerson, et al. 2012a).

The influence of exchanging heat, salt and momentum through narrow, shallow straits that link the open ocean to marginal basins is profound. The advection of cool or saline waters (Legg et al., 2009) helps drive global thermohaline circulation (Thomas et al., 2004; Alvarez et al., 2005; Rahmstorf, 2006). Since the ocean is the largest of the rapidly exchanging CO_2 reservoirs, this advection also increases the sensitivity of the ocean to atmospheric carbon changes (LaRiviere et al., 2012; Karas et al., 2017; Elsworth et al., 2017; Capella et al., 2019). While exchange through the Denmark Strait, Indonesian archipelago and Gibraltar Strait can all overprint both zonal and meridional circulation patterns, global ocean surface circulation and associated heat transport compensating for water-mass transformation on the basinward side of gateways, forces substantial impacts on sea-ice, warming or cooling of adjacent continents and the position of the atmospheric front (Ivanović et al., 2014b). Unsurprisingly, the opening and closure of oceanic gateways is therefore well recognized as having a profound impact on the Earth's climate, including its periodic switching from Greenhouse to Icehouse conditions (Kennett, 1982; Smith and Pickering, 2003; Knutz, 2008).

The impact of regional changes on global-scale processes are generally ideal questions for Earth System Models. However, because of the inherent small-scale of marine gateways relative to global circulation model grid cells, the gateways are either hugely enlarged in the model or the transport of heat and water through them is parameterized rather than explicitly modelled (e.g., Dietrich et al., 2008; Ivanović et al., 2013). An excellent example of the problem occurs at Gibraltar (Fig. 1), where model grid cells ~400km^2, which are suitable for the long global simulations necessary for paleoclimate studies, are ill-equipped to simulate hydraulic control in a strait ~12km in width, and consequently generates exchange behavior which differs from observations (Ivanović et al., 2013; Alhammoud et al., 2010). Consequently, the co-dependence of ocean and marginal sea in simulations is reduced, preconditioning models to be insensitive to exchange-driven change. A view of past and future climate derived from global circulation assessments alone therefore systematically under-estimates the role of gateway processes, eliminating a crucial feedback within the Earth system***. In summary, exchange through marine gateways is an example of a key climate process which can only be constrained through interrogation of the record of ocean-marginal basin exchange in a specific sedimentary archive, and as a result, is a target that fits precisely with the climate themes stated in the IODP and ICDP science plans.***

1.1 Atlantic-Mediterranean exchange, now and in the past

In the Atlantic, several marine overflows (Denmark Strait, Mediterranean, Weddell Sea) supply dense water that collectively feeds the thermohaline circulation system (Smethie et al. 2000). The transportation of dense water from the Mediterranean into the interior of the Atlantic (Fig. 1) is amongst the largest in the global ocean (Legg et al., 2009; Table 1) and exchange also provides a key exit point for Atlantic buoyancy, the underlying driver behind Atlantic deep convection (Broecker 1991).

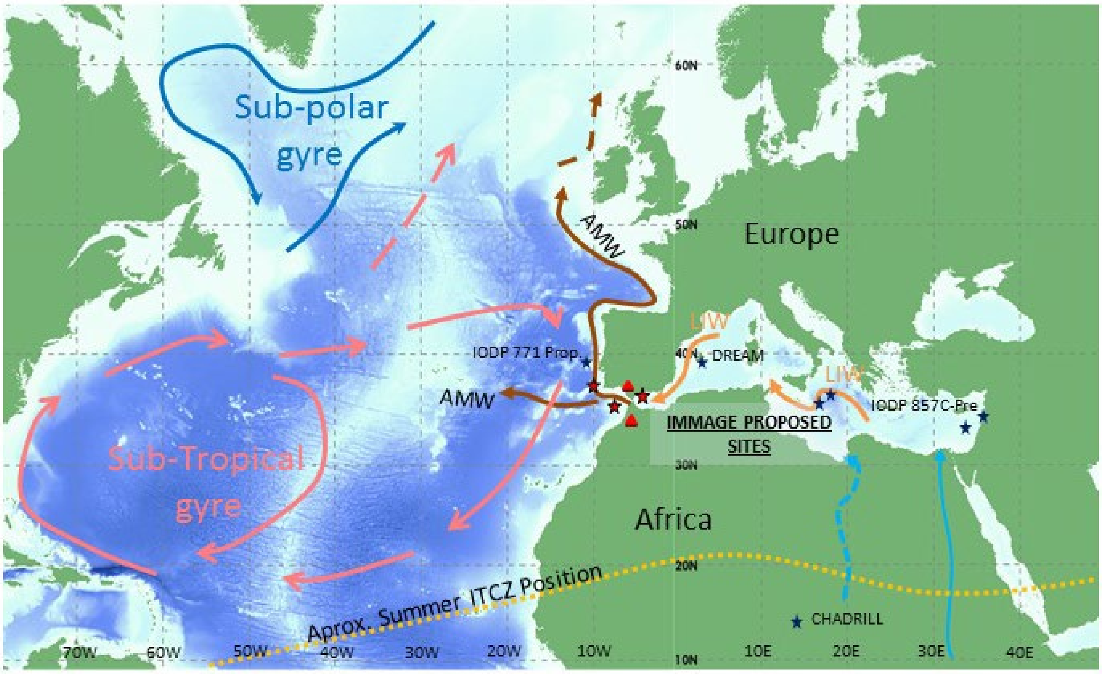


Figure 1. Climatic transport system linking the North African monsoonal system, via Mediterranean overflow to thermohaline circulation in the North Atlantic. Red stars are the proposed IODP IMMAGE sites; red triangles are the ICDP IMMAGE sites. Blue stars represent existing, accepted and proposed IODP-ICDP drill locations that complement IMMAGE objectives. Arrows indicate surface and intermediate water-masses (Atlantic-Mediterranean Water-mass: AMW; Levantine Intermediate Water: LIW; Intertropical Convergence Zone: ITCZ).

The Mediterranean's dense overflow (MO) is generated as a consequence of its mid-latitude setting where evaporation exceeds precipitation (Peixoto & Kettani, 1973) generating a warm, salty water-mass. The negative hydrologic budget varies in severity through time, amplifying the climate signal transmitted principally through the Mediterranean's southern catchments and derived from North African monsoon rainfall (Marzocchi et al., 2015; Fig. 1). This sub-tropical monsoonal climate signal with its strong precessional pulse, is then propagated into the Atlantic by density-driven exchange (Fig. 1; Bahr et al., 2015) through the Gibraltar Strait. Water flowing out of the Mediterranean at depth entrains ambient Atlantic water as it goes (Dietrich et al., 2008), generating a distinctive Atlantic Mediterranean Water-mass (AMW; Rogerson et al., 2012a) in the central and north Atlantic, and large depositional and erosional features including extensive sandy contouritic drifts (Nelson et al., 1999; Stow et al., 2013; Hernández-Molina et al., 2003; 2014a; 2014b). AMW flows north fueling the Norwegian Seas with higher density water that helps sustain the formation and southward flow of North Atlantic Deep Water (Fig. 1; Khélifi et al., 2011; Rogerson et al., 2012a; Kaboth et al., 2018).

Table 1. Data from several overflows for comparison with present day exchange through the Gibraltar Strait and estimated Late Miocene Atlantic-Mediterranean exchange. Data for the modern ocean is taken from Legg et al., (2009).

	Faroe Bank	Denmark Strait	Red Sea	Gibraltar Exchange		
				Today	**Messinian Halite Phase**	**Lago Mare phase**
Source water						
Potential temperature	0	0.25	22.8	14	14	14
Salinity (g/kg)	34.92	34.1	39.8	38.4	360	36
Density at Surface (σ units)	28.07	27.94	27.7	28.94	~300	~26.96
Sill depth (m)	800	500	200	300	20	200
Density difference at gateway (σ)	1.57	1.44	1.2	2.44	~275	~0.5
Product water						
Potential temperature	3.3	2.1	21.7	11.8	?	?
Salinity (g/kg)	35.1	34.84	34.67	36.4	?	?
Density at Surface (σ units)	27.9	27.85	27.48	27.6	?	?
Depth (m)	3,000	1,600	750	850	?	?
Velocity Source (m/s)	1	0.7	0.55	1	>>1	<<1
Transport						
Source	1.8	2.9	0.3	0.8	<<0.8	?
Product (Sv)	3.3	5.2	0.55	2.3	~2.3	?
Entrainment %	183	179	183	288	>>288	?

Despite the challenges of modelling the gateway, the exchange that occurs through the Gibraltar Strait today is a sufficiently influential component of the Earth System for GCMs to capture at least part of its impact (Bigg et al., 2003; Bigg and Wadley 2001). Experiments without Atlantic-Mediterranean exchange show that its presence makes Greenland warmer and Antarctica cooler (Bigg, et al. 2003). This in turn is sufficient to shift the position of the ITCZ (Fig. 1), and hence the location of monsoons, storm tracks and the hyper-arid zones between them. Atlantic-Mediterranean exchange is also a critical component of Atlantic Meridional Overturning Circulation (AMOC) particularly at times of weak North Atlantic Deep-Water formation (Bigg and Wadley, 2001; Ivanović et al., 2014a; 2014b; Penaud et al., 2011; Rogerson et al., 2010; 2006; Voelker et al., 2006). Furthermore, the transport of dense water from the Mediterranean into the interior of the Atlantic entrains ambient Atlantic water on route, contributing significantly to global carbon drawdown (2-5% of today's total net ocean carbon sink; Tans et al., 1993; Siegenthaler and Sarmiento, 1993; Dixon et al., 1994). ***In summary, Atlantic-Mediterranean exchange is a key teleconnection that links African monsoon precipitation from the south Atlantic with the northern high-latitudes.***

Exchange through a single gateway at Gibraltar is a relatively recent phenomenon (Hernández-Molina et al., 2014a; van der Schee et al., 2016; Garcia-Gallardo et al., 2017a;b).

As a result of Africa-Eurasia convergence, westward docking of the Alborán Plate and simultaneous slab-retreat (Jolivet and Faccenna, 2000; Faccenna et al., 2004; van Hinsbergen et al., 2014), the Atlantic-Mediterranean connection evolved from a single, wide open seaway (Fig. 2, T1) linking a Mediterranean that was more of an embayment of the Atlantic than a distinct marginal marine system (Flecker et al., 2015), to two narrow corridors: one in northern Morocco; the other in southern Spain (Benson et al., 1991; Fig. 2, T2). The onset of episodic organic-rich sedimentation (sapropels) in the Middle Miocene (Hilgen et al., 2005; Taylforth et al., 2014) is the earliest evidence of the Mediterranean operating separately from the Atlantic. On-going progressive restriction of the marine corridors permitted Mediterranean salinity to rise and a distinct, dense water-mass formed. This dense water over-spilled into the Atlantic for the first time at some point during the Middle-Late Miocene (Capella et al., 2017; 2019). Ultimately, the narrowing and closure of these connections resulted in extreme salinity fluctuations in the Mediterranean (Fig. 2), leading to the precipitation of more than 1 million km^3 of salt, equivalent to ~6% of the total dissolved oceanic NaCl (Blanc, 2006; Ryan et al., 1973) in the latest Miocene. This event is known as the Messinian Salinity Crisis (MSC; Hsü et al., 1973). On-going tectonic convergence coupled with isostatic rebound related to lithospheric mantle dynamics (Duggen et al., 2003), not only severed these earlier marine connections, but also uplifted and exposed them on land (Capella et al., 2017). In the early Pliocene (Fig. 2, T3) two-way exchange was established through a single conduit, the Gibraltar Strait.

During the Messinian Salinity Crisis, the amplified net evaporative flux changed to such an extent that the salinity of water flowing into the Atlantic varied between near-equality with Atlantic water (~36 g/kg), to halite-depositing brine (>360 g/kg) and brackish water conditions (<20 g/kg). Gibraltar exchange today exhibits one of the largest density contrasts in the modern ocean (Table 1), but this contrast was increased by up to two orders of magnitude during the acme of the MSC. The water flowing into the Atlantic at this time was probably the most extremely dense overflow of oceanographic scale in the history of the Earth, and all other aspects of the exchange would have been proportionally exaggerated. ***The scientific aim of IMMAGE is to determine when Mediterranean overflow first occurred and to constrain quantitatively how the Atlantic Ocean and global climate were altered as a consequence of***

both the inception of Atlantic-Mediterranean exchange and extreme density contrast between the two. This can only be achieved by recovering:

- ***the Late Mio-Pliocene gateway sediments preserved onshore in Morocco and Spain (ICDP drilling);***
- ***a record of the water-mass from which Mediterranean overflow derived (IODP drilling in the Alborán Basin); and***
- ***Atlantic sediments impacted by Mediterranean overflow (IODP drilling).***

IMMAGE therefore requires an amphibious drilling strategy.

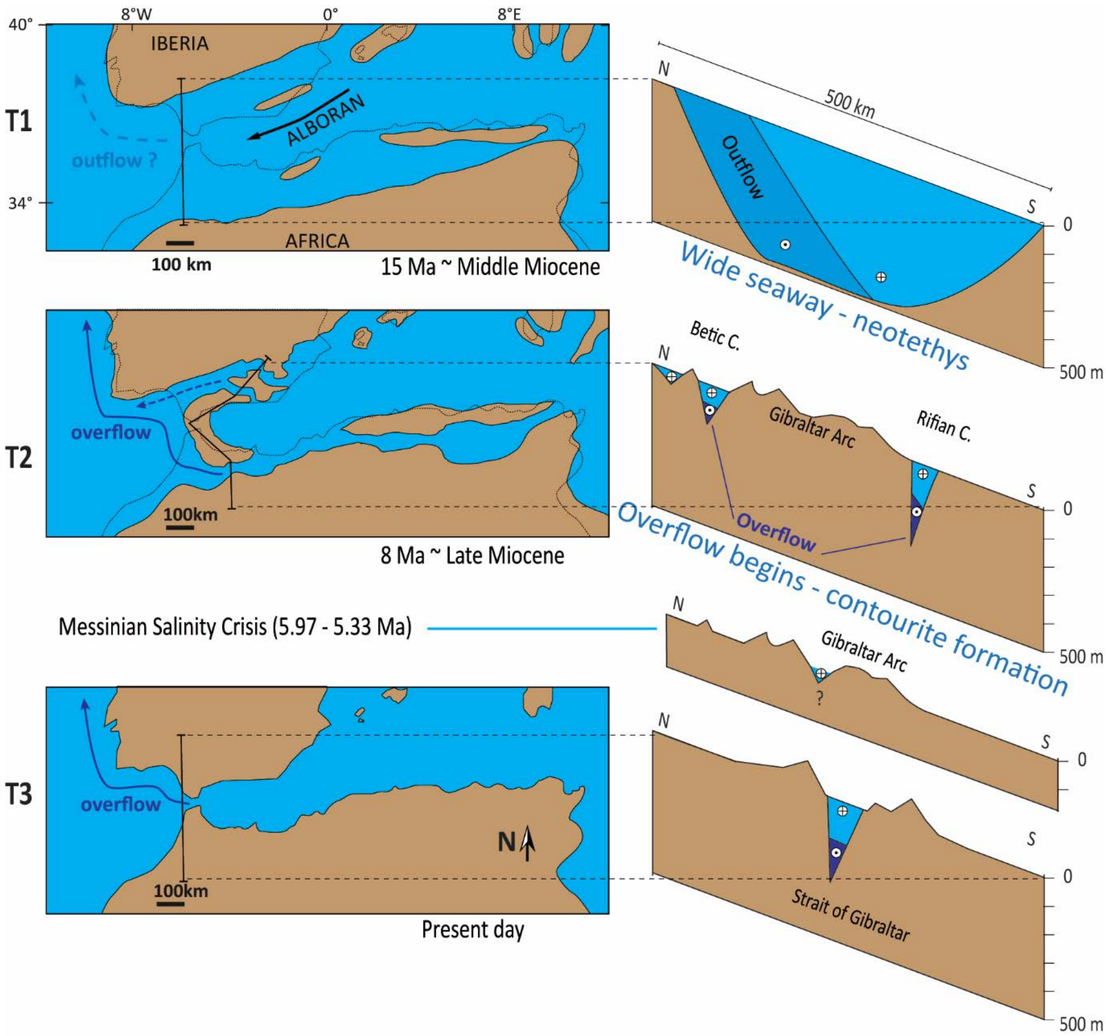


Figure 2. Three-step sketch showing the tectonically-controlled reconfiguration of the Mediterranean-Atlantic seaways from Middle Miocene to present-day. Paleogeography of the Western Mediterranean after Do Couto et al., (2016). The Rifian/Betic seaways (T2) which replaced a wider seaway (T1) are now exposed on land in northern Morocco and southern Spain. The T2 scenario (~8 Ma) is the first with potential impact on Atlantic-Mediterranean salinity gradients and overflow formation. (Figure from Capella et al., 2019.)

1.2 Late Miocene Climate

The mid-Cenozoic cooling trend documented by the global $\delta^{18}O_{benthic}$ record (Fig. 3a; Zachos et al., 2001; 2008) has been linked to the onset and growth of the East Antarctic Ice Sheet (Gulick et al., 2017). By the Late Miocene this was well established (Fig. 3a) with evidence of ephemeral continental ice sheets elsewhere (Larsen et al., 1994; St John and Krissek, 2002; Mercer and Sutter, 1982; Williams et al., 2010). Intriguingly, while deep-sea cooling appears to stabilize in the Late Miocene (Fig. 3a), sea surface temperatures (SST) indicate up to 6° C of cooling between 7-5.3 Ma (Fig. 3b; Herbert et al., 2016). This cooling trend occurs in both hemispheres and across all the world's major oceans. It amplifies towards the high-latitudes, and terminates at 5.3 Ma, coincident with the Mio-Pliocene boundary and the end of the MSC, with temperatures almost equivalent to modern values (Herbert et al., 2016).

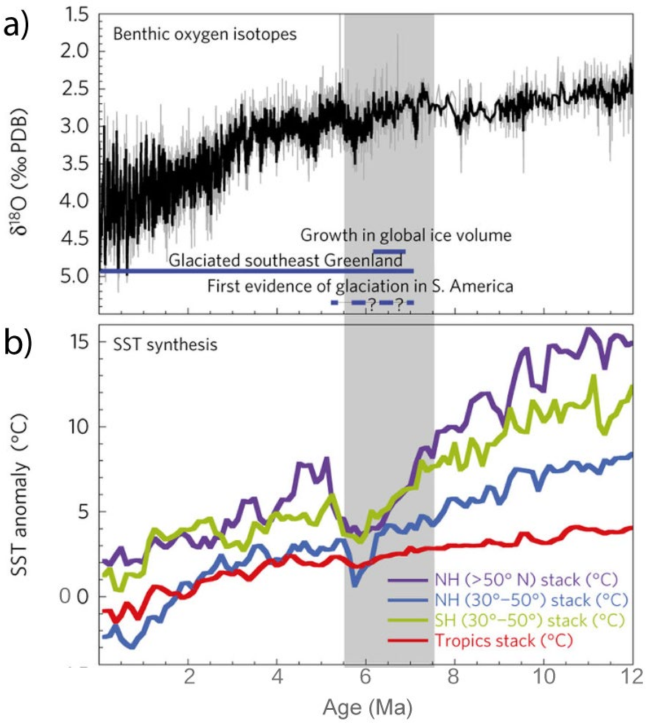


Figure 3. Sea water temperature records for a) deep water derived from benthic $\delta^{18}O$ composite (Zachos et al., 2001); b) Alkenone-derived sea surface temperatures for Northern Hemisphere High and Mid latitudes, Southern Hemisphere Mid latitude, and Tropics (Herbert et al., 2016). Grey bar indicates the duration of the discrepancy between the implicit temperature evolution of oceanic bottom and surface water. This period ends at the Mio-Pliocene boundary, coincident with the end of the MSC.

