



Helmholtz-Zentrum für Ozeanforschung Kiel

R/V POSEIDON

Fahrtbericht / Cruise Report

P457

ICELAND HAZARDS

Volcanic Risks from Iceland and Climate Change: The Late Quaternary to Anthropogene Development

Reykjavík / Iceland – Galway / Ireland
7.-22. August 2013



Berichte aus dem GEOMAR
Helmholtz-Zentrum für Ozeanforschung Kiel

Nr. 14 (N. Ser.)

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SUMMARY

R/V POSEIDON cruise P457 aimed further development of detailed marine tephrochronology of Iceland by sediment coring in order to improve our knowledge of the spatio-temporal evolution of Icelandic volcanism and related hazards. In addition, the marine record contains paleoclimatic information, which may relate recurrent glacier advances and land degradation periods to ocean and atmospheric circulation changes. A minor sub-project should contribute to a better understanding of Surtsey volcanism by investigations of marine Surtsey tephra. P457 conducted extensive sediment echosounding (11 surveys with a total length of c. 425 nm) in order to identify undisturbed sediment sequences for coring. At 20 appropriate sites, P457 deployed gravity and/or gaint box corers to recover ultra-high resolution sediment cores from < 100 m to ~1,600 m water depth at the south-western, southern and eastern sectors of the Icelandic shelf and slope. Of these deployments, 9 gravity corers yielded altogether 59.5 m core recovery and 11 box corers recovered surface sediment samples. Additionally 7 CTD/rosette water sampling stations have been performed at shallow sites close to Iceland and at deep sites further offshore in order to determine the REE distributions and the Nd and Hf isotope compositions of the sea water. No equipment was lost or significantly damaged. Cruise P457 was particularly successful in the working areas southwest and south of Iceland but failed to recover long sediment cores in the eastern working areas and at Surtsey. Sand, clayey silt, clayey sandy silt, sandy clayey silt, and volcanic ashes are the dominant lithologies in the P457 sediment cores. Preliminary studies of selected sedimentary records along the Iceland margin from ca. 24°W to 12°W on both sides of Reykjanes Ridge suggest that a correlation of these cores is possible, implying that sedimentary records are undisturbed and of high quality. Notably, distinct volcanic ash layers can apparently be traced in the P457 cores across the working area. Preliminary age models of selected cores show that the sedimentation rates around Iceland are low with only a thin Holocene. Sediment records cover approximately 120.000 years at most.