This Late Miocene sea surface cooling resulted in stronger equator-pole temperature gradients, intensifying subtropical aridity and contributing to major continental ecosystem change (Herbert et al., 2016) including the expansion of C_4 plants (e.g., Dupont et al., 2013; Cerling et al., 1997). Herbert et al., (2016) attribute the cooling to a decline in Late Miocene atmospheric CO_2. Although the P_{CO2} reconstruction from this period appears to show no significant change during the Late Miocene (Foster et al., 2017), benthic carbon isotope records support a major perturbation of the global carbon cycle (Hodell and Venz-Curtis, 2006). Possible drivers of this CO_2 drawdown are sequestration in the deep ocean of eroded organic soil matter released from a less vegetated land surface (Diester-Haas et al., 2006) and ocean gateway change causing shoaling of the thermocline (LaRiviere et al., 2012). What has not previously been considered is the role of MO in oceanic circulation, the ephemeral northern hemisphere Messinian ice ages (van der Laan et al., 2012) and marine CO_2 storage during the late Miocene (Capella et al., 2019)***. By recovering a record of the inception of Atlantic-Mediterranean exchange we will be able to quantify the impact of this new source of advecting water on the Late Miocene North Atlantic, northern hemisphere glaciation, ocean CO_2 and the other CO_2 reservoirs with which it exchanges.***

1.3 Testing the global versus regional significance of the MSC

This potential driver for global climatic change also has important implications for our understanding of the evolution of the MSC, which languishes in the grip of an enduring controversy over the relative importance of eustatic sea level change and local tectonics. Astronomical tuning of Late Miocene Mediterranean successions quashed initial hypotheses supporting the global-scale importance of the MSC (see Stanley 1975 for a review) and suggested that regional tectonics rather than global eustatic change controlled the onset (Krijgsman et al., 1999) and termination (van der Laan et al., 2006) of the MSC. This conclusion renders the Mediterranean salt giant an extraordinary, but fundamentally parochial phenomenon. Over the past few years, however, the potential global interconnectedness and significance of the MSC has revived as a result of retuning key sections (Manzi et al., 2013), a greater appreciation of the uncertainties in sub-precessional phasing of Mediterranean successions (Modestou et al., 2017) and the intricate history of the MSC (Hilgen et al., 2007), the generation of Late Miocene orbital resolution stable isotope records in the open ocean (e.g., van der Laan et al., 2012; Drury et al., 2017), improved understanding of the ocean-dynamic consequences of decreased global salinity arising from sinking 6% of global NaCl into the salt giant itself (Cullum et al., 2016), as well as the new SST synthesis (Herbert et al., 2017). Despite this expanding evidence base, this global versus local paradox has not been tested because we lack the high-resolution records of Atlantic-Mediterranean exchange. ***The precessional-scale correlation of Mediterranean and Atlantic successions will allow us to test rigorously hypotheses that relate the MSC to global climatic change.***

1.4 Relationship with ICDP and IODP science plans

The target of the IMMAGE drilling proposal is the record of Atlantic-Mediterranean exchange during the most dynamic and variable period of its history, from inception, through salt giant formation, to the establishment of an exchange configuration similar to today. The sediments either side of the gateway region, which are preserved both onshore and offshore, record the changing nature of Atlantic-Mediterranean exchange allowing quantitative evaluation of its role in global-scale climate systems, its impact on major climatic events, and influence over extreme environmental change in the Mediterranean. ***IMMAGE's scientific objectives therefore fall under IODP's science plan for Climate and Ocean Change: Reading the Past, Informing the Future, addressing Challenges 1, 2, 3 and 4, Biosphere Frontiers Challenge 7 and Earth in Motion Challenge 13 and ICDP's focus on Global Cycles and Environmental Change.***

A Late Miocene drilling target focused on the gateway also provides an unparalleled opportunity to test physical oceanographic representations of extreme high-density overflow dynamics that do not exist in the world today on this scale. This objective extends beyond the remit of the IODP and ICDP science plans, providing insights into the role and behavior of all marine gateways and their impact on global climate.

Finally, recent studies demonstrate that MO may be able to force European ice-sheet dynamics during glacial periods (Kaboth et al., 2018). IMMAGE will provide quantitative constraints on mid-latitude processes and teleconnections that link low-latitude climate signals such as monsoons with high-latitude glacial variability. It will complement the complete Messinian sequences recovered in East Africa (IODP site 1476) and substantial recent and planned IODP and ICDP activity in the high (IODP- 318 Wilkes Land, 374 Ross Sea West Antarctic Ice Sheet History, 382 Iceberg Alley Paleoceanography) and low-latitudes (monsoons: ICDP- Lake Malawi, Lake Challa, Eastern Rift Valley; IODP- 353 Indian Monsoon Rainfall, 354 Bengal Fan, 355 Arabian Sea Monsoon, 356 Indonesian Throughflow, 361 South African climates.

2. History

The IMMAGE proposal evolved from two main research initiatives:

- MEDGATE, an EU-funded Initial Training Network (2012-16), which reconstructed Mediterranean-Atlantic exchange from exposures in Spain and Morocco;
- IODP Expedition 339 which recovered Plio-Quaternary records of MO in the Gulf of Cadiz.

In 2015, a MagellanPlus workshop on Late Miocene Mediterranean-Atlantic exchange, concluded that:

1. ***a complete, high-resolution record of Late Miocene-Pliocene Mediterranean-Atlantic exchange is essential*** both for constraining the initiation of the global-scale climate system that links the North African Monsoon via Mediterranean amplification with North Atlantic climate variability (Fig. 1) and to evaluate the impact of the MSC locally, regionally and globally;
2. the record of exchange can only be obtained through ***drilling both on land and offshore*** (Figs. 1 & 2);
3. there is considerable ***uncertainty about the physical oceanographic processes that occur when extremely dense water overflows into the open ocean***.

An IODP pre-proposal and ICDP workshop application in 2016 led to full drilling proposals for both organizations in 2018. ICDP awarded IMMAGE $1.5 million towards onshore drilling costs subject to support from IODP for the ocean drilling and submission of an addendum. The IODP SEP review while supportive of IMMAGE's science, required modifications to the drilling strategy. Both the revised IODP proposal and the ICDP addendum were submitted in April 2019. The SEP review acknowledged that their major concerns had been addressed, but in view of the complexity of an amphibious proposal requested one further revision. ICDP's response to the addendum was positive.

3. Objectives and testable hypotheses

Objective 1: To document the time at which the Atlantic first started to receive a distinct overflow from the Mediterranean and to evaluate quantitatively its role in Late Miocene global climate and regional environmental change. Today, dense water (13°C, 37g/kg; Price et al., 1993) pools on the floor of the Mediterranean behind a shallow (300 m), narrow sill (15 km), the Gibraltar Strait. Mediterranean waters overspill the sill and cascade down the continental slope. The density contrast between Mediterranean and ambient Atlantic water generates substantial current speed leading to extensive contouritic drifts (Hernández-Molina et al., 2016). Recent fieldwork in Morocco has revealed that the Rifian Corridor in northern Morocco contains upper Miocene contouritic sediments (Capella et al., 2017) resembling the Plio-Pleistocene contourites in the Gulf of Cadiz (IODP Expedition 339; Stow et al., 2013).

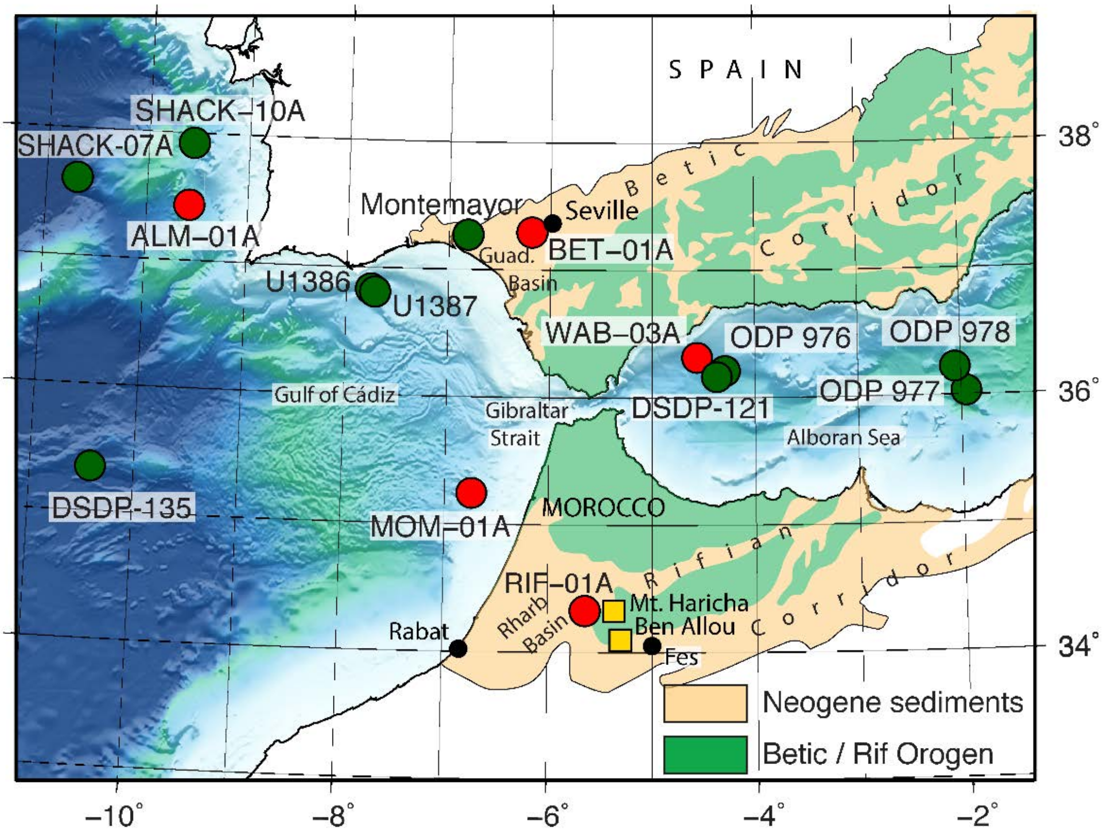


Figure 4. Map of the Mediterranean-Atlantic gateway at Gibraltar and the two Miocene connections, the Betic and Rifian corridors that are now exposed on land in Spain and Morocco respectively (brown shading). Red dots indicate IMMAGE IODP and ICDP primary drilling targets. Yellow squares are the location Miocene contourite exposures in Morocco (Capella et al., 2017). Green dots indicate proposed (SHACK-10A, SHACK-07A IODP Iberian Margin proposal) and existing (U1386, U1387, IODP Expedition 339; Montemayor borehole) holes that recovered or target upper Miocene sediments.

The presence of 7.8-6.3 Ma contourites in Morocco (Capella et al., 2017) indicates that an overspill geometry had already formed in the Late Miocene, ~two million years before the MSC, allowing a density contrast between the Mediterranean and Atlantic to develop and feeding saline Mediterranean water into the North Atlantic (Capella et al., 2017; 2019). The outstanding question is whether these exposed Rifian contourites are the <u>first</u> products of MO, or whether older, buried contourites exist in either the Rifian and/or Betic corridors (Figs. 2 & 4).

One possibility is that initiation of MO helped trigger northern hemisphere glaciation, altering the North Atlantic density structure and increasing CO_2 drawdown by entraining Atlantic surface water and its dissolved CO_2 in the dense AMW plume (Capella et al., 2019). Correlation with similarly high-resolution sites in the North Atlantic will be required to test this mechanism and assess its importance in modulating NADW formation. Correlation with new Messinian sequences recovered during IODP expeditions 346 (Japan Sea) and 361

(Agulhas Current) will allow us to evaluate the influence of the MSC on atmospheric conditions and continental-scale aridification (Zhang et al., 2014).

Hypothesis 1.1: The earliest contourites formed as a result of Atlantic-Mediterranean exchange, correlate with the onset of Late Miocene SST decline in the mid and high latitudes: dating the first Atlantic-Mediterranean contourites will test this hypothesis.

Hypothesis 1.2: Atmospheric CO_2 sequestration in the deeper ocean through the initiation and development of Atlantic-Mediterranean Water can account for the degree and distribution of SST cooling observed: reconstructing the velocity, density and flux of AMW through time, quantifying its impact on CO_2 advection (Capella et al 2019) and then modelling the resulting SST distribution (e.g. Ivanović et al 2014b) tests this hypothesis.

Hypothesis 1.3: Atlantic-Mediterranean Water modulates North Atlantic Deep Water formation, triggers glacial inception and influences continental-scale aridification: model-based testing of this hypothesis requires the correlation of IMMAGE records with existing high-resolution records globally.

Objective 2: To recover a complete record of Atlantic-Mediterranean exchange before, during and after the Messinian Salinity Crisis and to evaluate the causes and consequences of this extreme oceanographic event, locally, regionally and globally.

Today, Mediterranean seawater flows through the Gibraltar Strait forming a saline plume at intermediate depths in the Atlantic (Iorga and Lozier, 1999). The plume's record of Plio-Quaternary contouritic sediments has been recovered from the Gulf of Cadiz (IODP Expedition 339) documenting a Mediterranean contribution to Atlantic thermohaline circulation since the Pliocene (Hernández-Molina et al., 2014a; van der Schee et al., 2016; Garcia-Gallardo et al., 2017a; 2017b). However, there was also a late Miocene episode of Mediterranean influence on the Atlantic (Capella et al., 2017; 2019) although the conduit for Atlantic-Mediterranean exchange is unclear since Gibraltar may have already been open alongside marine corridors in northern Morocco and southern Spain (Fig. 4; Flecker et al., 2015; Martín et al., 2009; Krijgsman et al., 2018) and the Alborán Basin may have been an intermediate system separated from the Mediterranean by the Alborán volcanic arc (Booth-Rea et al., 2018). The sedimentary expression of restriction and closure of these Miocene connections in the Mediterranean comprises both thick evaporites (e.g., Roveri et al., 2014) and brackish "Lago Mare" sediments (Fig. 5; Iaccarino and Bossio, 1999; Orszag-Sperber, 2006; Rouchy et al., 2007; Guerra-Merchan et al., 2010). Understanding the causes of high-amplitude salinity change in the Mediterranean, and its global consequences depends on recovering a complete record of Atlantic-Mediterranean exchange before, during and after the MSC.

Hypothesis 2.1: The Alborán Basin was an intermediate marine system influenced by the Atlantic and separated from the Mediterranean by the Alborán volcanic arc during the MSC.

Hypothesis 2.2: Extreme environmental fluctuations in the Mediterranean had negligible impact on Atlantic-Mediterranean Water.

Both these hypotheses require the reconstruction and comparison of the physical properties of late Miocene water in the Atlantic (ALM-01A), Alborán Sea (WAB-03A) and existing Mediterranean successions.

Objective 3: To test our quantitative understanding of the behavior of ocean overflow plumes during the most extreme exchange in Earth's history.

There are ~20 major, ocean-scale overflow systems in the world today (Legg et al., 2009). These include some of the most important and sensitive oceanic transport systems e.g., Denmark Strait and Weddell Sea. All these systems are driven by source water density anomalies, upstream of the overflow (Price and O'Neill-Baringer, 1994). However, the range of source water density today is rather small; 27.7 σ units (Red Sea) to 28.95 σ units (Mediterranean Sea; Table 1). In comparison, the density of Mediterranean water during gypsum (stages 1 and 3 of the MSC; Fig. 5) and halite deposition (stage 2) would have been enormous (110 and ~300 σ units respectively; Table 1). This presents an opportunity and a challenge for existing representations of oceanographic overflow physics (e.g., Legg et al., 2009), since we can test hypotheses derived from physical theory through scientific drilling. This is the first experiment of its type that we are aware of and is ground-breaking in the field of quantitative paleoceanography.

The application of physical theory to the paleoceanography of MO is well established (Rogerson et al., 2012b), and suggests the following hypotheses:

Hypothesis 3.1: The velocity of the plume is a function of the Atlantic-Mediterranean density contrast, limitation on flow through the strait (Bryden et al., 1994), the gradient of the slope and the degree of mixing (Price et al., 1993);

Hypothesis 3.2: Mixing with ambient water causes a strong negative feedback on the size of the plume, limiting the degree of its variability (Price et al., 1993). This means that only minor changes in the physical size of the plume are expected, despite the proportion of plume water derived directly from the outflow varying significantly. As a result, changes in Mediterranean density have little impact on the plume position. Consequently,

Hypothesis 3.3: The main control on the settling depth of MO is the vertical density gradient in the North Atlantic which is a product of North Atlantic overturning circulation (Rogerson et al., 2012b).

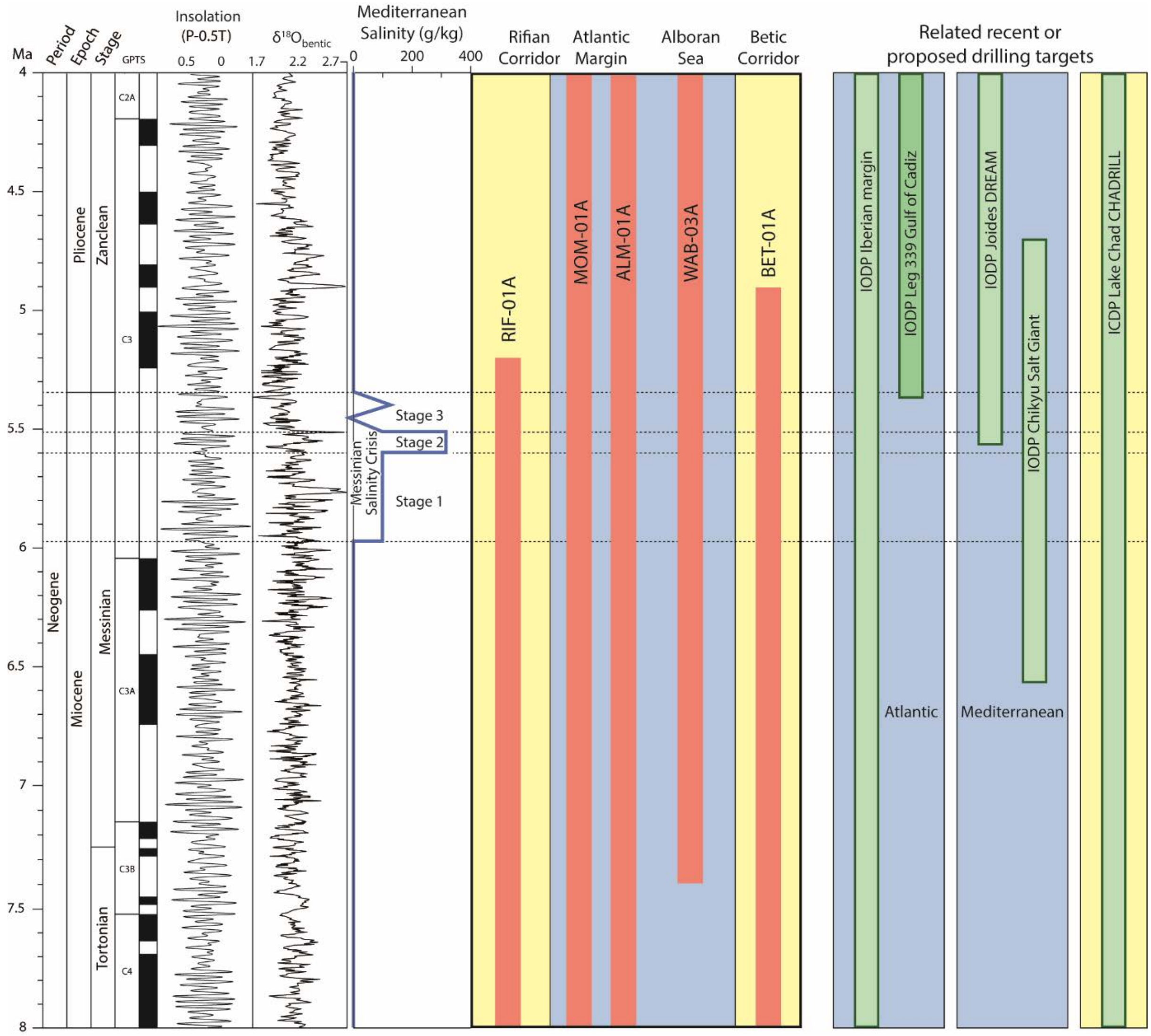


Figure 5. Chart showing the temporal range of the different IMMAGE sites with the ICDP targets highlighted in yellow and the IODP targets in blue. Recovered (IODP Leg 339; dark green) and proposed drilling targets (Iberian Margin, DREAM, Lake Chad; light green) of related projects are also shown. A reconstructed salinity profile of Mediterranean water through time (Flecker et al., 2015) illustrates the enhanced salinity during the three stages of the Messinian Salinity Crisis. Insolation (Lourens et al., 1996), which has a strong precessional component which is reflected in the sedimentary record, the benthic foraminifera δ^{18}O curve generated for the Salé Core, Morocco (Hodell et al., 2001) and the Plio–Pleistocene stack (Lisiecki and Raymo, 2005) are plotted alongside.