ZUSAMMENFASSUNG

Die FS POSEIDON-Reise P457 sollte durch Sedimentbeprobungen vor Ísland zu einer Weiterentwicklung der Tephrostratigraphie von Ísland beitragen, um unser Wissen über die zeitlich-räumliche Entwicklung des isländischen Vulkanismus und den damit verbundenen Naturgefahren zu verbessern. Paläozanographische Untersuchungen dienten dazu, Wechselbeziehungen zwischen ozeanischen, terrestrischen und atmosphärischen Prozessen zu erfassen. Im Rahmen eines Teilprojektes sollte die Entwicklung des Vulkanismus, der die Insel Surtsey bildete, anhand mariner vulkaniklastischer Abfolgen rekonstruiert werden. Während P457 wurden insgesamt 11 Sedimentecholot-Profilierungen mit einer Gesamtlänge ca. 425 nm durchgeführt, um ungestörte Sedimentabfolgen zu finden. An 20 geeigneten Lokationen im Südwesten, Süden und Osten Íslands wurden ein Schwerelot und/oder ein Kastengreifer eingesetzt, um hochauflösende Sedimentkerne aus < 100 m bis zu ca. 1.600 m Wassertiefe zu gewinnen. Von diesen Geräteeinsätzen erbrachten 9 Schwerelote insgesamt 59,5 m Kerngewinn und 11 Kastengreifer Oberflächensedimente. Zusätzlich erfolgten 7 CTD-Einsätze mit Kranzwasserschöpfer nahe der Küste sowie weiter seewärts, um die Verteilung der Seltenen Erden Elemente und die Nd- und Hf-Isotopenzusammensetzung des Meerwassers zu bestimmen. Während P457 gingen weder Geräte verloren noch wurden sie nennenswert beschädigt. Die Sedimentbeprobung verlief im Arbeitsgebiet ab Wassertiefen von ca. 250 m sehr erfolgreich. In flacheren Regionen, insbesondere um Surtsey herum, war der Probengewinn aufgrund des grobsandigen Materials gerätebedingt eingeschränkt. Die vorherrschenden Lithologien in den Kernen sind Sand, toniger sandiger Silt, sandiger toniger Silt sowie Lagen vulkanischer Aschen und eistransportierten Detritus. Erste Kernlogging-Verfahren lassen erkennen, dass sich die Sedimentkerne süd- und südwestlich Íslands beidseitig des Reykjanes Rückens im Bereich von ca. 24°W bis 12°W gut miteinander korrelieren lassen und von einer ungestörten Sedimentabfolge ausgegangen werden kann. Dabei lassen sich markante vulkanische Aschelagen über weite Bereiche des Arbeitsgebiet korrelieren. Vorläufige Altersmodelle ausgewählter Sedimentkerne zeigen, dass die Sedimentationsraten relativ gering sind, die Sedimentabfolgen bis ca. 120.000 Jahre zurückreichen und ein nur geringmächtiges Holozän aufweisen.

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Lastly, the chief scientist would like to thank the scientific shipboard party for their excellent work and their high level of motivation that significantly contributed to the success of the cruise and the good atmosphere on board throughout this expedition.

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2.1. Ship's Crew

Hammacher, Rainer	Master	Stange, Hans-Otto	Chief Engin.
Griese, Theo	Chief Mate	Hagedorn, Günther	2 nd Engineer
Pengel, Sebastian	2 nd Mate	Kasten, Stefan	Electrician
Ennenga, Johann	Cook	Gerischewski, Bernd	Steward
Mischker, Joachim	Boatswain	Kruse, Marius Antonius	SM
Meiling, Ralf	SM	Peters, Ralf	SM
Janssen, Sören	SM	Erber, Sven	SM

2.2. Principal Investigators for ICELAND HAZARDS *(in alphabetical order)*

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Nürnberg, Dirk	GEOMAR
Portnyagin, Maxim	GEOMAR
Werner, Reinhard	GEOMAR

2.3. Shipboard Scientific Party *(in alphabetical order)*

Bonanati, Christina	Scientist	GEOMAR
Evers, Florian	Technician	GEOMAR
Friðriksson, Árni	Student	IES
Hümbs, Peter	Technician	INNOMAR
Nürnberg, Dirk	Co-Chief Scientist	GEOMAR
Portnyagin, Maxim	Senior Scientist	GEOMAR
Raddatz, Jacek	Senior Scientist	GEOMAR
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van den Bogaard, Christel	Senior Scientist	GEOMAR/HOSST
Werner, Reinhard	Chief Scientist	GEOMAR
Zieringer, Moritz	Scientist	GEOMAR



The P457 Shipboard Scientific Party.

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3. BACKGROUND AND MAJOR OBJECTIVES OF P457

R/V POSEIDON cruise P457 is part of the cooperative project "Iceland Hazards" jointly led by the working groups of Prof. Kaj Hoernle (GEOMAR, RD4, volcanology and magmatic geochemistry), Prof. Dirk Nürnberg, and Prof. Martin Frank (GEOMAR, RD1, paleoceanography). This research project aims at further development of the detailed marine tephrochronology of Iceland by offshore sediment coring. It is intended to improve our knowledge on the spatial and temporal evolution of Icelandic volcanism and related hazards to human population and economy. Volcanic eruptions on Iceland, for example, can pose a major risk to air travel over the North Atlantic and Europe and to health in northern Europe. Active volcanoes on Iceland are not only hazardous for the local environment and economy, but their eruptions can have a strong regional to global impact due to comparatively high explosivity, wide tephra dispersal and abundant volcanic gas emissions. They can also influence seawater chemistry due to the dissolution of the tephra.