These qualitative hypotheses have been quantitatively investigated in pilot experiments exploring a range of MSC-like salinity scenarios. They show that only minor changes in the position and size of the MO plume result from extreme differences between "evaporite depositing" (MSC) and "Lago Mare" (brackish-water) boundary conditions (Fig. 6). The brackish plume (Fig. 6B) lies at the depth of the upper part of the modern MO (Borenas et al., 2002; Fig. 6A), while the evaporite plume (Fig. 6C) coincides with the lower part of the modern flow. In phases, the plume extends over roughly half the area influenced by the modern plume. The response of MO settling depth to the North Atlantic density gradient is shown in Figure 6D. As Miocene AMOC may have been either lower or higher than today (Butzin et al., 2011; Panitz et al., 2018), the position of the plume could be either higher or lower on the slope than indicated in Figures 6A-C and will also vary on orbital timescales, as this forcing is expected to cause variations in AMOC (Panitz et al., 2018), but to a much smaller extent than during the Pleistocene.

These results suggest that both secular and cyclic changes in the position of the plume will be recorded in its sedimentary product and that the position of the plume is almost independent of Mediterranean salinity. Coring locations based on the modern plume position, Late Miocene paleogeography of the coastline and slope and seismic evidence of Late Miocene contouritic sedimentation, should recover the full Late Miocene record of exchange. MOM-1A will target plume sediments immediately downstream of the gateway (Fig. 4), while ALM-01A will provide a record of its equilibrium depth. The targeted sites will provide high-resolution records that complement, but do not replicate the two planned Iberian margin sites (SHACK-10A, SHACK-07A; Fig. 4) which are more distal and too thin and deep to provide the high-resolution precessional record required.

The opportunity to integrate physical and geological oceanography envisaged here is unique, exciting, and ensures that regardless of the record we recover, the results will have far-reaching implications. IMMAGE is a direct hypothesis test, investigating whether the representations of overflows within general circulation models (GCMs) are effective outside the range of validation provided by the modern ocean. If the record fulfils the patterns predicted (Fig. 6), this will, for the first time, provide empirical evidence that these representations are adequate under extreme boundary conditions. Moreover, this success will allow us to embed physical oceanography more explicitly in our interpretation of the record, laying the foundation for a new and fully quantitative understanding of the past. If the record is inconsistent with the hypotheses, this will be an important, empirical challenge to assumptions used in climate modelling, casting doubt on all modelling experiments in which part of the ocean-atmosphere system is outside the range exhibited today. We are not aware of a previous case where scientific drilling has been used to test ocean physics hypotheses as explicitly as we propose here. Extreme differences between our predictions and core evidence which are nevertheless resolvable by iterative modelling, for example an extremely deep plume comparable to late Quaternary Heinrich Events (Rogerson et al., 2012b), will also be incompatible with current conceptualization of how the Miocene Atlantic operated, and will provide very high-impact results.

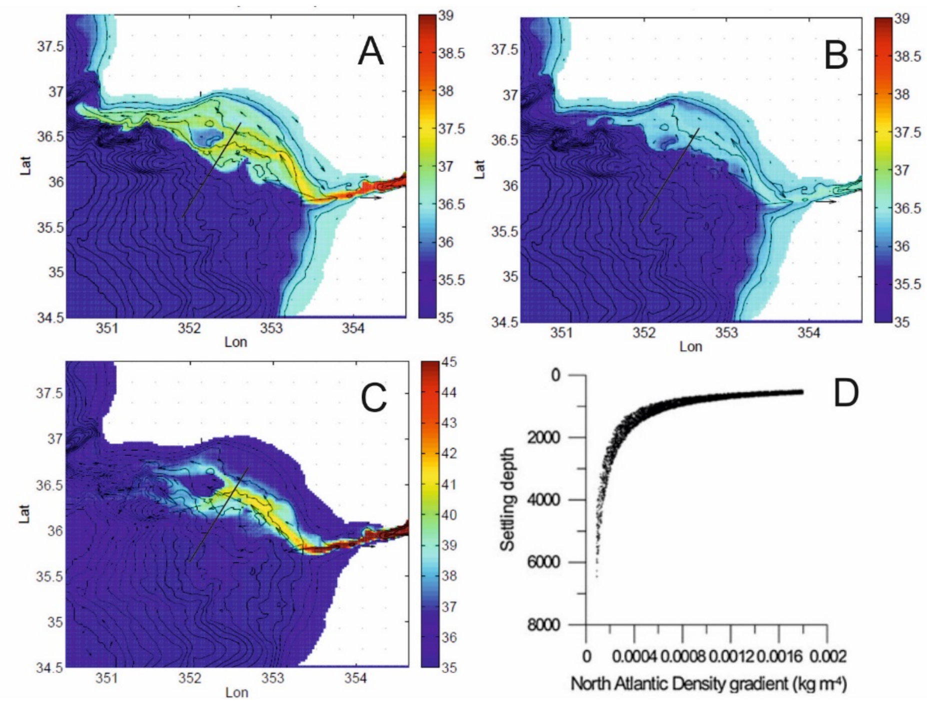


Fig. 6. Salinity (color) and velocity field (arrows) for simulated Mediterranean Outflow at different time periods showing the size and location of the resulting overflow plume in the Gulf of Cadiz. A: modern configuration, B: Lago Mare (brackish water) submaximal exchange, C: Messinian Salinity Crisis gypsum-depositional phases. D: impact of altering Atlantic vertical density gradient on the setting depth of Mediterranean Outflow Water (Rogerson et al., 2012b).

Main Anticipated Scientific Outcomes:

IMMAGE aims to recover a complete record of Late Mio-Pliocene Atlantic-Mediterranean exchange. By reconstructing the physical properties of each water-mass and generating a multi-proxy climate time-series at each site, these sediments will permit the quantitative evaluation of the impact of mid-latitude overflow on ocean circulation, as well as regional and global environmental change. This aim will require us to:

- reconstruct and quantify MO and AMW (**H1.1**, **H2.1**, **H2.2**, **H3.1**, **H3.2**, **H3.3**) and the global climate impact of the Late Miocene inception of a major source of dense water (**H1.2**, **H1.3**);
- generate a unique record that constrains the poorly defined teleconnections between better understood low- and high-latitude climate systems (**H1.2**, **H1.3**);
- test the physical oceanography of overflows (**H3.1**, **H3.2**, **H3.3**);
- reconstruct quantitatively the evolution of Atlantic-Mediterranean exchange during the MSC providing a true boundary condition on this episode of extreme environmental change (**H2.1**, **H2.2**).

To achieve these outcomes, analyses that constrain the physical and chemical properties of water passing through the Atlantic-Mediterranean corridor are required.

- Water density. This is a key requirement for testing IMMAGE hypotheses (**H1.2**, **H2.1**, **H2.2**, **H3.2**) for which a new proxy approach is required. The Gibraltar exchange and outflow system is so strongly controlled by differences in salinity that representations of its physics today entirely neglect differences in temperature (Bryden and Kinder, 1991). As the proportional differences in temperature are orders of magnitude smaller than changes in salinity during the MSC, this assumption can be maintained in the past permitting Mg/Ca and $\delta^{18}O$ analyses of benthic formaninifera to function as proxies for density. A regionally-specific density calibration for $Mg/Ca_{calcite}$ and $\delta^{18}O_{epifauna}$ will be constructed from core-top to reduce measurement uncertainty and the impact of variable temperature.
- Distribution of MO water. The distribution of MO across the Gulf of Cadiz is diagnostic of the degree to which ambient (CO_2-rich, **H1.2**) Atlantic water is entrained and the physical properties of both water sources (**H2.1**, **H2.2**, **H3.2**). MO is dense, warm and salty by comparison with the Atlantic waters. Its temperature and salinity drive $Mg/Ca_{calcite}$ in the same direction (Ferguson et al., 2008) and there is a strong correlation between $\delta^{18}O_{epifauna}$ and MO presence in core tops (Rogerson et al., 2011). The core top data will therefore also be calibrated for the fraction of MO present at each site, providing an additional means of

estimating MO source properties independent of the assumptions used to reconstruct density.

- Water-mass tracers. Sediment provenance, $\delta^{13}C_{calcite}$, Sr on biogenic carbonate (Flecker et al., 2002; Modestou et al., 2017) and Nd isotopes (Khélifi et al., 2014) on fish teeth, manganese crusts and detrital fractions will be used as water-mass tracers. These data are essential in identifying the Mediterranean origin of the earliest contourites (**H1.1**). Benthic $\delta^{13}C_{calcite}$ also reflect MO ventilation where low benthic $\delta^{13}C_{calcite}$ values are linked to water stratification in the Mediterranean at times of enhanced freshwater discharge (Voelker et al. 2006). These Mediterranean-specific signatures are transferred to the Atlantic through the corridors and vary as pure MO mixes to become AMW. They will therefore correlate closely with density and MO distribution, validating the relative changes in plume activity and distribution (**H1.2**, **H2.1**, **H2.2**, **H3.1**, **H3.2**).
- Water velocity. This parameter, essential for testing **H1.2**, **H3.1,** will be generated from grainsize analysis, sedimentary structures, epifauna and benthic assemblages and elemental ratios (e.g., Zr/Al; Bahr et al., 2014). Although variations in velocity at each site are directly controlled by density, their methods are independent of each other. The relative trends in density and velocity will therefore provide cross-validation.
- Surface water hydrography. This will be reconstructed from $\delta^{18}O$, Mg/Ca, TEX_{86}, $U^{k'}_{37}$ and planktic assemblages. Surface water circulation within the Gulf of Cadiz and Alborán Sea are dominated by Gibraltar exchange, so major changes in spatial gradients are diagnostic of changes in the exchange (Rogerson et al., 2008) and are required for testing **H3.1**, **H3.2** and **H3.3**. Although there is no seismic evidence for evaporites in the Alborán Basin, it is likely to have experienced salinities that exceded the ecological range of planktic foraminfera (>49 g/kg; Fenton et al., 2000; **H2.1**), resulting in discontinuous proxy records reliant on foram archives during the MSC. However, biomarker proxies are effective at much higher salinities (up to ~250‰; Turich and Freeman, 2011) and will provide a complete record of the Alborán Basin hydrography that tests **H2.2**.
- Bottom water oxygenation and nutrient availability. CT-scanning of all cores will be used to reconstruct trace-fossil assemblages. Combined with elemental ratios (e.g., U/Th), sedimentary structures and benthic assemblages, this will tease apart bottom water oxygenation and nutrient availability (Rodriguez-Tovar et al., 2015a; 2015b) and contribute to contourite identification (**H1.1**).

- Regional aridity and dust production. Dust sedimentation in the Mediterranean and adjacent Atlantic is an effective way of resolving regional aridity variability and a means of astronomically tuning and correlating marine records (Larrasoaña et al., 2008; Trauth et al., 2009). We will use magnetic approaches to identify variations in dust supply (Larrasoaña et al., 2008), and mineral geochemistry and geochronology to identify dust sources (Torfstein et al., 2018). This constraint on aridity is key to testing **H1.1** and **H1.3**.
- CO_2. Good constraints on the Mio-Pliocene pCO_2 are critical for evaluating the impact of initiating MO on CO_2 sequestration in the deep Atlantic (Capella et al., 2019) and observed sea surface cooling in the Late Miocene (Herbert et al., 2016; **H1.2**). However, the most recent CO_2 compilation demonstrates that the dataset (paleosols, alkenones and marine Boron) is sparse for this period (Foster et al., 2017). We will analyse Boron to generate a global pCO_2 record on the same IMMAGE samples used to reconstruct the inception of Atlantic-Mediterranean exchange, reducing age uncertainty inherent in correlating to pCO_2 records elsewhere in the world. We will also analyse compound-specific $\delta^{13}C$ of plant waxes (Eglinton and Hamilton, 1967). Combined with pollen analysis, this will identify the C_3-C_4 transition locally (e.g. Rommerskirchen et al., 2006) and test the other possible driver for Late Miocene CO_2 reduction, major ecosystem change (Herbert et al., 2016; Dupont et al. 2013; Diester-Haas et al., 2006).
- Age constraints. Tie-points for astronomical tuning will be drawn from magnetostratigraphy, biostratigraphy (forams, nannos, and diatoms) and where available, tephra-chronology. The age model underpins all three objectives and associated hypotheses.
- Modelling studies. Regional physical oceanographic models (Hughes et al., 2015; Megann 2018) configured for Late Miocene Mediterranean-Atlantic exchange will be used to simulate the response of outflow to different Mediterranean water densities, flow rates, sill geometries and Atlantic stratification. This is consistent with best practice as determined by the Gravity Current Entrainment Climate Process Team (Legg et al, 2009). We will adapt the approach used for contemporary and recent time periods to permit cross-validation of model and empirical constraints (Fox-Kemper et al., 2019). Best-estimate paleogeographies will be used in the model, to maximise model-data comparability. The combination of parameters which gives rise to an outflow plume that best matches the characteristics (density, velocity, location, distribution) observed both

upstream (WAB-03A) and downstream (MOM-01A; ALM-01A) of the sill(s), will be determined through iterative regional model simulations. This vastly improves on previous 1-Dimensional experiments (Rogerson et al., 2012b). Optimal parameters for MO will then be implemented in a coarser-resolution global simulation of the Late Miocene to examine the impact of MO on large-scale meridional overturning circulation (Ivanović et al., 2014a; **H1.3**). These simulations will also explore the sensitivity of simulated outflow plumes to the variability of plume parameterization before, during and after the MSC (**H3.1, H3.2, H3.3**). We anticipate using the open source MITgcm and MOM6 code for the regional simulations (Legg et al., 2009) and a range of different models for the global simulations.

5. Drilling and logging strategy and time estimates.

The strategy is designed to recover as complete a record of Atlantic-Mediterranean exchange during the Late Miocene-early Pliocene as possible from three IODP sites and two ICDP sites (Fig. 4). However, locations where the Late Miocene is sufficiently shallowly buried to be accessible to JOIDES Resolution drilling are rare. This limits the number of alternate sites, which are typically some distance from the primary site.

In addition, recent political challenges encountered by scientific drilling activities suggest that it would be prudent to locate at least one possible target for each site outside Spanish jurisdiction. This has been achieved for all IMMAGE's IODP sites. It is not possible however, to use the same approach to shift the ICDP site in the Betic Corridor (BET-01A) out of Spanish territory, because other suitable locations within the corridor are also on the Spanish mainland and potential adjacent offshore locations are both still in Spanish waters and are buried too deeply to be accessible to JOIDES drilling (one of the reasons that amphibious drilling is required for the IMMAGE project). We have therefore scheduled drilling in the Betic Corridor as the second phase of the ICDP project. This gives our Co-Is at the Spanish Geological Survey (IGME) additional time (5-6 years) to obtain the required drilling permits from the Spanish authorities.

We are confident that drilling the BET-01A site will be achieved. However, both SAG and SEP requested we evaluate the impacts of a delay recovering of this record. Previous investigations of Plio-Quaternary MO behaviour (e.g. IODP Expedition 339) had no corridor record equivalent to BET-01A, because the Strait of Gibraltar flow is erosive. Instead, the timing and nature of Atlantic-Mediterranean exchange was constrained by downflow sites

(Esteras et al., 2000: Hernández-Molina et al., 2016). IMMAGE's objectives can be achieved in the same way using the down-flow site, ALM-01A. However, the value of BET-01A is that it permits us to make more exact reconstructions of flow in the Strait during the Miocene than we can currently achieve for the Early Holocene and will help make our physical reconstructions more precise. In summary, the Betic site is not a risk to meeting IMMAGE's scientific objectives, but rather an opportunity to make Miocene reconstructions more accurate and quantitative than is possible for more recent time periods.

Critical to the success of the science is the ability to correlate each site at a precessional scale both with each other and with global climate and paleoceanographic records. All the sediments targeted will record a strong precessional pulse derived from the African monsoon and North Atlantic storm tracks (Marzocchi, 2016). These successions also show characteristic eccentricity modulation that provides astrochronological tie-points in addition to bio- and magneto-stratigraphic age constraints. While a high percentage recovery for the ICDP holes is anticipated, the IODP sites are deep and a complete sedimentary record is therefore improbable. Instead, our strategy is to construct the precessional framework at each site using high resolution logging data (i.e. Formation Image logs implemented with standard GR, PEF, neutron porosity, density, resistivity, and sonic logs). The use of industrial logging data for astronomical tuning has been demonstrated in the Guadalquivir Basin close to the BET-01A site (Ledesma, 2000; Sierro et al., 2000).

Two holes will be drilled at each site. Hole A, will be APC/XCB cored to refusal and monitored for hydrocarbons throughout. The depth at which XCB coring provides diminishing returns with respect to core recovery (~5-700m) determines the depth at which the casing will be set in Hole B. Hole B will be drilled using the re-entry system and case off the unlithified upper part of the hole. RCB coring will then be carried out below the casing, coring and logging to total depth.

For all Atlantic sites the velocity conversion for Plio-Quaternary deposits is based on the vertical seismic velocity (VSV) collected during IODP Expedition 339. We have used "check shot" measurements to relate in-hole depth to travel-time in reflection seismic lines (Expedition 339, 2013). The regional data set from REPSOL, based on existing regional wells and vertical seismic velocity (VSV) has provided the equivalent information for Tortonian-Messinian deposits. In the Alborán Sea for WAB-03A (primary) the interval sonic velocities (m/s) for the different seismic units were calculated by using best-fit functions of Vplog data and *in situ* measurements from the adjacent ODP site 976B. For the two alternate sites, EAB-02A and EAB-03A, the same approach was used with *in situ* measurements from ODP sites 976, 977, 978 and 979.

Estimates of the time required to drill and log each site are summarised in Table 2. The total time required to drill all three IODP sites is 56 days including 5 days port call (contingency).

6. IODP Site Descriptions.

The drilling proposal includes three primary IODP sites and two ICDP targets with alternate sites for each. **All sites were selected because they record a Late Miocene-Pliocene succession that can be used to reconstruct Atlantic-Mediterranean exchange.** We present an interpretation of the seismic lines on which the sites are located and which highlights the stratigraphic interval of interest. Details of the proposed ICDP drilling are in Appendix 3-9.

Table 2. Coring and logging time estimates generated by Kevin Grigar (8th March 2019).

Investigation Miocene Mediterranean-Atlantic Gateway Exchange (P895-ADP)

Operations Plan Summary

Grigar, 08 March 2019

Site No.	Location (Latitude Longitude)	Seafloor Depth (mbrf)	Operations Description	Transit (days)	Drilling Coring (days)	LWD/MWD Log (days)
Marseille			Begin Expedition 5.0	port call days		
			Transit ~663 nmi to WAB-03A @ 10.5	7.6		
WAB-03A	36° 18.7526' N	811	Hole A - APC/HLAPC/XCB to refusal (~750 mbsf) - 4 ea APCT3 measurements - Log with Triple Combo, FMS Sonic & VSP	0.0	4.1	1.4
	4° 34.2728' W		Hole B - Install HRT w/10-3/4" CSG to 650 mbsf - RCB Core to 1700 mbsf - Log with Triple Combo, FMS Sonic & VSP	0.0	10.7	2.1
			Sub-Total Days On-Site: 18.3			
			Transit ~128 nmi to MOM-01A @ 10.5	0.5		
MOM-01A	35° 14.4574' N	566	Hole A - APC/HLAPC/XCB to refusal (~750 mbsf) - 4 ea APCT3 measurements - Log with Triple Combo, FMS Sonic & VSP	0.0	4.0	1.4
	6° 44.8703' W		Hole B - Install HRT w/10-3/4" CSG to 650 mbsf - RCB Core to 1460 mbsf - Log with Triple Combo, FMS Sonic & VSP	0.0	8.5	1.7
			Sub-Total Days On-Site: 15.6			
			Transit ~190 nmi to ALM-01A @ 10.5	0.1		
ALM-01A	37° 25.9020' N	1578	Hole A - APC/HLAPC/XCB to refusal (~750 mbsf) - 4 ea APCT3 measurements - Log with Triple Combo, FMS Sonic & VSP	0.0	5.0	1.5
	9° 34.6020' W		Hole B - RCB Core to 990 mbsf - Log with Triple Combo, FMS Sonic & VSP	0.0	4.4	1.9
			Sub-Total Days On-Site: 12.8			
			Transit ~81 nmi to Lisbon @ 10.5	0.8		
Lisbon			End Expedition	4.2	36.7	10.1

Port Call:	5.0	Total Operating Days:	51.0
Sub-Total On-Site:	46.8	Total Expedition:	56.0

6.1 Alentejo Margin (IODP) Site, offshore Portugal - ALM-01A (Figs. 7 and 8a)

The primary scientific objective of ALM-01A is to recover a distal record of Late Mio-Pliocene MO that captures the evolution of the plume's equilibrium depth and hence tests quantitative constraints on the behavior of dense overflows (**H3.1**, **H3.2**, **H3.3**). This high-resolution record also constrains the strength and attenuation rate of the Atlantic-Mediterranean exchange signal beyond the gateway and permits evaluation of the impact of changing exchange on the

Atlantic water-mass structure (**H1.1, H2.2**). ALM-01A is at the intersection of Lines PDOO-522 and PD00610 (Fig. 7) and has been selected as the primary site because it requires shallower penetration to recover the late Miocene-Pliocene record than, ALM-02A (alternate; Fig. 7).