The history of Icelandic volcanism has been extensively studied on land. Instead, the marine record of Icelandic volcanism, in particular during the pre-Holocene time period, is not well known although it bears the potential to extend the knowledge on Icelandic volcanism further back in time at high temporal resolution. In addition, the marine record contains paleoceanographic and paleoclimatic information, which may relate recurrent glacier advances and land degradation periods to ocean and atmospheric circulation changes. A minor sub-project conducted on cruise P457 aimed to contribute to a better understanding of Surtsey volcanism by investigations of marine Surtsey tephra.

3.1. MARINE TEPHROCHRONOLOGY OFF-SHORE ICELAND

In the largest continuous soil sections within the eastern and northern volcanic zones, the number of tephra layers is 100–200, depending on the location with respect to the gradual retreat of the inland ice. The number of tephra layers, however, falls rapidly off with distance from the volcanic zones. Only about half of the historical tephra layers found in North Iceland at 65°20'N have been detected in sediment cores off the northern coast at 66°30'N (Larsen and Eiríksson, 2008). Nevertheless, in the depositional environments of the northern North Atlantic, the Nordic Seas and the surrounding land areas, tephrochronology has proved to be an outstanding tool for chronostratigraphical correlation and dating of Quaternary sedimentary sequences. As the deposition of tephra layers is essentially instantaneous on a geological timescale, these layers have provided distinctive and widespread isochronous stratigraphical marker horizons usually independent of their depositional environment (terrestrial, marine, lacustrine, ice sheets). The distinct petrographic character of the tephra glass shards, combined with unique geochemical fingerprints characterizing most of these widespread tephra layers, has made it possible to isolate and identify single volcanic glass grains with high precision and to link them to their respective tephra horizons. The use of tephra layers as chronostratigraphical event markers has been especially important during the last deglaciation and early Holocene, where the application of the radiocarbon dating method is hampered by low organic carbon content of the sediments. Additionally, these tephra horizons have been an important factor in the determination of both spatial and temporal variations in marine reservoir

radiocarbon age (see Hafliðason et al., 2000; Lacasse and Garbe-Schönberg, 2001; Larsen et al., 2002 and refs. therein).

One of the key requirements for documenting and understanding the mechanism of rapid environmental and sedimentological fluctuations is access to high-quality climate records. A good example of such a record is a 37 m long core taken on the northern Icelandic shelf (Eiríksson et al., 2000; Gudmundsdóttir et al., 2011; Larsen et al., 2002), which extends back in time to 13.5 kyr. About 60 ash layers were identified so far in the core, which provides a reference tephra sequence for the northern direction from Iceland. To the best of our knowledge, no other core with a comparable time resolution is yet known from any other sector of the Icelandic shelf. Such data, however, is essential to reconstruct the evolution of volcanism on Iceland.

3.2. MAJOR OBJECTIVES OF CRUISE P457

Cruise P457 and the project "Iceland Hazards" aims to explore the potential of marine tephrochronology for reconstruction of the temporal evolution of Icelandic volcanism and also to clarify the Holocene interrelationships between oceanic, continental and atmospheric processes driving climate change. To achieve these objectives we conduct a high-resolution study of sediment cores from the southwestern, southern and southeastern sectors of the Icelandic shelf, which were previously not sampled but correspond to the direction of ash transport toward Europe. By studying these ash-bearing sediment cores we intend to address the following major questions:

- (1) How many and which ash layers are present in the sediment cores? What are their source volcanoes and their age? Can the ash layers be used as isochrones to correlate the sediment cores with each other, with cores from the northern shelf of Iceland, with soil, peat and lake sections on Iceland and in Northern Europe?
- (2) Are there tephra layers which correspond to some ash layers identified in North Europe? Can these eruptions be analogues to the 2010 Eyjafjallajökull eruption?
- (3) Does the number of ash layers in Holocene marine sediments increase in comparison to the (de)glacial time periods? Does this indicate an increase of volcanic activity on Iceland due to ice unloading and additional decompression melting in the mantle and/or crust?
- (4) Does the increased frequency of ash falls in Europe during the last 1,500 years, as revealed from the presence of microscopic ash layers in peats and lake sediments in Northern Europe, correlate with the abundance of ash layers in the marine sediments?
- (5) Are the Holocene glacier advances, increasing over the last 5 kyrs, related to changing volcanic activity or rather to re-organizations in oceanic and atmospheric circulation.
- (6) Does the Geyer and Bindemann (2011) hypothesis hold that in particular interstadial periods during long glacial periods create most favorable conditions for volcanic eruptions?
- (7) How does exchange with volcanic ash change the dissolved REE patterns and the Nd and Hf isotope composition of seawater near Iceland? Are changes in the Nd and Hf isotope compositions of seawater reflected in the signatures of authigenic phases in the sediments near Iceland and how did these changes influence the isotope composition of past water masses in other areas in the North Atlantic?

Furthermore, coring of volcanoclastic successions close to Surtsey should contribute to a better understanding of eruption and transport processes during the formation of this young volcanic island in 1963 - 1967.

4. CRUISE NARRATIVE

The starting point of R/V POSEIDON expedition P457 was the port of Reykjavík (Iceland, Figs. 4.1 and 4.2), where the P457 scientific party arrived in the afternoon of August 5th, 2013. The unloading of containers with scientific equipment for P457 and preparation of the ship's laboratories kept us busy during the following day. In the morning of August 7th, R/V POSEIDON left Reykjavík. By the early afternoon of the same day, R/V POSEIDON sailed northwest approximately 60 nautical miles (nm) and arrived at the first working area (Area I, Fig. 4.1). Under little time it was managed to prepare all laboratories and devices punctually thanks to the excellent support from the POSEIDON crew.

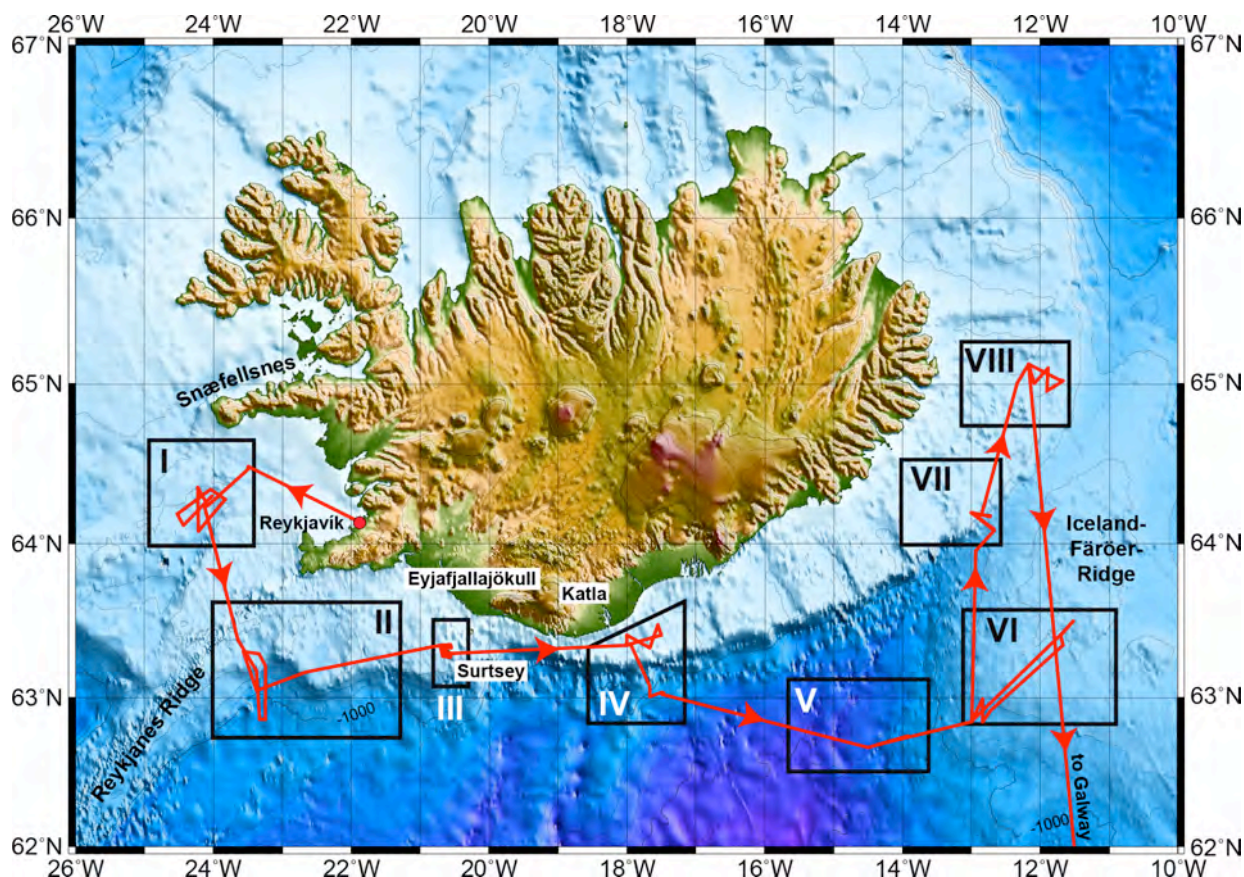


Fig. 4.1: Cruise track (red) and planned working areas I-VIII (black frames) of P457.

The scientific work of cruise P457 started immediately after arrival in Working Area I with tests of the "SES 2000 Medium" sediment echo sounding system and the "SB 3050" multi-beam system. The sediment echo sounding system worked properly and recorded data in excellent quality, but we did not receive data from the multi-beam system most likely because of problems with the motion sensor. During the next days, various attempts failed to put the motion sensor and multi-beam system into operation, so that we finally were forced to conduct the P457 working program without multi-beam surveys.

In the afternoon of August 7th, R/V POSEIDON stopped south of the Snæfellsnes Peninsula to sample and analyze the water column in various depths from the ocean floor up to the water surface using a CTD (Conductivity, Temperature, Density) and a rosette water sampler. Subsequently, we started an extensive sediment echo sounding survey to identify the best site for a coring station scheduled for the next morning. During the night, however, wind speed and wave heights increased significantly since a vast atmospheric pressure low passed our working area (Fig. 4.3). The weather conditions during the next one and a half days hampered any station work and profiling and therefore, caused a significant delay of our schedule. In the afternoon of August 9th, the weather cleared off and we were able to continue profiling. The first coring station of our cruise has been accomplished on August 10th. At each coring station, we commonly deployed one to two gravity corers (5 and/or 10 m long depending on sediment

properties) to recover sediment cores as long as possible. Additionally, a giant box corer was run to sample the sediment surface, which is usually destroyed in the cores recovered by gravity corer. Luckily the coring station in Working Area I was very successful and yielded 4.10 m and 10 m long sediment cores as well as a full box corer. Immediately afterwards, R/V POSEIDON headed to next working area.