Site U1391 (Expedition 339; Fig. 7 & 8a), recovered Plio-Quaternary muddy contourites with interbedded sands, hemipelagites and several layers of mass movement deposits (Stow et al., 2013). Similar Messinian seismic facies in ALM-01A suggest that we will recover plume-derived stratified mud and silty contourite sediments overlain by hemipelagites (Fig. 8a). The Tortonian probably comprises a mixture of contourite and gravity-driven deposits with interbedded hemipelagites.

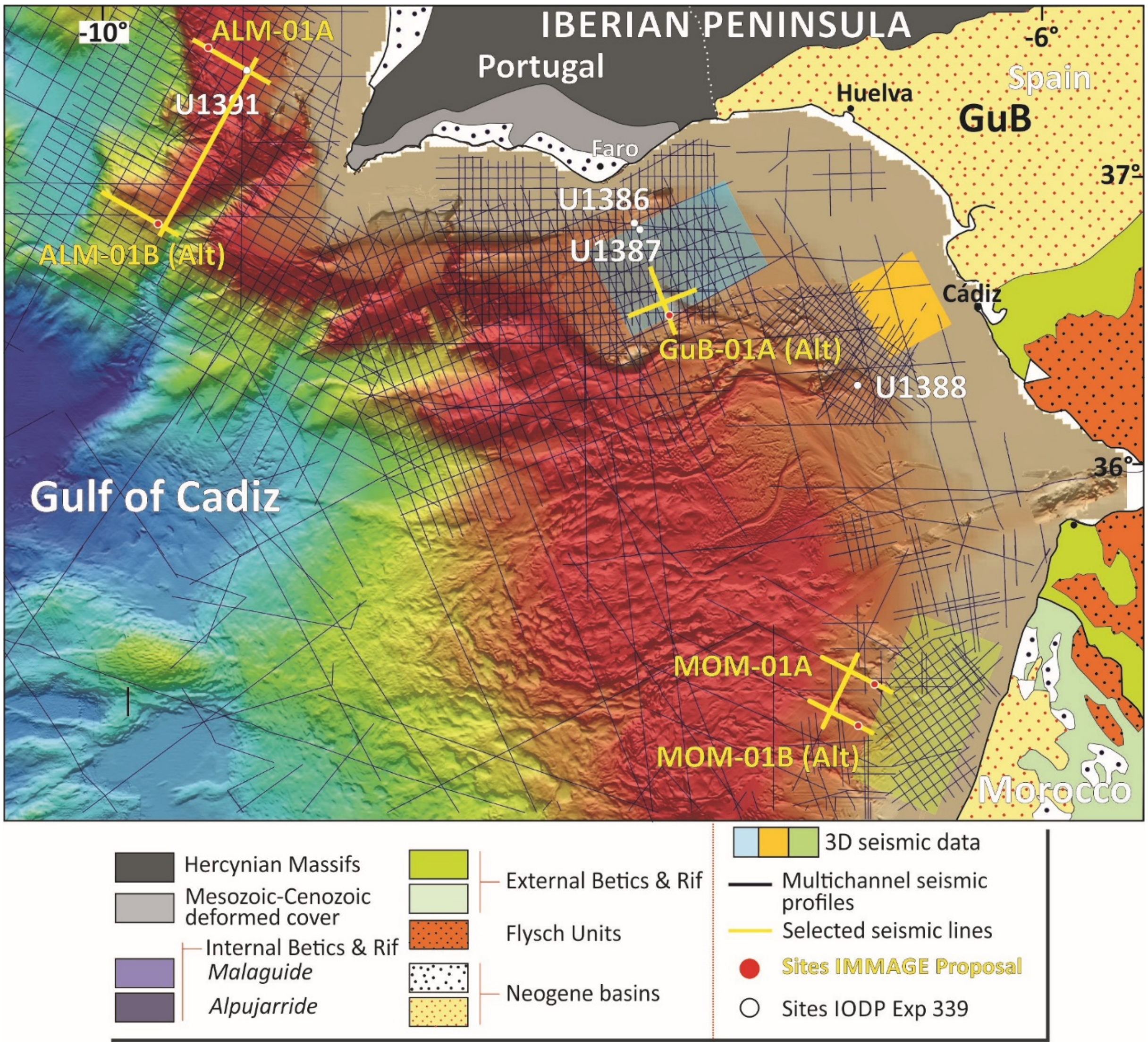


Figure 7. Bathymetry, seismic data and site locations of the two primary IMMAGE IODP holes on the Atlantic margin: ALM-01A on the Alentejo Margin, offshore Portugal and its alternate site ALM-02A; and MOM-01 on the Moroccan Margin and its two alternate sites, MOM-02A and GUB-01A on the Guadalquivir Bank in the Gulf of Cadiz. Adjacent IODP holes from Expedition 339 are also shown in white.

6.2 Morocco Atlantic Margin (IODP) Site, Offshore Morocco – MOM-01A (Fig. 8b)

This site targets a thick Late Miocene-Pliocene succession on the Moroccan continental margin. MOM-01A is located in an intermediate position along a transect linking the source of MO from the Rifian Corridor (RIF-01A) with the distal record of fully mixed Atlantic Mediterranean Water on the Alentejo Margin (ALM-01A). A record from this position provides quantitative constraints on the physical and chemical properties of the initial mixed water-mass and hence constrains the degree of Atlantic entrainment. This site therefore contributes to **H1.2, H1.3, H2.2, H3.1, H3.2, H3.3**. An adjacent alternate site (MOM-02A; Fig. 7) records a slightly thinner Mio-Pliocene succession at shallower depths, providing a good back-up should drilling MOM-01A prove problematic. Another alternate site (GUB-01A) with a thinner, shallower succession, is substantially further from MOM-01A and in Spanish waters.

Age control for MOM-01A and MOM-02A is based on regional data sets for the Late Miocene and Early Pliocene (REPSOL; Instituto Dom Luiz, Portugal) and from IODP Site U1391 for the Late Plio-Quaternary. Anticipated lithologies are Tortonian marls; lower Messinian contouritic sand-clay beds; upper Messinian marls and Plio-Quaternary muddy-fine sands. The age control for GUB-01A is based on the REPSOL's regional data set for the Late Miocene-Early Pliocene and IODP Site U1386 and U1387 for the latest Miocene-Quaternary. Anticipated lithologies are Tortonian marls; lower Messinian contourites; upper Messinian marls and Plio-Quaternary muddy-fine sands.

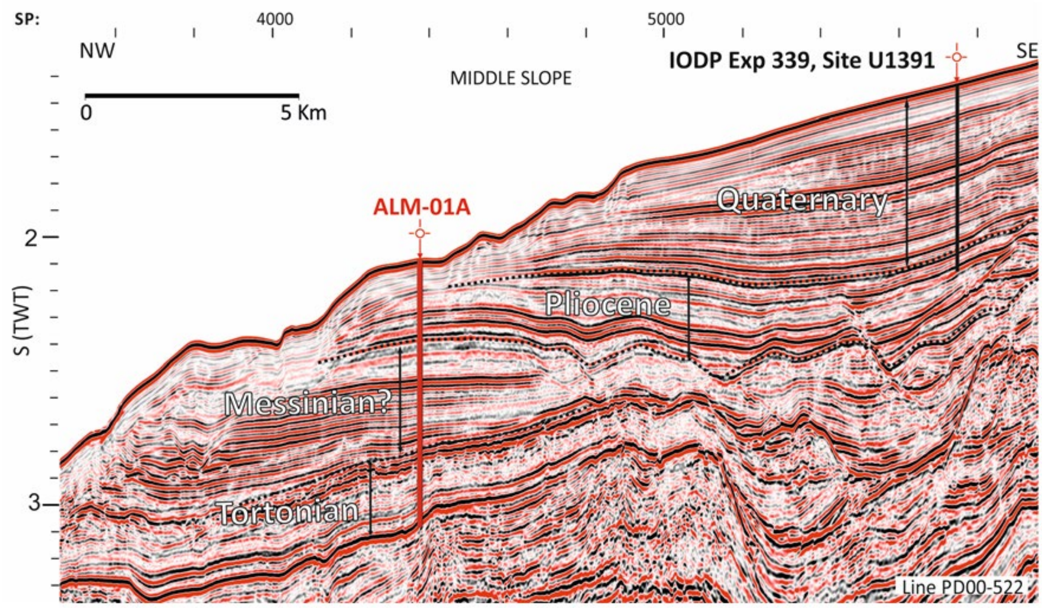
6.3 Alborán Sea (IODP) Sites, Western Mediterranean – WAB-03A (Fig. 9)

The Alborán Sea site is designed to record the changing physical and chemical characteristics of Mediterranean source water throughout the Late Miocene-Pliocene and to evaluate the role of Atlantic exchange in influencing the Mediterranean's evolution (Booth-Rea et al., 2018). Sediments recovered from this location are therefore critical in addressing **H1.1, H1.3, H2.1, H2.2, H3.1, H3.2, H3.3**.

There are four previous DSDP and ODP holes in the Alborán Basin that recovered Miocene sediment: two in the eastern Alborán Basin (ODP-977, -978), and two in the western Alborán Basin (DSDP-121, ODP-976; Fig. 9a). Both the western Alborán sites were drilled in the central part of the basin where a major erosional unconformity has removed most of the Messinian deposits (Ryan et al., 1973). This strongly erosive (up to 860 ms TWTT), regional unconformity (Lofi et al., 2011; 2018), was mainly formed by channelized Atlantic flooding of the

Mediterranean at the end of the MSC (Estrada et al., 2011; Garcia-Castellanos et al., 2009). WAB-03A is located towards the basin margin where there is a substantially thicker Messinian succession and minimal erosion (Fig. 9b; Chalouan et al., 1997; Do Couto et al., 2016).

a)



b)

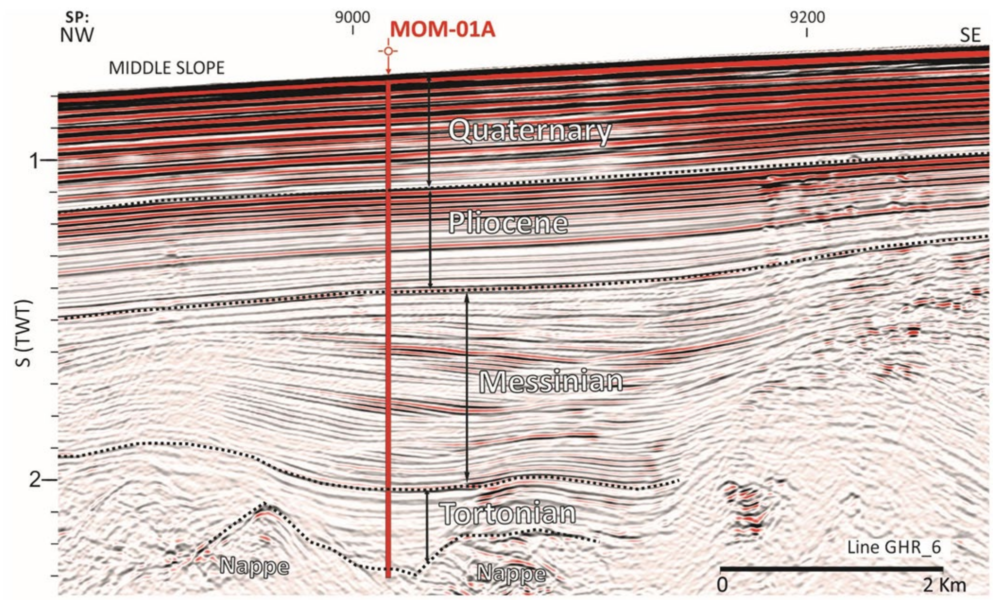


Figure 8.a) Seismic line PDOO-522 on the Alentejo Margin, offshore Portugal showing the proposed drilling site, ALM-01A and the adjacent Exp. 339 site U1391. b). Seismic line GHR-2_GHR10 off the Atlantic coast of Northern Morocco showing the proposed drilling site, MOM-01A. Position of these lines is shown in Fig. 7.

To develop this proposal, a review of the Mio-Pliocene biostratigraphy of all four DSDP and ODP holes in the Alborán Basin was undertaken by Francisco Sierro. The acme of

Sphaeroidinellopsis (unambiguous biostratigraphic marker of the base of the Pliocene; Cita 1973), has been identified in core 61X, ODP-976 which corresponds to the prominent unconformity. From core 63X downwards, the fauna indicate the succession at Site 976 is earliest Messinian and then late Tortonian and middle Miocene (Comas et al., 1996), consistent with the adjacent Andalucia G1 well (Sierro pers. comm.; Fig. 9a). Core 62X, should therefore contain Messinian sediments. However, only 35cm of material was recovered in the core-catcher (Comas et al., 1996) comprising soft nannofossil clay and small, hard rock fragments. These sediments contain rare *Globorototalia margaritae* which is common in Late Miocene Atlantic successions (Sierro et al., 1993), but does not occur in the Mediterranean until the Pliocene (Cita 1973). There are two possible explanations for the presence of *G. margaritae* here: either it derives from the Lower Pliocene and was incorporated in Messinian sediments as a consequence of problematic drilling; or it represents *in situ* late Messinian deposition suggesting on-going exchange between the Atlantic and Alborán Basin with associated high sea-level and strongly contrasting environmental conditions between the Alborán Basin and the Mediterranean during the MSC. WAB-03A sediments will allow us to test this (**H2.1**) as well as recording the environmental evolution of the Alborán Basin during the MSC (**H2.2, H3.1, H3.2, H3.3**).

Thick MSC successions in the Alborán Basin are rare, small patches. Consequently, the two alternate sites, EAB-02A and EAB-03A (Fig. 9a), are some distance from WAB-03A, straddling the Moroccan-Spanish water border to provide political flexibility. Both sites record a relatively continuous Messinian succession (Medaouri et al., 2014) allowing us to test **H2.2, H3.1, H3.2 and H3.3**. In addition, their position within the Alborán volcanic arc zone (Booth-Rea et al., 2018), will provide a different perspective on the role of this feature during the MSC (**H2.1**).

7. Logistical Issues.

Hydrocarbon exploration and production in this area is mainly from deeper stratigraphic levels. However, we have ensured that IMMAGE sites are well away from possible accumulations.

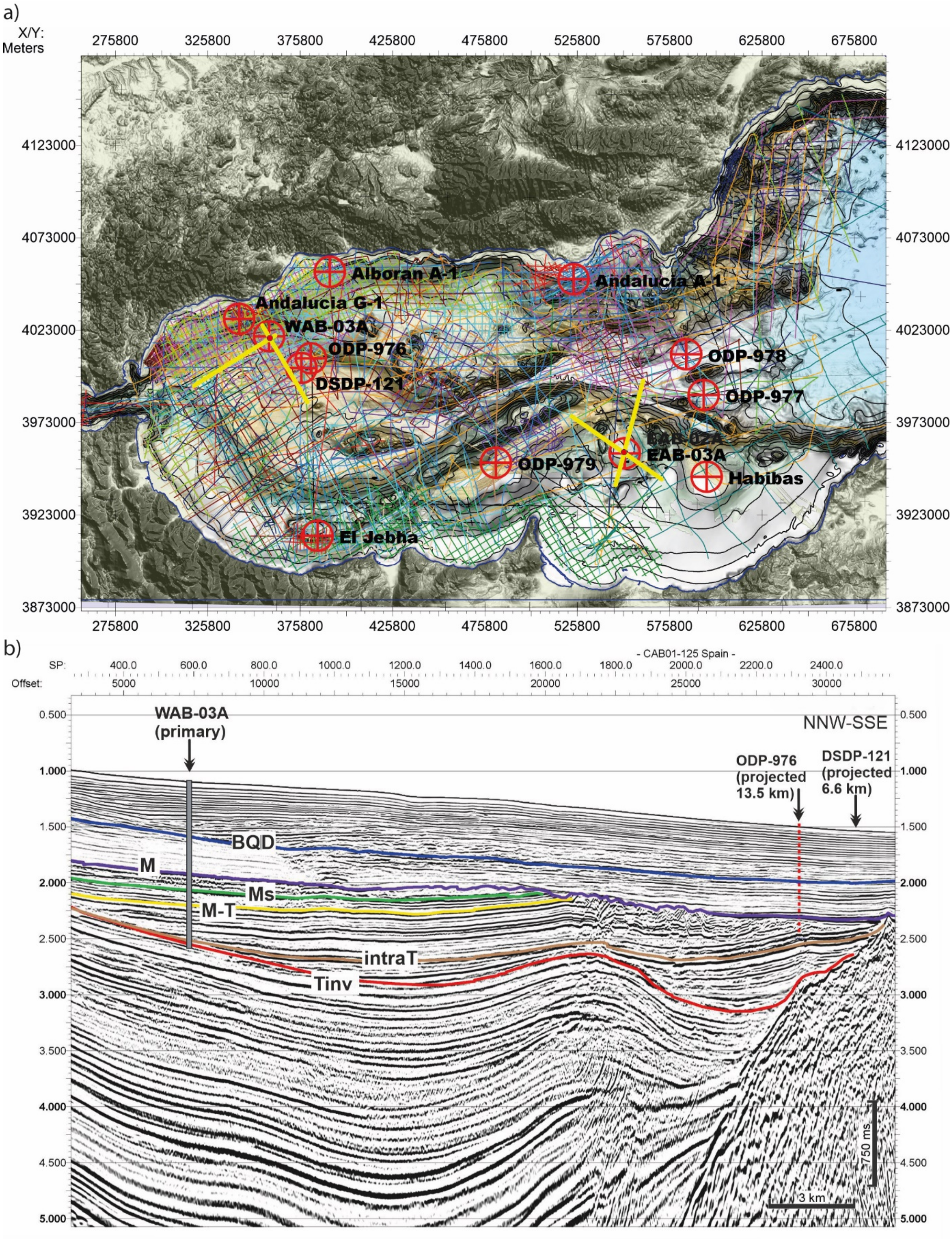


Fig. 9a) Bathymetry, seismic data and site location of existing ODP and DSDP holes that recovered Late Miocene sediment and proposed IODP primary (WAB-03A) and alternate sites (EAB-02A and EAB-03A), b) Seismic line CAB01-125 on the northern margin of the West Alborán Basin showing the proposed drilling site WAB-03A. BDQ marks the base of the Quaternary; M is the Mio-Pliocene boundary; Ms is the base of the Messinian Salinity Crisis; M-T is the Messinian-Tortonian boundary; intraT is a prominent intra-Tortonian surface; Tinv is the Tortonian inversion structure.

8. Relationships with other international geoscience programs and/or initiatives.

The IMMAGE initiative provides a mid-latitude link between drilling targets in high- and low-latitude areas and is closely related to recent (IODP Leg 339, Gulf of Cadiz), current (IODP Proposal 771 “Iberian Margin Paleoclimate”) and several potential IODP proposals that target different elements of the North African monsoon-Mediterranean-North Atlantic Circulation System e.g. 857C Eastern Mediterranean; 857B Balearic Promontory, ICDP CHADRILL, Lake Chad (Fig. 1A). IMMAGE is also part of the EU Cost Action, MEDSALT and ETN, SALTGIANT.

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IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	To recover a thick, shallow Late Miocene succession which contains distal Mediterranean overflow deposits. The main contribution of this site is that it captures the evolution of the equilibrium depth of the plume and hence tests quantitative constraints on the behavior of dense overflows (Objective 3). In addition, the high resolution (precessional) record we will recover at this site is a key component of the complete record of Mediterranean-Atlantic exchange during the Late Miocene-Pliocene (Objectives 1 and 2).
List Previous Drilling in Area	IODP site U1391

Section B: General Site Information

Site Name:	ALM-01A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 37.4317
Longitude:	Deg: -9.5767
Coordinate System:	WGS 84
Priority of Site:	Primary: ✓ Alternate: ☐

Area or Location:	Alentejo Margin, Iberian Margin
Jurisdiction:	Portugal
Distance to Land: (km)	50
Water Depth (m):	1567

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	990	0
	Total Sediment Thickness (m) 990	
		Total Penetration (m): 990
General Lithologies:	mud, muddy sands, marls	Sedimentary

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 9.4 | Logging: 3.4 | Total On-site: 12.8

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

3-4 temperature measurements to establish a geothermal gradient

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	April-September
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:

Generated: 2019-09-27T21:30:35+00:00

IODP Site Forms

Form 2 - Site Survey Detail

Proposal #: 895 - Full 3	Site #: ALM-01A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: PD00522_ALM-1A_W PORTUGAL Position: SHOT POINT 4340
2b Deep penetration seismic reflection (crossing)	yes	Line: PD00610_ALM-1A_W PORTUGAL
3 Seismic Velocity	yes	Velocity conversion information provided: velocity_conversion_IMMAGE_Atlantic.docx
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Regional_bathymetry_Atlantic
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	Nav_PD00-610.dat Nav_PD00-522.dat
17 Other		

Proposal #: 895 - Full 3	Site #: ALM-01A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Hole A: APC to refusal; XCB to refusal and define casing point; log hole A; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No significant hydrocarbon occurrences in U1391 at this stratigraphic depth
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	Hydrocarbon occurrences are at deeper stratigraphic levels
4. Indications of gas hydrates at this location	No
5. Are there reasons to expect hydrocarbon accumulations at this site?	Hydrocarbon accumulations are at deeper stratigraphic levels
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	cable locations need checking
9. Summary: What do you consider the major risks in drilling at this site?	None

Proposal #: 895 - Full 3	Site #: ALM-01A	Date Form Submitted: 2019-09-27 14:26:27

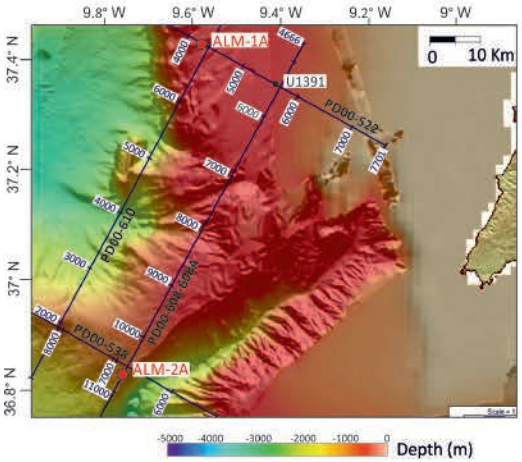
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 258	Plio-Quaternary	0-5.33	1.775	Mud, silt and silty sand	Hemipelagic and muddy contourites	48	
258 - 410	Messinian transparent unit	5.33-5.6	1.9	Nannofossil marl	Hemipelagic	562	
410 - 704	Messinian contourites	5.6-7.2	2.1	Nannofossil marls and silty sands	Hemipelagic and silty contourites	183	
704 - 990	Tortonian	7.2-11.6	2.2	Nannofossil marls and silty sands	Hemipelagic, contourites and turbidites	65	

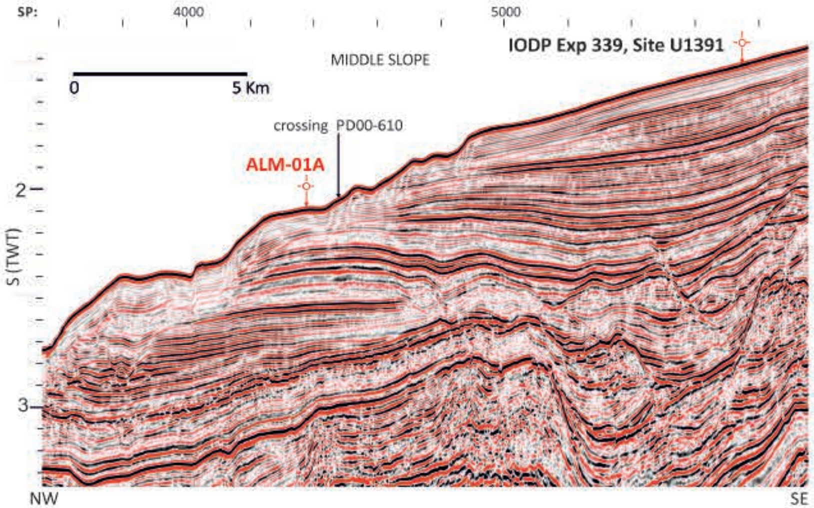
Site Summary Form 6

IODP proposal 895-Full

Site ALM-01A

Coordinates: 37.4317; -9.5767
Water depth: 1567 m
Penetration: 990 m





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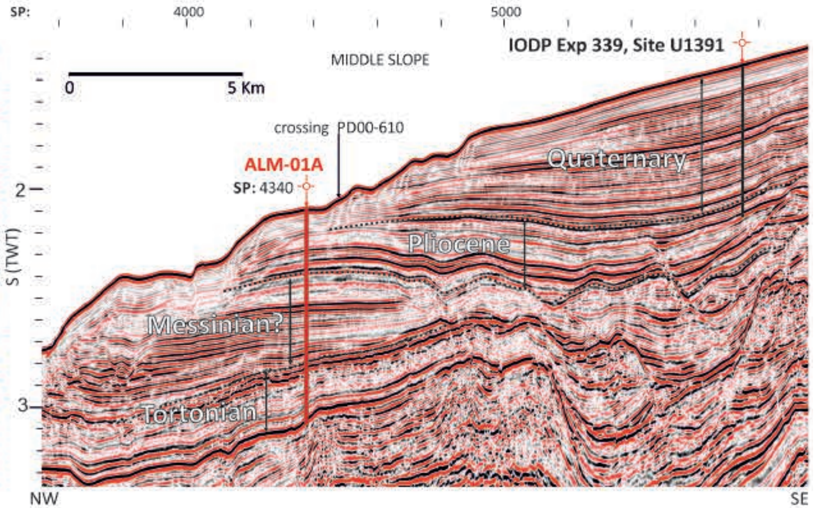

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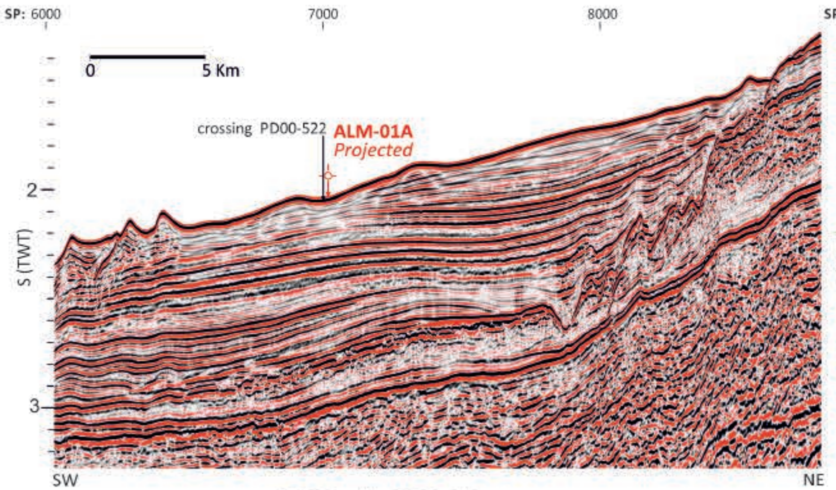
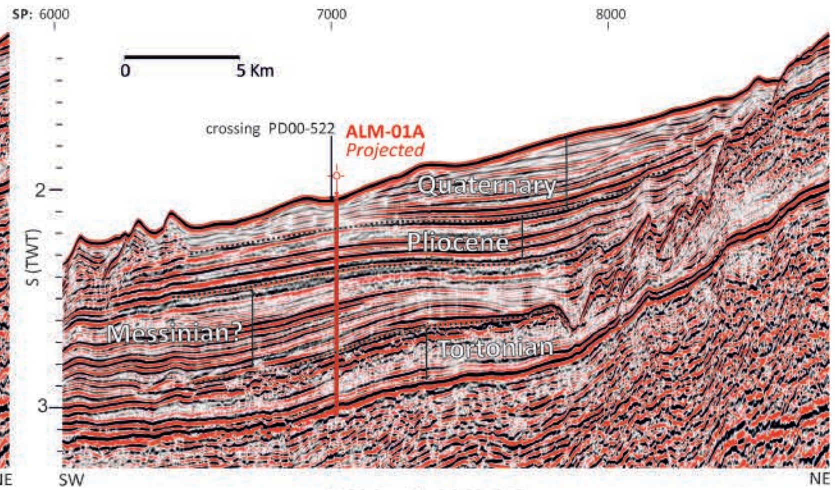


MCS Profile PD00-610



MCS Profile PD00-610

Remarks:

.- Seismic images are time migrated stacks
.- Seismic data in SP order

Data files in SSDB:

.- PD00522_ALM-1A_WPORTUGAL
(Time migrated stacks, TMS)
.- *Crossing profile*:
PD00610_ALM-1A_WPORTUGAL (TMS)

Additional data available:

.- multibeam, wells, velocity information

IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	To recover a thick, shallow Late Miocene succession which contains distal Mediterranean overflow deposits. The main contribution of this site is that it captures the evolution of the equilibrium depth of the plume and hence tests quantitative constraints on the behavior of dense overflows (Objective 3). In addition, the high resolution (precessional) record we will recover at this site is a key component of the complete record of Mediterranean-Atlantic exchange during the Late Miocene-Pliocene (Objectives 1 and 2).
List Previous Drilling in Area	IODP site U1391

Section B: General Site Information

Site Name:	ALM-02A	Area or Location:	Alentejo Margin, Iberian Margin
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.8359	Jurisdiction:	Portugal
Longitude:	Deg: -9.7481	Distance to Land: (km)	70
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	2265

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1630	10
	Total Sediment Thickness (m): 1640	
		Total Penetration (m): 1640
General Lithologies:	mud, muddy sands, marls	sedimentary

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 18.5 | Logging: 3.6 | Total On-site: 22.1

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

3-4 temperature measurements to establish a geothermal gradient

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: April - September

Other:

Proposal #: 895 - Full 3	Site #: ALM-02A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: PD00608-608A_ALM-1B_W PORTUGAL Position: SP 10685
2b Deep penetration seismic reflection (crossing)		Line: PD00538_ALM-2A_WPORTUGAL
3 Seismic Velocity	yes	Velocity conversion information provided: velocity_conversion_IMMAGE_Atlantic.docx
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Region_bathymetry_Atlantic
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores		
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	yes	Nav_PD00538_ALM-02A.dat Nav_PD00608_608A_ALM-02A.dat
17 Other	no	

Proposal #: 895 - Full 3	Site #: ALM-02A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Hole A: APC to refusal; XCB to refusal and define casing point; log hole A; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	No significant hydrocarbon occurrences in U1391 at this stratigraphic depth
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	Hydrocarbon occurrences are at deeper stratigraphic levels
4. Indications of gas hydrates at this location	No
5. Are there reasons to expect hydrocarbon accumulations at this site?	Hydrocarbon accumulations are at deeper stratigraphic levels
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	cable locations need checking
9. Summary: What do you consider the major risks in drilling at this site?	None

Proposal #: 895 - Full 3	Site #: ALM-02A	Date Form Submitted: 2019-09-27 14:26:27

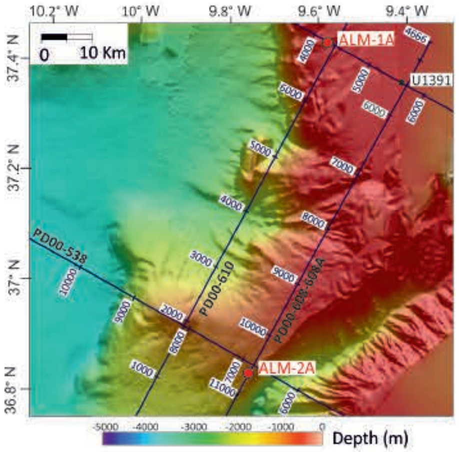
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 693	Plio-Quaternary	0-5.33	1.775	Mud, silt and silty sand	Hemipelagic and muddy contourites	130	
693 - 874	Messinian transparent unit	5.33-5.6	1.9	Nannofossil marl	Hemipelagic	670	
874 - 1209	Messinian contourites	5.6-7.2	2.1	Nannofossil marls and silty sands	Hemipelagic and silty contourites	334	
1209 - 1629	Tortonian	7.2-11.6	2.2	Nannofossil marls and silty sands	Hemipelagic, contourites and turbidites	50	

Site Summary Form 6

IODP proposal 895-Full

Site ALM-02A

Coordinates: 36.8358; -9.7480
Water depth: 2265 m
Penetration: 1629 m



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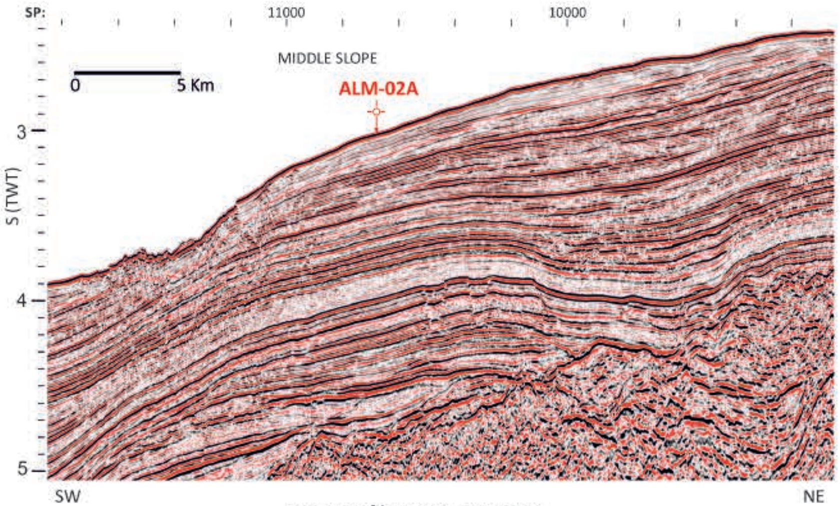
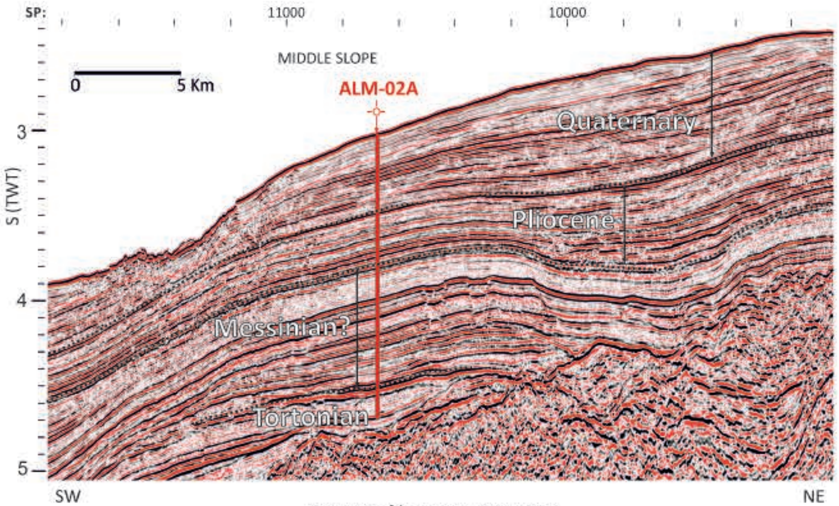
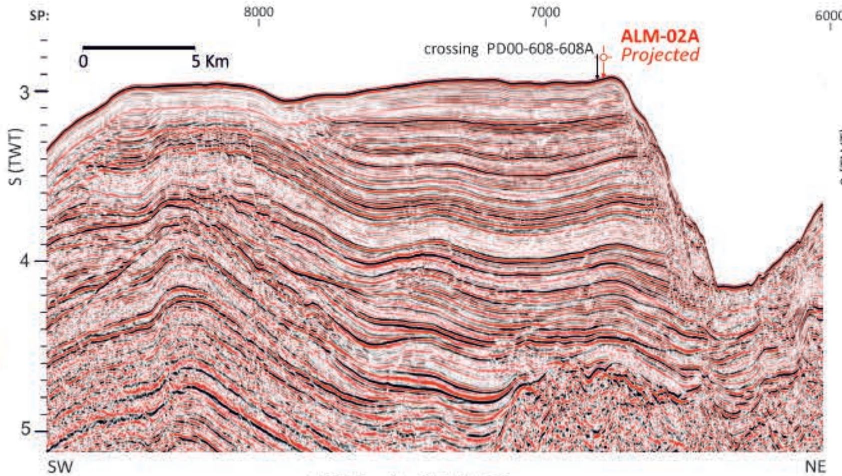


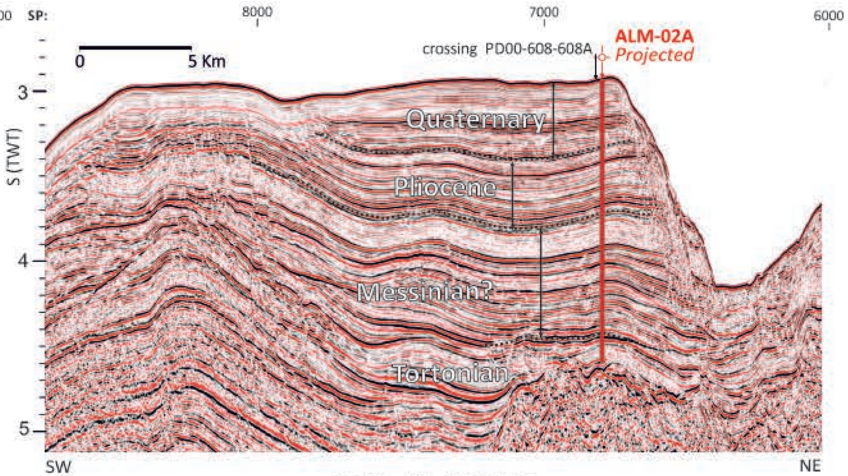
MCS Profile PD00-608-608A



MCS Profile PD00-608-608A



MCS Profile PD00-538



MCS Profile PD00-538

Remarks:

.- Seismic images are time migrated stacks
.- Seismic data in SP order

Data files in SSDB:

.- PD00608_608A_ALM-2A_WPORTUGAL
(Time migrated stacks, TMS)
.- *Crossing profile*:
PD00538_ALM-2A_WPORTUGAL (TMS)

Additional data available:

.- multibeam, wells, velocity information

IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	This site targets a complete late Miocene succession in the pathway of Mediterranean overflow linking the onshore record at RIF-01A with the distal site ALM-01A. The aim is to obtain a high-resolution (precessional) record of Miocene Mediterranean overflow. This record provides critical information for all three objectives.
List Previous Drilling in Area	DSDP 370, DSDP 544-547

Section B: General Site Information

Site Name:	MOM-01A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 35.240956
Longitude:	Deg: -6.747839
Coordinate System:	WGS 84
Priority of Site:	Primary: ✓ Alternate: ☐

Area or Location:	Atlantic Margin of Morocco
Jurisdiction:	Morocco
Distance to Land: (km)	52
Water Depth (m):	555

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1460	10
	Total Sediment Thickness (m): 1449	
		Total Penetration (m): 1470
General Lithologies:	Muds, silts and silty sands	Sedimentary

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing.