Fig. 4.2: *The port of Reykjavik with the new concert hall in the background (photo: J. Raddatz).*



Fig. 4.3: *Stormy conditions in the first working area (photo: C. Bonanati).*

Working Area II comprises the Icelandic shelf and slope southeast of the northernmost part of the Reykjanes Ridge (Fig. 4.1). Here, two coring stations, one in shallow water and the other one in deep water, were planned. Based on nightly sediment profiling, we selected the sites for both stations in the early morning of August 11th. Thanks to the crew of R/V POSEIDON, we managed to accomplish successfully both stations as well as two CTD deployments on the same day, so that we could regain some of the time lost by bad weather. In the late evening, R/V POSEIDON sailed c. 60 nm westward to the island Surtsey, which has been formed by volcanic eruptions between 1963 and 1967 (Fig. 4.4). On request of colleagues from Iceland and New Zealand, we intended to core the volcanoclastic deposits close to Surtsey to allow a better reconstruction of the eruption history of this volcano. A comprehensive sediment echo sounding survey around Surtsey revealed up to c. 10 m thick, nicely laminated deposits in the vicinity of the island (see Appendix II), which are clearly soft and not lavas. Despite these apparently good preconditions, all gravity corer deployments failed. Due to time constraints, we gave up after 8 unsuccessful coring attempts at altogether 6 different sites in various distances from Surtsey. Only one box corer recovered the uppermost 20 cm of surface sediments. The coarse, consolidated, and dewatered volcanic sand most likely prevented the successful penetration of the coring device into the seafloor. The perfect, sunny and clear weather conditions on that day, however, compensated the frustrating coring attempts at least a little bit. Crew and scientists were very impressed by the view on Surtsey, the Vestmannaeyar, the Icelandic south coast, and some Orcas, which suddenly appeared close to the ship.

After a 60 nm long transit along the Icelandic south coast, which was nicely illuminated by the evening sun (Fig. 4.5), R/V POSEIDON arrived in Working Area IV in the late evening of August 12th. This working area extends from the shallow shelf over the slope into the deep sea directly southeast of the Eyjafjalljökull and Katla volcanoes (Figs. 4.1 and 4.5). Amongst others this area was chosen to sample deposits of these volcanoes. Station work started with a CTD in the early morning of August 13th. Afterwards a 5 m gravity corer failed to return sediments from the shelf and a box corer yielded only 25 cm surface sediment from this site. Since we had again the impression that the gravity corer cannot penetrate the surface of the deposits on the shelf (as it was the case at Surtsey), we moved further south and conducted a short sediment echo sounding survey to locate an appropriate site for alternative coring in deeper water. We received a 5 m and a 10 m long sediment core and a full box corer from c. 1,300 m water depth. In the evening of August 13th, station work in Working Area IV was finished with a CTD deployment and R/V POSEIDON headed towards southeast.



Fig. 4.4: The volcanic island Surtsey off the Icelandic south coast (photo: R. Werner).

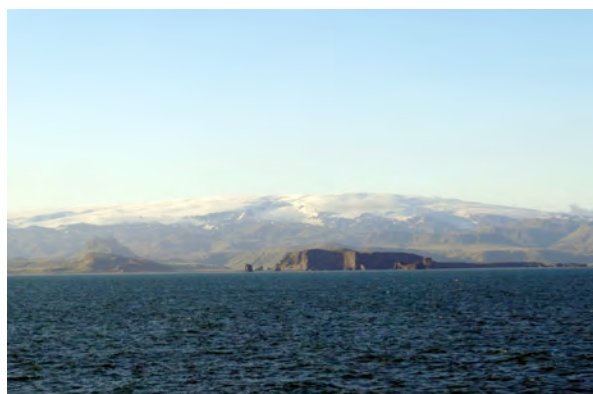


Fig. 4.5: Katla volcano covered by the glacier Myrdalsjökull (photo: C. Bonanati).