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: PEF, Neutron and Dipmeter

Estimated Days:

Drilling/Coring:	Logging:	Total On-site:
12.5	3.1	15.6

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

3-4 temperature measurements to establish a geothermal gradient

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: April-September

Other:

Generated: 2019-09-27T21:30:35+00:00

Proposal #: 895 - Full 3	Site #: MOM-01A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: GHR_6_MOM1A_MOROCCO Position: SP9015
2b Deep penetration seismic reflection (crossing)	yes	Line: GM-15_MOROCCO
3 Seismic Velocity	yes	Velocity conversion information provided: velocity_conversion_IMMAGE_Atlantic.docx
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Regional_bathymetry_Atlantic
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity		
16 Navigation	yes	Nav_GM-15_MOROCCO Nav_GHR_6_MOM1A_MOROCCO
17 Other	no	

Proposal #: 895 - Full 3	Site #: MOM-01A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Hole A: APC to refusal; XCB to refusal and define casing point; log hole A if casing point is below Mio-Pliocene boundary; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	Mention of low hydrocarbon concentrations mainly in deeper sediments
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	At deeper stratigraphic levels
4. Indications of gas hydrates at this location	No
5. Are there reasons to expect hydrocarbon accumulations at this site?	May be some at deeper stratigraphic levels
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	cable locations need checking
9. Summary: What do you consider the major risks in drilling at this site?	None

Proposal #: 895 - Full 3	Site #: MOM-01A	Date Form Submitted: 2019-09-27 14:26:27

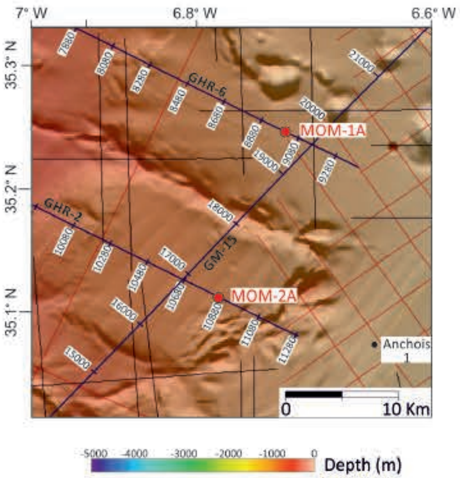
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 576	Plio-Quaternary	0-5.33	1.775	muds and silty sands	Hemipelagic and muddy contourites	108	
576 - 1174	Messinian	5.33-7.2	1.900	muds, silts and silty sands	Hemipelagic and silty contourites	319	
1174 - 1449	Tortonian	7.2-11.6	2.2	marls and sands	hemipelagic, turbidites and contourites	62.5	

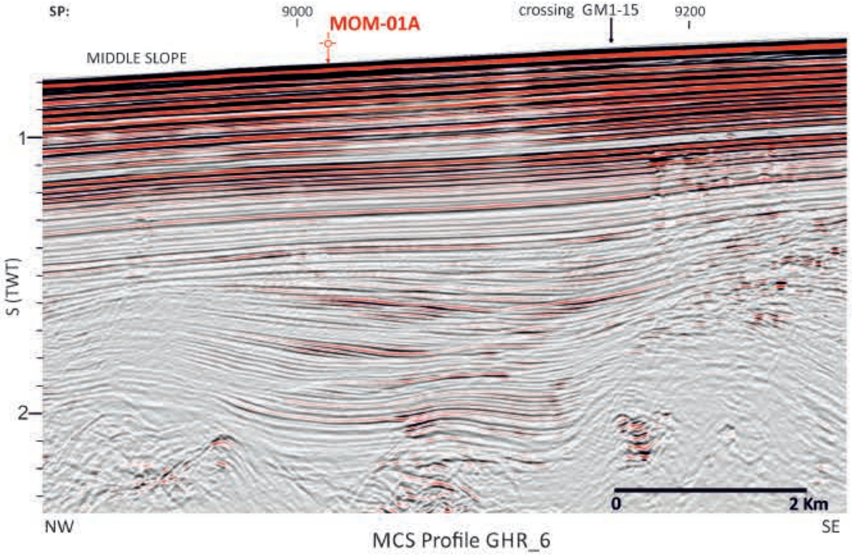
Site Summary Form 6

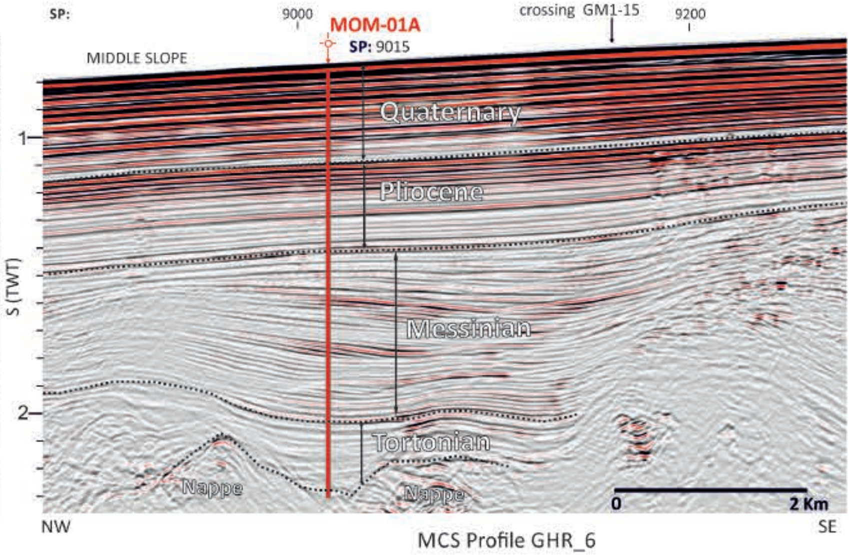
IODP proposal 895-Full

Site MOM-01A

Coordinates: 35.2409; -6.7478
Water depth: 555 m
Penetration: 1500 m



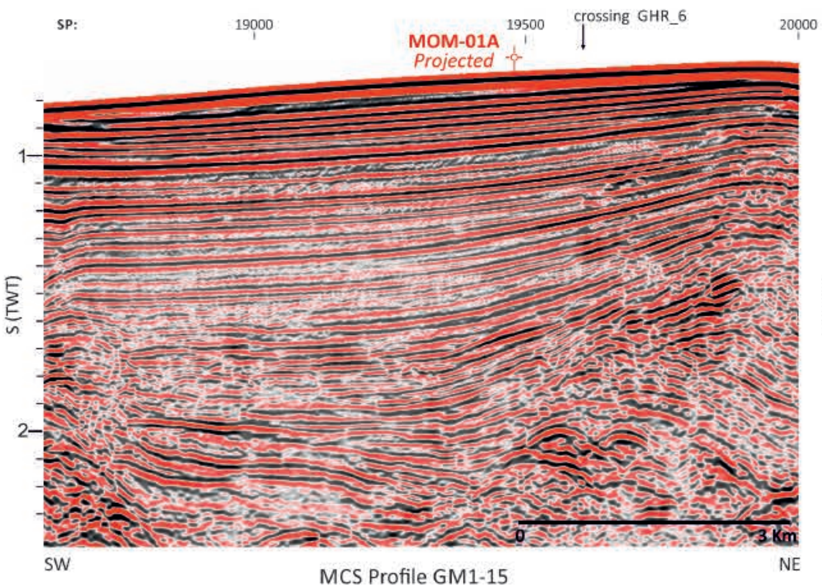


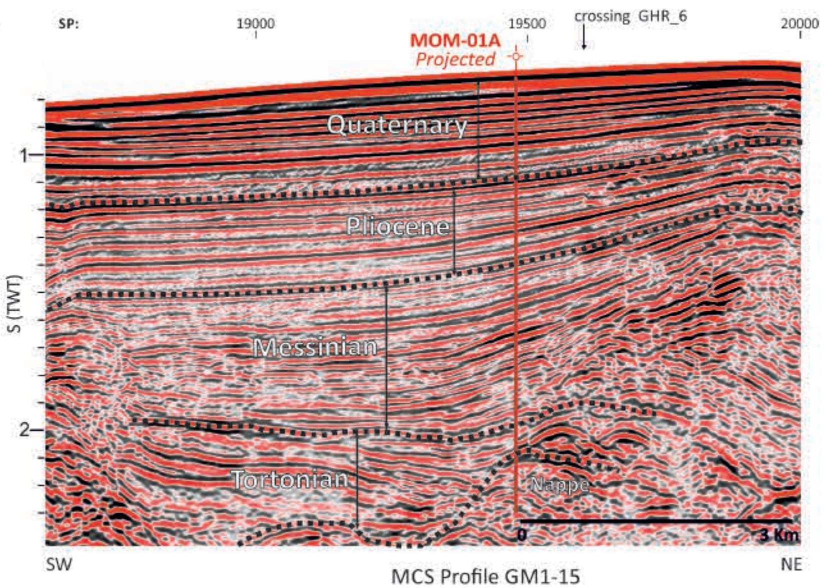


Remarks:
.- Seismic images are time migrated stacks
.- Seismic data in SP order

Data files in SSDB:
.- GHR_6_MOM1A_MOROCCO (Time migrated stacks, TMS)
.- *Crossing profile*: GM_15_MOM-01A_MOROCCO (TMS)

Additional data available:
.- multibeam, wells, velocity information





IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	This site targets a complete late Miocene succession in the pathway of Mediterranean overflow linking the onshore record at RIF-01A with the distal site ALM-01A. The aim is to obtain a high-resolution (precessional) record of Miocene Mediterranean overflow. This record provides critical information for all three objectives.
List Previous Drilling in Area	DSDP 370, DSDP 544-547

Section B: General Site Information

Site Name:	MOM-02A	Area or Location:	Eastern Central Atlantic
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 35.107278	Jurisdiction:	Morocco
Longitude:	Deg: -6.818264	Distance to Land: (km)	54
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	712

Generated: 2019-09-27T21:30:35+00:00

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	997	10
	Total Sediment Thickness (m): 1100	
		Total Penetration (m): 1007
General Lithologies:	mud and silty sands and sands	sedimentary

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 8.8 | Logging: 3.3 | Total On-site: 12.1

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

3-4 temperature measurements to establish a geothermal gradient

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: April-September

Other:

Proposal #: 895 - Full 3	Site #: MOM-02A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: GHR_2_MOM2A_MOROCCO Position: SP10868
2b Deep penetration seismic reflection (crossing)	yes	Line: GM_15_MOROCCO
3 Seismic Velocity	yes	Velocity conversion information provided: velocity_conversion_IMMAGE_Atlantic.docx
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Regional_bathymetry_Atlantic
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation		Nav_GM-15_MOROCCO.dat GHR-2_Unprojected_Lat_Long.dat
17 Other	no	

Proposal #: 895 - Full 3	Site #: MOM-02A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	XCB to refusal and define casing point; log hole A if casing point is below Mio-Pliocene boundary; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	Mention of low hydrocarbon concentrations mainly in deeper sediments
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	At stratigraphically deeper levels
4. Indications of gas hydrates at this location	No
5. Are there reasons to expect hydrocarbon accumulations at this site?	At stratigraphically deeper levels
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	cable locations need checking
9. Summary: What do you consider the major risks in drilling at this site?	None

Proposal #: 895 - Full 3	Site #: MOM-02A	Date Form Submitted: 2019-09-27 14:26:27

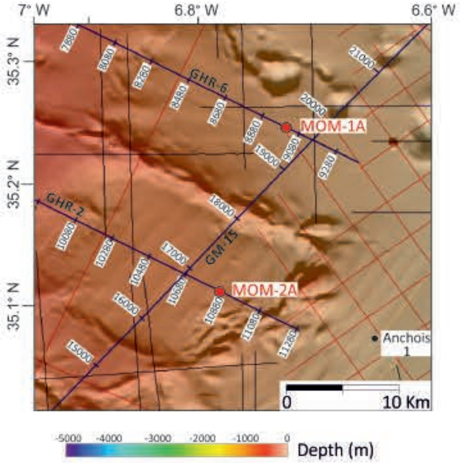
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 266	Plio-Quaternary	0-5.33	1.775	muds, silts and silty sands	Hemipeligic and contourites	49	
266 - 693	Messinian	5.33-7.2	1.9	marls and sands	Hemipelagic and contourites	228	
693 - 997	Tortonian	7.2-11.6	2.1	muds and sands	Hemipelagic, contourites and turbidites	69	

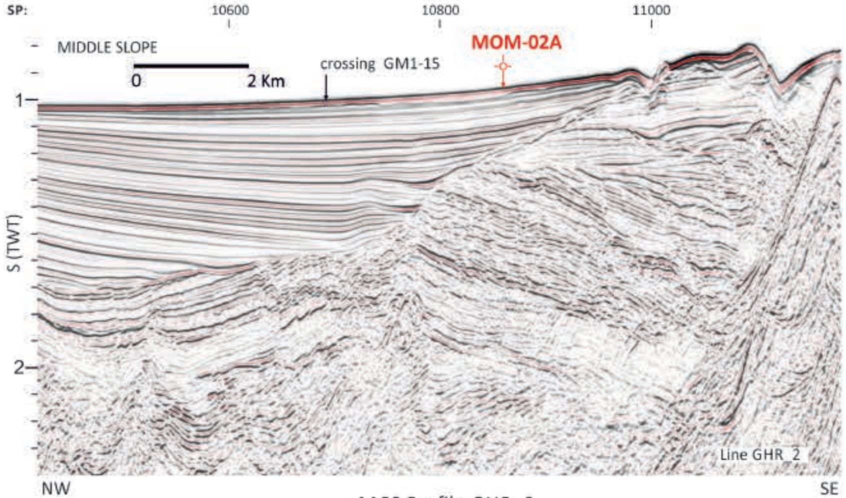
Site Summary Form 6

IODP proposal 895-Full

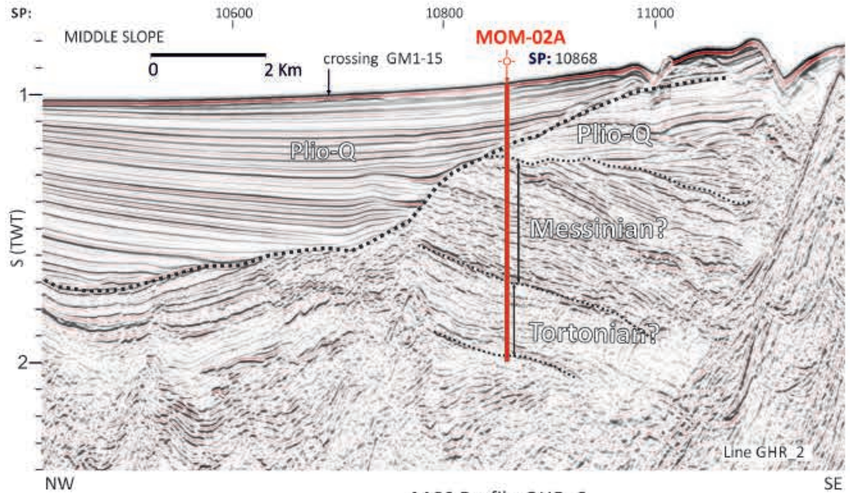
Site MOM-02A

Coordinates: 35.1075; -6.8181
Water depth: 712m
Penetration: 997 m

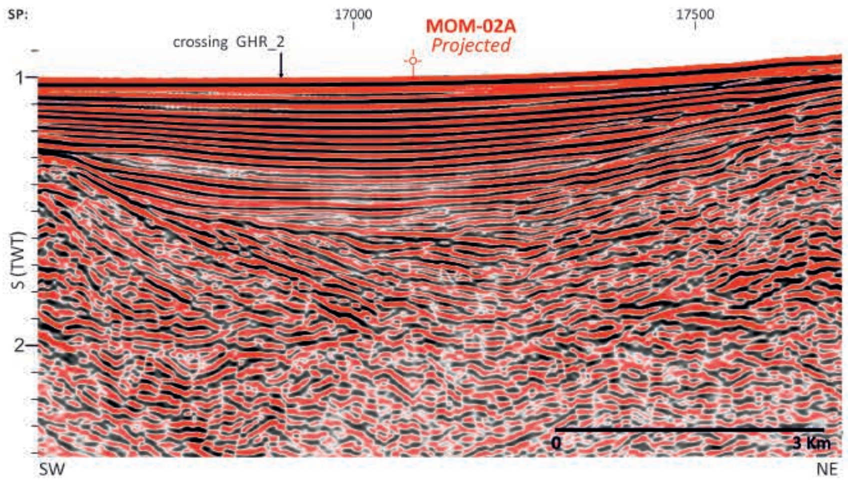




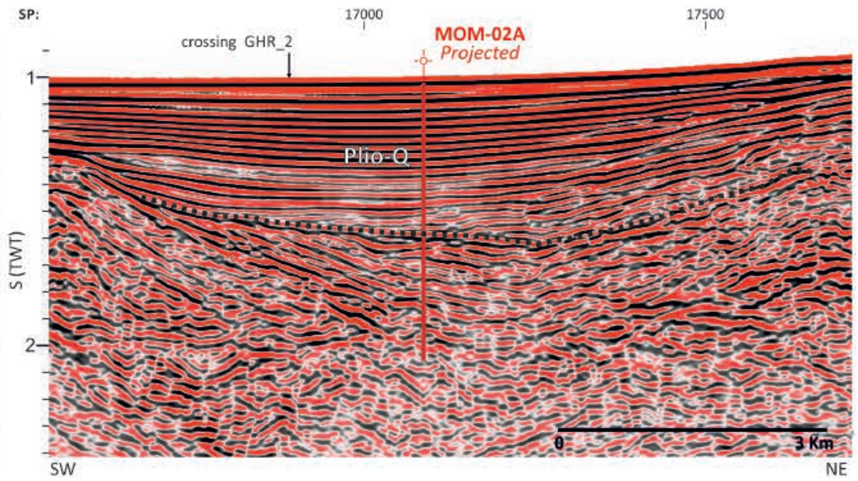
MCS Profile GHR_2



MCS Profile GHR_2



MCS Profile GM1-15



MCS Profile GM1-15

Remarks:

.- Seismic images are time migrated stacks
.- Seismic data in SP order

Data files in SSDB:

.- GHR_2_MOM2A_MOROCCO
(Time migrated stacks, TMS)
.- *Crossing profile*:
GM_15_MOM2A_MOROCCO (TMS)

Additional data available:

.- multibeam, wells, velocity information

IODP Site Forms

Form 1 – General Site Information

895 - Full	3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	This site targets a complete late Miocene succession in the pathway of Mediterranean overflow. The aim is to obtain a high-resolution (precessional) record of Miocene Mediterranean overflow at an intermediate site between the onshore records (RIF-01A and BET-01A) and the distal record (ALM-01A). This record makes a critical contribution to all three objectives
List Previous Drilling in Area	IODP U1386, U1387, U1388, U1389, U1390,

Section B: General Site Information

Site Name:	GUB-01A	Area or Location:	Algarve Basin, Gulf of Cadiz
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.5256	Jurisdiction:	Spain
Longitude:	Deg: -7.6059	Distance to Land: (km)	120
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	637

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	911	10
	Total Sediment Thickness (m): 911	
		Total Penetration (m): 921
General Lithologies:	muds, muddy sands, marls, sands, turbidites	Sedimentary

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 7.5 | Logging: 3.1 | Total On-site: 10.6

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

3-4 temperature measurements to establish a geothermal gradient

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: April - September

Other:

Generated: 2019-09-27T21:30:35+00:00

Proposal #: 895 - Full 3	Site #: GUB-01A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: PD0030_GUB-1A_GULF CADIZ Position: SP343.3 N.B. this is the name of the file that has been uploaded, but in fact it should be PD0830_GUB-1A_GULFCADIZ.sgy and this would then mirror what is on the site form and the navigation data
2b Deep penetration seismic reflection (crossing)	yes	Line: PD00709_GUB-1A_GULFCADIZ.sgy
3 Seismic Velocity	yes	Velocity conversion information provided: velocity_conversion_IMMAGE_Atlantic.docx
4 Seismic Grid	no	
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	no	
7 Swath bathymetry	yes	Region_bathymetry_Atlantic
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity		
16 Navigation	yes	Nav_PD00-709.dat PD-830_Unprojected_Lat_Long.dat
17 Other	no	

Proposal #: 895 - Full 3	Site #: GUB-01A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	XCB to refusal and define casing point; log hole A if casing point is below Mio-Pliocene boundary; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	At deeper stratigraphic levels
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	At deeper stratigraphic levels
4. Indications of gas hydrates at this location	No
5. Are there reasons to expect hydrocarbon accumulations at this site?	At deeper stratigraphic levels
6. What "special" precautions will be taken during drilling?	None
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	cable locations need checking
9. Summary: What do you consider the major risks in drilling at this site?	None

Proposal #: 895 - Full 3	Site #: GUB-01A	Date Form Submitted: 2019-09-27 14:26:27

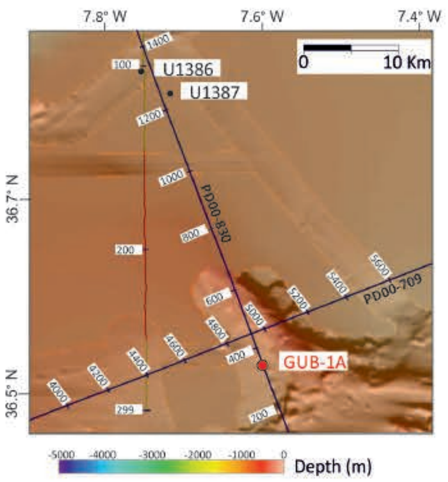
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 320	Plio-Quaternary	0-5.33	1.775	muds and silty sands	Hemipelagic and contourite	60	
320 - 444	Messinian transparent unit	5.33-5.6	1.9	Nannofossil marl	Hemipelagic	459	
444 - 549	Lower Messinian	5.6-7.2	2.1	sands, silty sands, muds	Hemipelagic, contourites and turbidites	65	
549 - 901	Tortonian	7.2-11.6	2.2	sands, silty sands, muds	Hemipelagic, contourites and turbidites	80	

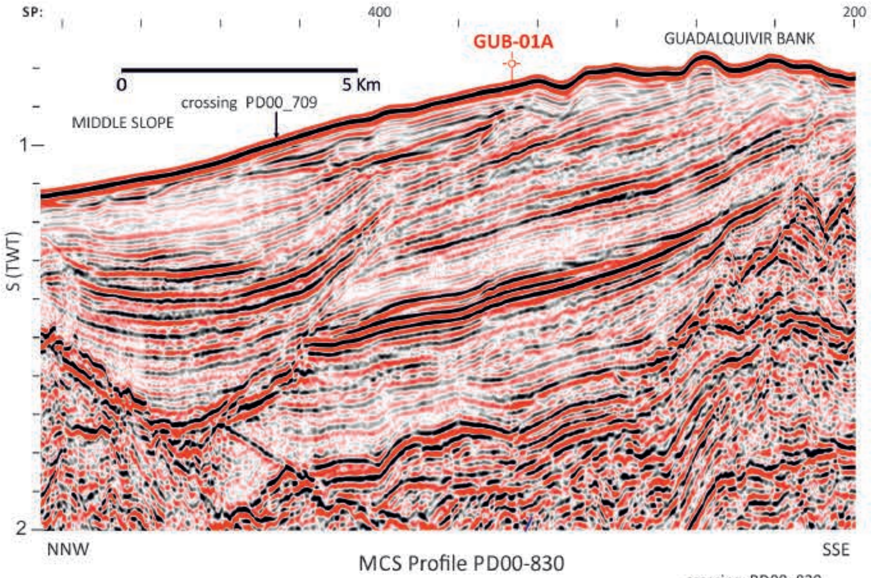
Site Summary Form 6

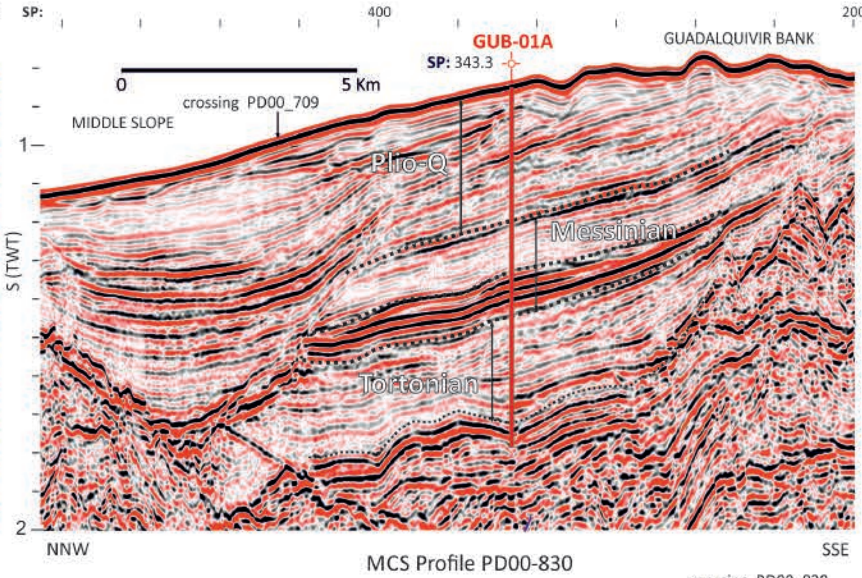
IODP proposal 895-Full

Site GUB-01A

Coordinates: 36.5256; -7.6059
Water depth: 637 m
Penetration: 901 m

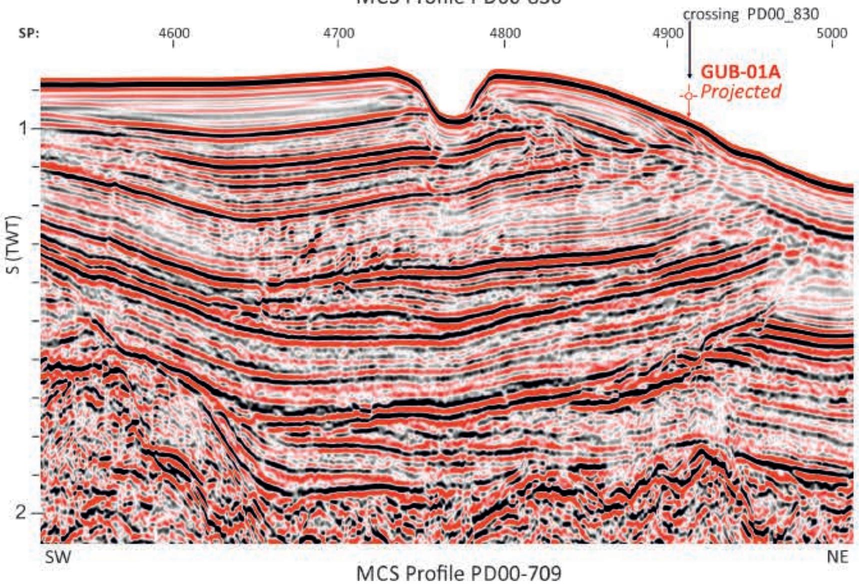


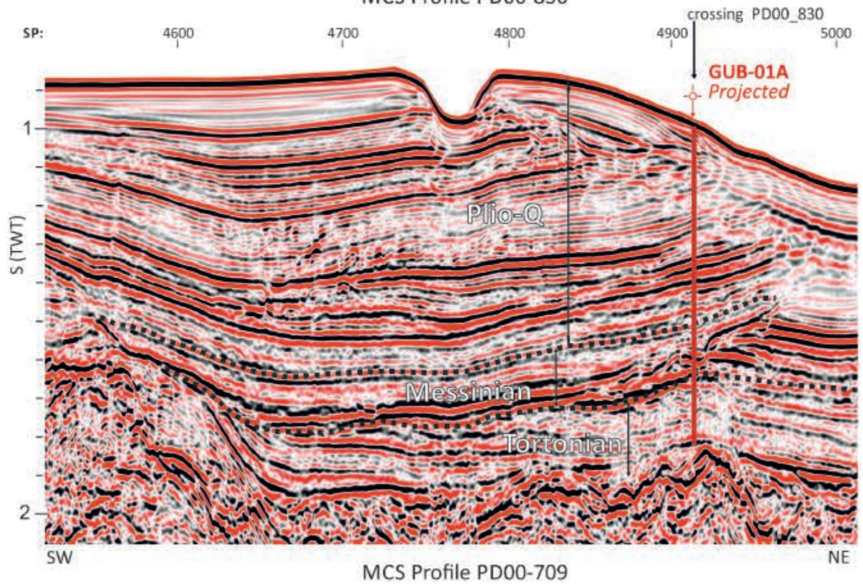




Remarks:

.- Seismic images are time migrated stacks
.- Seismic data in SP order





Data files in SSDB:

.- PD00830_GUB-1A_GULFCADIZ (Time migrated stacks, TMS)
.- *Crossing profile*: PD00709_GUB-1A_GULFCADIZ (TMS)

Additional data available:

.- multibeam, wells, velocity information

IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	This site targets one of the few thick late Messinian sedimentary successions in the Alboran Basin. The record recovered from this location will provide key constraints on the chemistry and physical properties of Mediterranean overflow during the Late Miocene. This is critical for all three objectives.
List Previous Drilling in Area	DSDP121, ODP 976

Section B: General Site Information

Site Name:	WAB-03A	Area or Location:	Western Alboran Basin
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 36.312544	Jurisdiction:	Spain
Longitude:	Deg: -4.571213	Distance to Land: (km)	22
Coordinate System:	WGS 84		
Priority of Site:	Primary: ✓ Alternate: ☐	Water Depth (m):	800

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1700	0
	Total Sediment Thickness (m) 1700	
		Total Penetration (m): 1700
General Lithologies:	Conglomerates, sandstones, marls, shales, volcanoclastics, clays, minor anhydrite/gypsum	

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 9.4 | Logging: 3.4 | Total On-site: 12.8

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

3-4 temperature measurements to establish a geothermal gradient

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: April - September

Other:

Generated: 2019-09-27T21:30:36+00:00

Proposal #: 895 - Full 3	Site #: WAB-03A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: CAB01-125 Position: SP: 590 High-resolution multichannel
2b Deep penetration seismic reflection (crossing)	yes	Line: CAB01-106 Position: 472 High-resolution multichannel; 1.2 km far
3 Seismic Velocity	no	
4 Seismic Grid	yes	1 to 2 km spaced grid of multi-channel seismics
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Parametric profile; 200 m far from site
7 Swath bathymetry	yes	50x50m
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	no	
17 Other	no	

Proposal #: 895 - Full 3	Site #: WAB-03A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Hole A: APC to refusal; XCB to refusal and define casing point; log hole A; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	For Site 976, located in the Western Alboran Basin, the data quality of compressional-wave velocities was degraded in the sediment cores because of gas expansion (Comas et al., 1996).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	Seismic research and exploratory drilling have been activities in the Alboran Sea for more than 30 years. During the 1980s three exploration wells were drilled. None of these surveys found evidence of a significant presence of oil in the basin. In 2005 the project Siroco was launched by the Spanish oil company Repsol, focusing on the search for natural gas. The project was abandoned in 2015 and exploratory drilling operations weren't carried out. Kuo et al. (2002), Mountfield et al. (2002), and Weinzapfel et al. (2003) recently reassessed and specified the hydrocarbon potential ofthe Alboran Sea arguing in favor of a Miocene petroleum system in this basin.
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?	Standard precautions
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	Presence of organic-rich layers in the Plio-Quaternary deposits.Presence of close fault, landslides and turbidites in the sedimentary register
9. Summary: What do you consider the major risks in drilling at this site?	Presence of organic-rich layers in the Plio-Quaternary deposits.Presence of close fault, landslides and turbidites in the sedimentary register

Proposal #: 895 - Full 3	Site #: WAB-03A	Date Form Submitted: 2019-09-27 14:26:27

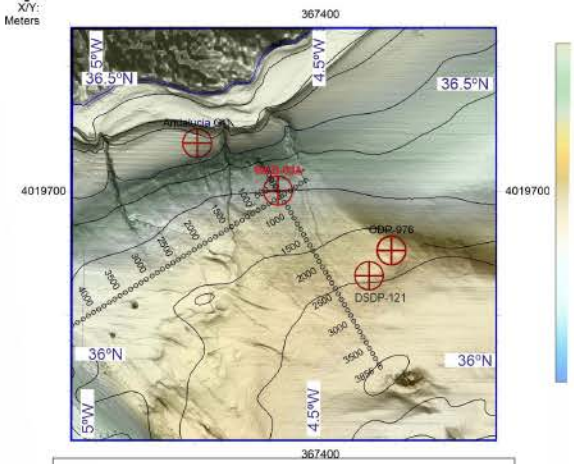
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 428	BQD boundary at 428 m; bottom Quaternary	2.6	1.69	Quaternary deposits comprise coarse to fine deposits based on seismic facies	Contourite and turbidite sedimentation	150	Depths measured from seafloor. Sedimentation rate based on ODP 976 & 977
428 - 739	M boundary at 739. Mio-Pliocene boundary	M: 5.33 /5.46 (Bache et al., 2012)	1.94	Pliocene deposits comprise coarse to fine deposits based on seismic facies. Marls and shale on the commercial well Andalucia-G1	Contourite and turbidite sedimentation	Pliocene: 150	Depths measured from seafloor. Sedimentation rate based on ODP 976 & 977
739 - 956	Base of MSC	5.97	1.94	Clays, anhydrites and volcanoclastics on the commercial well Andalucia-G1	Subaereal/shallow waters during the MSC	176	Depths measured from seafloor
956 - 1108	Messinian-Tortonian boundary	7.2	2.9	Marls and Shales with intercalations of calcarenites on the commercial well Andalucia-G1	Deep-sea environment.		Depths measured from seafloor
1108 - 1666	Tortonian tectonic inversion	ca. 8	2.9	Conglomerates and sandstones in the commercial well Andalucia-G1	Deep-sea environment.	190	Depths measured from seafloor
1666 - 1700	Below the Tortonian tectonic inversion	>8	2.9	Marls, silts and sands	Hemipelagic marine deposition		

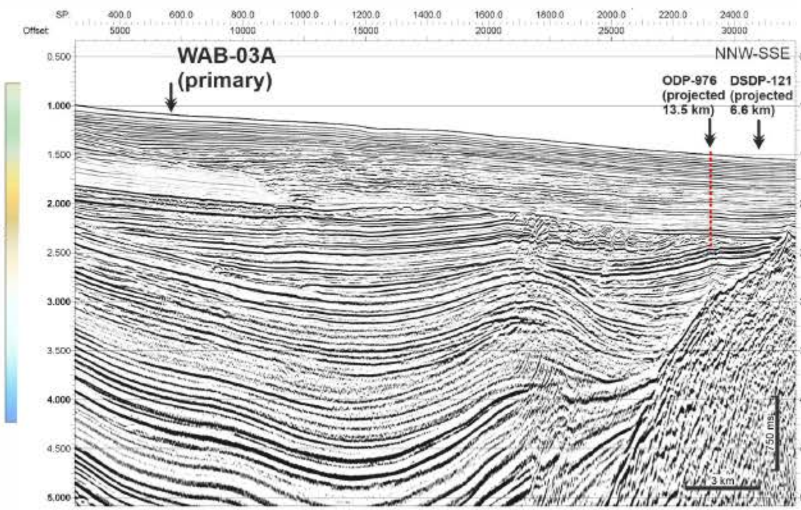
Site Summary

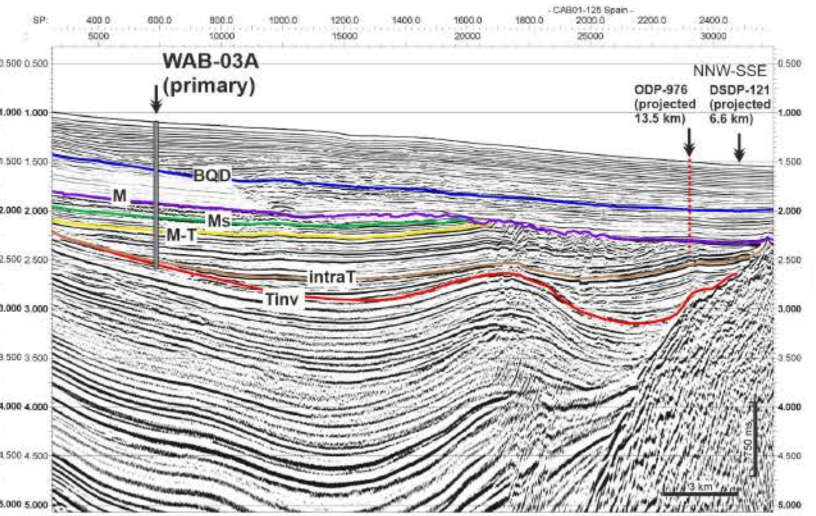
IMMAGE PROPOSAL

WAB-03A (primary)

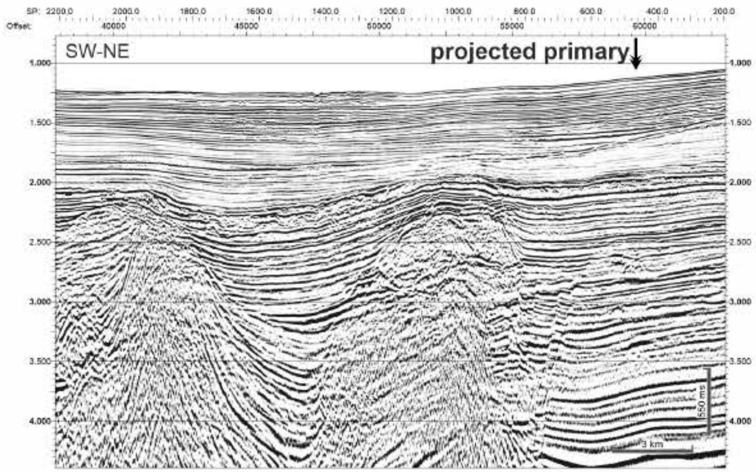
coordinates: 36.312544º/-4.571213º
water depth: 800 m
penetration: 1700 m

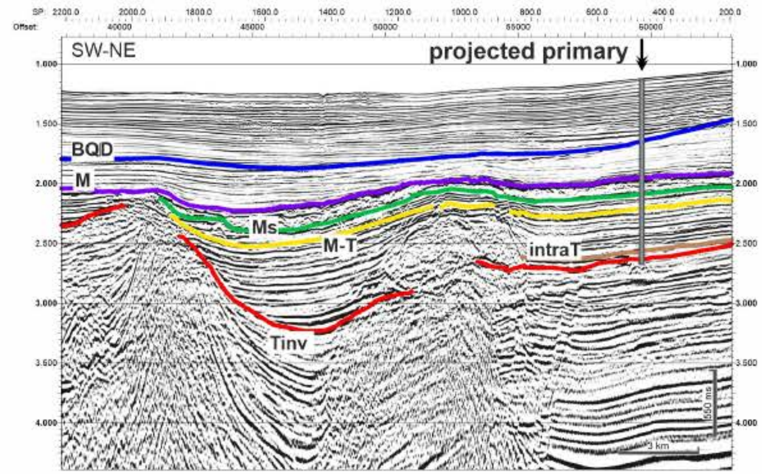






BQD: base Quaternary
M: Miocene-Pliocene boundary
Ms: base of MSC
M-T: Messinian-Tortonian boundary
intraT: IntraTotornian boundary
Tinv: Tortonian inversion





Remarks:
Seismic data in SP order
Navigation integrated in SGY

Data files:
Drill site on CAB01-125.segy; **SP:** 590
Crossing line: CAB01-106.segy; **SP:** 465

Additional information:
multibeam 50x50 m
parametric seismics 84 m far
Spanish waters

IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	This site targets one of the few thick late Messinian sedimentary successions in the Alboran Basin. The record recovered from this location will provide key constraints on the chemistry and physical properties of Mediterranean overflow during the Late Miocene. This is critical for all three objectives. The site is located on the Spanish side of the Moroccan-Spanish territorial boundary, very close to the other alternate site EAB-03A.
List Previous Drilling in Area	DSDP121, ODP 976, 977, 978, 979

Section B: General Site Information

Site Name:	EAB-02A	Area or Location:	Pytheas Basin, Alboran Sea
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#			
Latitude:	Deg: 35.75518251	Jurisdiction:	Spain
Longitude:	Deg: -2.43956525	Distance to Land: (km)	67
Coordinate System:	WGS 84		
Priority of Site:	Primary: ☐ Alternate: ☑	Water Depth (m):	845

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1277	0
	Total Sediment Thickness (m): 1277	
		Total Penetration (m): 1277
General Lithologies:	marls, silts, sands and clays	

Coring Plan: (Specify or check)

Hole A: APC to refusal; XCB to refusal and define casing point; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 11.7 | Logging: 3 | Total On-site: 14.7

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

3-4 temperature measurements to establish a geothermal gradient

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: April - September

Other:

Generated: 2019-09-27T21:30:36+00:00

Proposal #: 895 - Full 3	Site #: EAB-02A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: GBT02 Position: SP 1955 High-resolution multichannel
2b Deep penetration seismic reflection (crossing)	yes	Line: MSB12 Position: SP 1457 It is 450 m far from site
3 Seismic Velocity	no	
4 Seismic Grid	yes	2 to 5.3 km spaced grid of multi-channel seismics
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz		Parametric profile; 430 m far from site
7 Swath bathymetry	yes	50x50m
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	no	
17 Other	no	

Proposal #: 895 - Full 3	Site #: EAB-02A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Hole A: APC to refusal; XCB to refusal and define casing point; log hole A; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	For Site 976, located in the Western Alboran Basin, the data quality of compressional-wave velocities was degraded in the sediment cores because of gas expansion (Comas et al., 1996).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	Seismic research and exploratory drilling have been activities in the Alboran Sea for more than 30 years. During the 1980s three exploration wells were drilled. None of these surveys found evidence of a significant presence of oil in the basin. In 2005 the project Siroco was launched by the Spanish oil company Repsol, focusing on the search for natural gas. The project was abandoned in 2015 and exploratory drilling operations weren't carried out. Kuo et al. (2002), Mountfield et al. (2002), and Weinzapfel et al. (2003) recently reassessed and specified the hydrocarbon potential ofthe Alboran Sea arguing in favor of a Miocene petroleum system in this basin.
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?	Standard precautions
7. What abandonment procedures need to be followed?	
8. Natural or manmade hazards which may affect ship's operations	Presence of organic-rich layers in the Plio-Quaternary deposits.Presence of close fault, landslides and turbidites in the sedimentary register
9. Summary: What do you consider the major risks in drilling at this site?	Presence of organic-rich layers in the Plio-Quaternary deposits.Presence of close fault, landslides and turbidites in the sedimentary register

Proposal #: 895 - Full 3	Site #: EAB-02A	Date Form Submitted: 2019-09-27 14:26:27

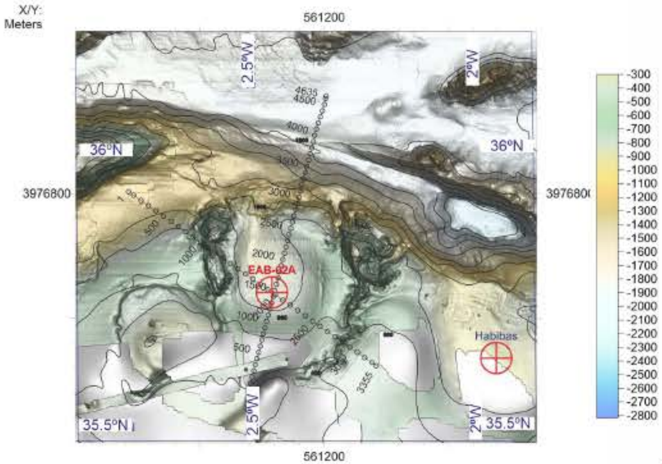
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 465	BQD boundary at 204 m; bottom Quaternary	2.6	1.65	Quaternary deposits comprise silty clay to clay	Deep-sea environment. Contourite sedimentation	150	Depths measured from seafloor. Sedimentation rate based on ODP 976 & 977
465 - 715	M boundary at 715m. Mio-Pliocene boundary	M: 5.33/5.46 (Bache et al., 2012)	1.81	Pliocene: silty clay to clay;	Deep-sea environment. Contourite sedimentation	Pliocene: 150	Depths measured from seafloor. Sedimentation rate based on ODP 976 & 977
715 - 1277	section: upper Miocene.	5.33/5.46 - < 7.2	2.9	Miocene sediments including marls, silts, sands and clays	Open marine		Depths measured from seafloor

Site Summary

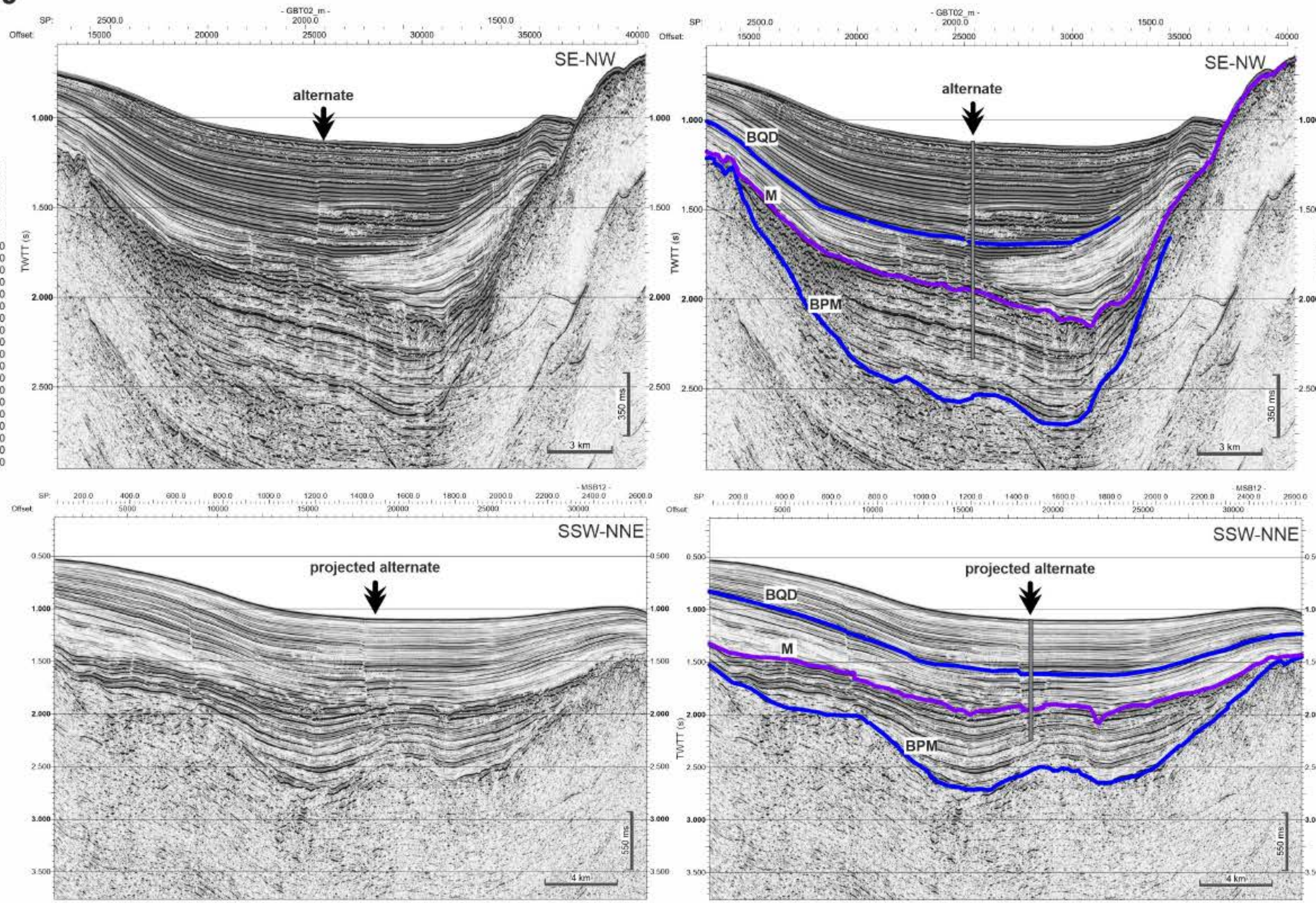
IODP IMMAGE PROPOSAL

SITE EAB-02A (alternate)

coordinates: 35.75518251º/-2.43956525º
water depth: 845 m
penetration: 1277 m



BQD: base Quaternary
M: Miocene-Pliocene boundary
BPM: Base post-rift Miocene



Remarks:
Seismic data in SP order
Navigation integrated in SGY

Data files:
Drill site on GBT02.segy; **SP:** 1955
Crossing line: MSB12.segy; **SP:** 1460

additional information:
multibeam 50x50 m
Spanish waters

IODP Site Forms

Form 1 – General Site Information

895 - Full 3

Section A: Proposal Information

Proposal Title	Investigating Miocene Mediterranean-Atlantic Gateway Exchange (IMMAGE)
Date Form Submitted	2019-09-27 14:26:27
Site-Specific Objectives with Priority (Must include general objectives in proposal)	This site targets one of the few thick late Messinian sedimentary successions in the Alboran Basin. The record recovered from this location will provide key constraints on the chemistry and physical properties of Mediterranean overflow during the Late Miocene. This is critical for all three objectives. The site is located on the Moroccan side of the Moroccan-Spanish territorial boundary, very close to the other alternate site EAB-02A.
List Previous Drilling in Area	ODP 977, 978, 979

Section B: General Site Information

Site Name:	EAB-03A
If site is a reoccupation of an old DSDP/ODP Site, Please include former Site#	
Latitude:	Deg: 35.750427
Longitude:	Deg: -2.431305
Coordinate System:	WGS 84
Priority of Site:	Primary: ☐ Alternate: ☑

Area or Location:	Pytheas Basin, Alboran Sea
Jurisdiction:	Morocco
Distance to Land: (km)	67
Water Depth (m):	838

Section C: Operational Information

	Sediments	Basement
Proposed Penetration (m):	1277	0
	Total Sediment Thickness (m) 1277	
		Total Penetration (m): 1277
General Lithologies:	marls, silts, sands and clays	

Coring Plan: (Specify or check)

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: PEF, Neutron and Dipmeter

Estimated Days: Drilling/Coring: 11.7 Logging: 3 Total On-site: 14.7

Observatory Plan:

Longterm Borehole Observation Plan/Re-entry Plan

3-4 temperature measurements to establish a geothermal gradient

Potential Hazards/ Weather:

						Preferred weather window
Shallow Gas	☐	Complicated Seabed Condition	☐	Hydrothermal Activity	☐	April - September
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:

Generated: 2019-09-27T21:30:36+00:00

Proposal #: 895 - Full 3	Site #: EAB-03A	Date Form Submitted: 2019-09-27 14:26:27

Data Type	In SSDB	Details of available data and data that are still to be collected
1a High resolution seismic reflection (primary)	no	
1b High resolution seismic seismic reflection (crossing)	no	
2a Deep penetration seismic reflection (primary)	yes	Line: Line: GBT02 Position: SP: 2004 High-resolution multichannel
2b Deep penetration seismic reflection (crossing)	yes	Line: Line: MSB12 Position: SP: 1432 It is 405 m far from site
3 Seismic Velocity	no	
4 Seismic Grid	yes	2 to 5.3 km spaced grid of multi-channel seismics
5a Refraction (surface)	no	
5b Refraction (bottom)	no	
6 3.5 kHz	yes	Parametric profile; 430 m far from site
7 Swath bathymetry	yes	50x50m
8a Side looking sonar (surface)	no	
8b Side looking sonar (bottom)	no	
9 Photography or video	no	
10 Heat Flow	no	
11a Magnetics	no	
11b Gravity	no	
12 Sediment cores	no	
13 Rock sampling	no	
14a Water current data	no	
14b Ice Conditions	no	
15 OBS microseismicity	no	
16 Navigation	no	
17 Other	no	

Proposal #: 895 - Full 3	Site #: EAB-03A	Date Form Submitted: 2019-09-27 14:26:27

Pollution & Safety Hazard	Comment
1. Summary of operations at site	Hole A: APC to refusal; XCB to refusal and define casing point; log hole A; offset to Hole B: drilling and case off upper part of the hole; re-enter and RCB coring below casing; log below casing in Hole B
2. All hydrocarbon occurrences based on previous DSDP/ODP/IODP drilling	For Site 976, located in the Western Alboran Basin, the data quality of compressional-wave velocities was degraded in the sediment cores because of gas expansion (Comas et al., 1996).
3. All commercial drilling in this area that produced or yielded significant hydrocarbon shows	Seismic research and exploratory drilling have been activities in the Alboran Sea for more than 30 years. During the 1980s three exploration wells were drilled. None of these surveys found evidence of a significant presence of oil in the basin. In 2005 the project Siroco was launched by the Spanish oil company Repsol, focusing on the search for natural gas. The project was abandoned in 2015 and exploratory drilling operations weren't carried out. Kuo et al. (2002), Mountfield et al. (2002), and Weinzapfel et al. (2003) recently reassessed and specified the hydrocarbon potential of the Alboran Sea arguing in favor of a Miocene petroleum system in this basin.
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?	
7. What abandonment procedures need to be followed?	Standard precautions
8. Natural or manmade hazards which may affect ship's operations	Presence of organic-rich layers in the Plio-Quaternary deposits. Presence of close fault, landslides and turbidites in the sedimentary register
9. Summary: What do you consider the major risks in drilling at this site?	Presence of organic-rich layers in the Plio-Quaternary deposits. Presence of close fault, landslides and turbidites in the sedimentary register

Proposal #: 895 - Full 3	Site #: EAB-03A	Date Form Submitted: 2019-09-27 14:26:27

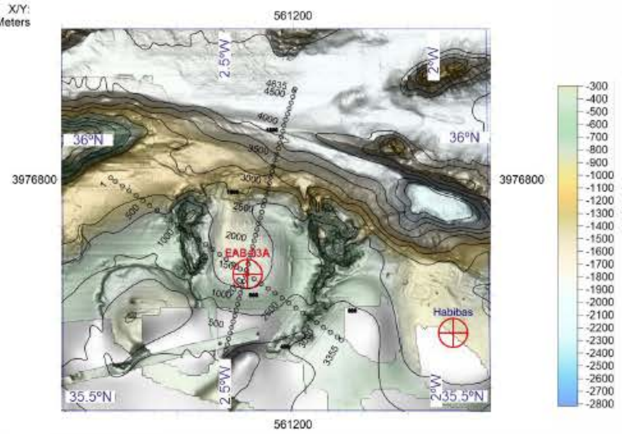
Subbottom depth (m)	Key reflectors, unconformities, faults, etc	Age (My)	Assumed velocity (km/s)	Lithology	Paleo-environment	Avg. accum. rate (m/My)	Comments
0 - 444	BQD boundary at 444 m; bottom Quaternary	2.6	1.65	Quaternary deposits comprise silty clay to clay	Deep-sea environment. Contourite sedimentation	150	Depths measured from seafloor. Sedimentation rate based on ODP 976 & 977
444 - 711	M boundary at 715m. Mio-Pliocene boundary	M: 5.33/5.46 (Bache et al., 2012)	1.81	Pliocene: silty clay to clay;	Deep-sea environment. Contourite sedimentation	Pliocene: 150	Depths measured from seafloor. Sedimentation rate based on ODP 976 & 977
711 - 1277	section: upper Miocene.	5.33/5.46 - < 7.2	2.9	Miocene sediments including marls, silts, sands and clays	Subaereal/shallow waters duirng the MSC; Open marine during the rest of the Miocene		Depths measured from seafloor

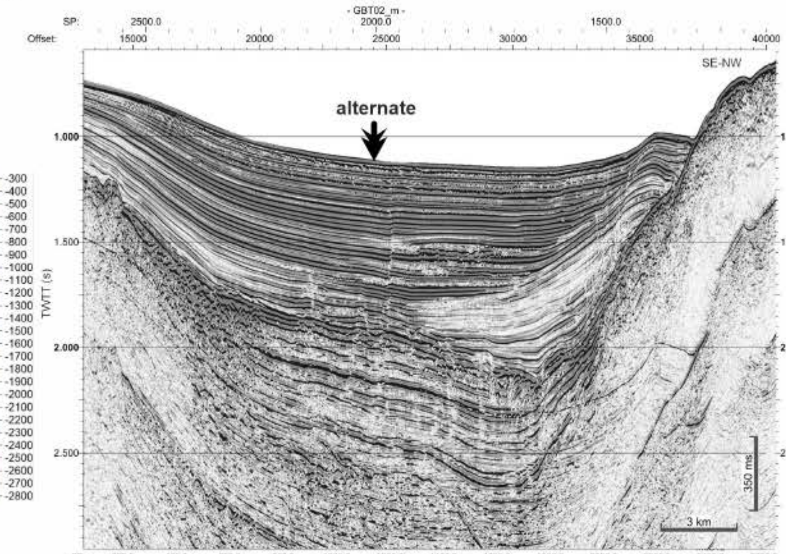
Site Summary

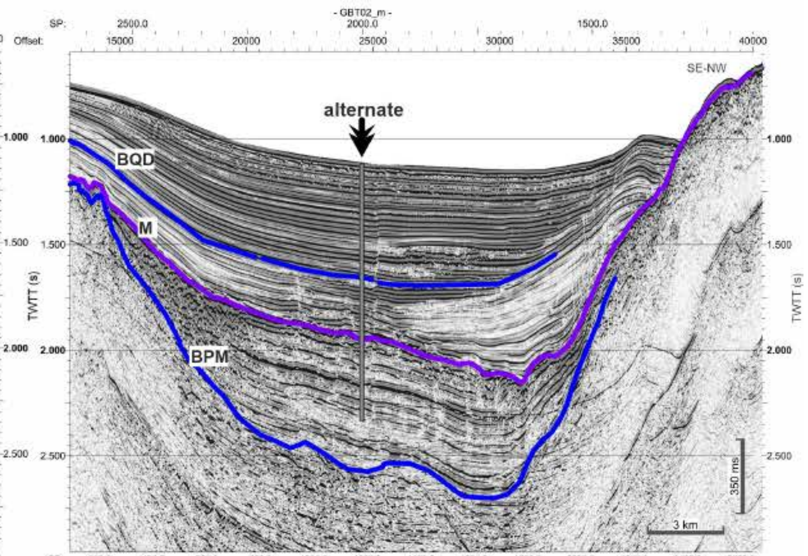
IODP IMMAGE PROPOSAL

SITE EAB-03A (alternate)

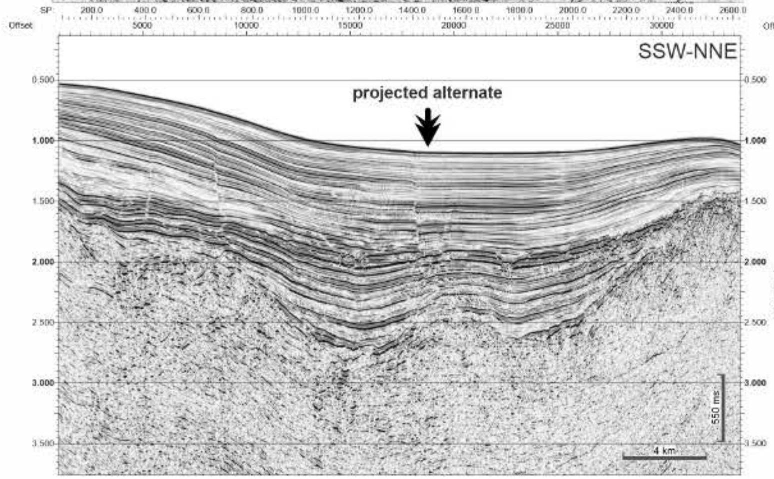
coordinates: 35.750427º/-2.431305º
water depth: 838 m
penetration: 1277 m

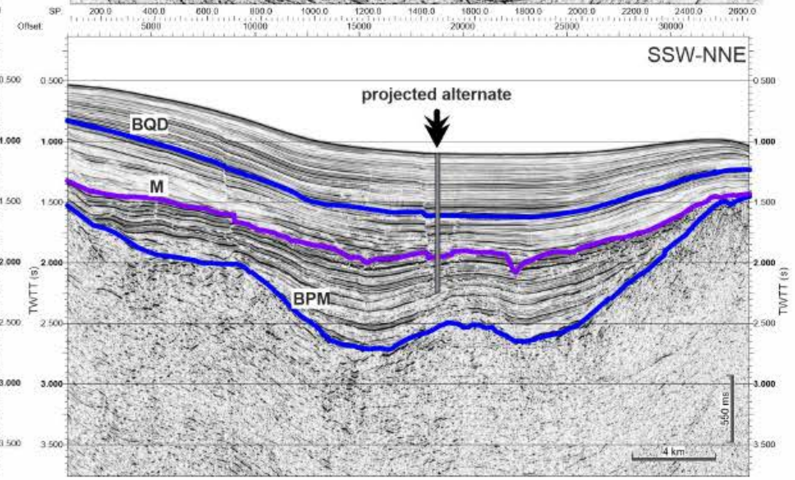






BQD: base Quaternary
M: Miocene-Pliocene boundary
BPM: Base post-rift Miocene





Remarks:
Seismic data in SP order
Navigation integrated in SGY

Data files:
Drill site on GBT02.segy; **SP:** 2004
Crossing line: MSB12.segy; **SP:** 1460

Additional information:
multibeam 50x50 m
Moroccon waters