Early on the next morning, R/V POSEIDON arrived at Working Area V southwest of the Iceland-Färöer-Ridge (Fig. 4.1). Luckily only a short sediment echo sounding survey was required to locate a promising coring site in 1,610 m water depth - the deepest station of the cruise. We deployed successfully a CTD, the box corer, and a 10 m gravity corer, which returned an 8.90 m long sediment core. Right after lunch, we sailed to Working Area VI on the Iceland-Färöer-Ridge, where we already arrived on the early evening of the same day. Here, two coring stations were planned, one on the western flank of the ridge and the other on its top region. The early arrival enabled us to complete comprehensive sediment profiling at both potential sites during the night from August 14th to 15th. The sediment echo sounding data revealed promising sediment sequences on the lower flank of the ridge, but hardly any sediment in its top region. Therefore, we decided to conduct just a box corer in the top region, which recovered 22 cm sediment. As expected the coring station on the flank was more successful and yielded a 7,6 m long sediment core and a full box corer out of 755 m water depth.



Fig. 4.6: The working deck of R/V POSEIDON with the box corer getting prepared for deployment (photo: C. Bonanati).

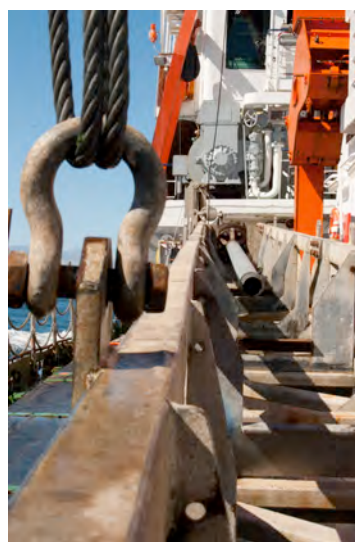


Fig. 4.7: A gravity corer lies in its stage, ready prepared for the next operation (photo: N. Schattel).

In the last two Working Areas VII and VIII, cruise P457 did not remain on „the sunny side of the street“ as during the past days. Both working areas are located on the eastern shelf of Iceland (Fig. 4.1). Sediment echo sounding surveys in Working Area VII did not reveal any sediment sequences suitable for coring. Nevertheless, we made several attempts to sample at least some surface sediments, but the 5 m gravity corer returned empty and 4 box corer deployments yielded only a few cm of sediment, stones or even nothing. Moreover, the

weather forecast predicted several vast atmospheric pressure lows, which crossed our way to our final destination Galway in Ireland. To arrive at Galway in time, it was decided to leave the working areas earlier than originally planned, since we expected that the bad weather conditions significantly will slow down the average cruising speed of R/V POSEIDON. Consequently, it was just time left for one quick coring station in Working Area VIII on the morning of August 17th. An almost full gravity corer raised hope to finish the station work of cruise P457 with a long sediment core, but the gravity corer recovered only 30 cm sediment.

On the same day at 10 am, R/V Poseidon headed on the c. 800 nm transit to Galway. In the evening, we celebrated the end of the P457 station work with a festive party in the geology lab. Despite temporarily rough weather conditions, the transit was used for preliminary studies of cores and their preparation for the analyses in the home labs. Furthermore, writing of reports, the big laboratory cleaning, and packing was on the agenda during the transit. Occasionally, however, the conditions were a bit better than expected and allowed a higher cruising speed as calculated. Therefore, R/V POSEIDON entered the port of Galway already in the late afternoon of August 21st. After unloading and container packing, the P457 scientists disembarked on Thursday, August 22nd in the late afternoon.

Complementing extensive sediment profiling, a total of 19 gravity corers, 14 box corers, and 7 CTD/rosette water sampling stations were carried out on cruise P457 (Fig. 4.8) during 8.5 days, when weather conditions allowed profiling and station work. Of these deployments, 9 gravity corers yielded altogether 59.5 m core recovery, 11 box corers recovered surface sediment samples, and the rosette returned 74 water samples. No equipment was lost or significantly damaged. Cruise P457 was particularly successful in the working areas southwest (I, II) and south (IV, V, VI) of Iceland with an average core recovery (5-10 m gravity corer) of 6.73 and 6.29 m, respectively, but failed to recover long sediment cores in the easternmost working areas (VII, VIII) and around Surtsey..

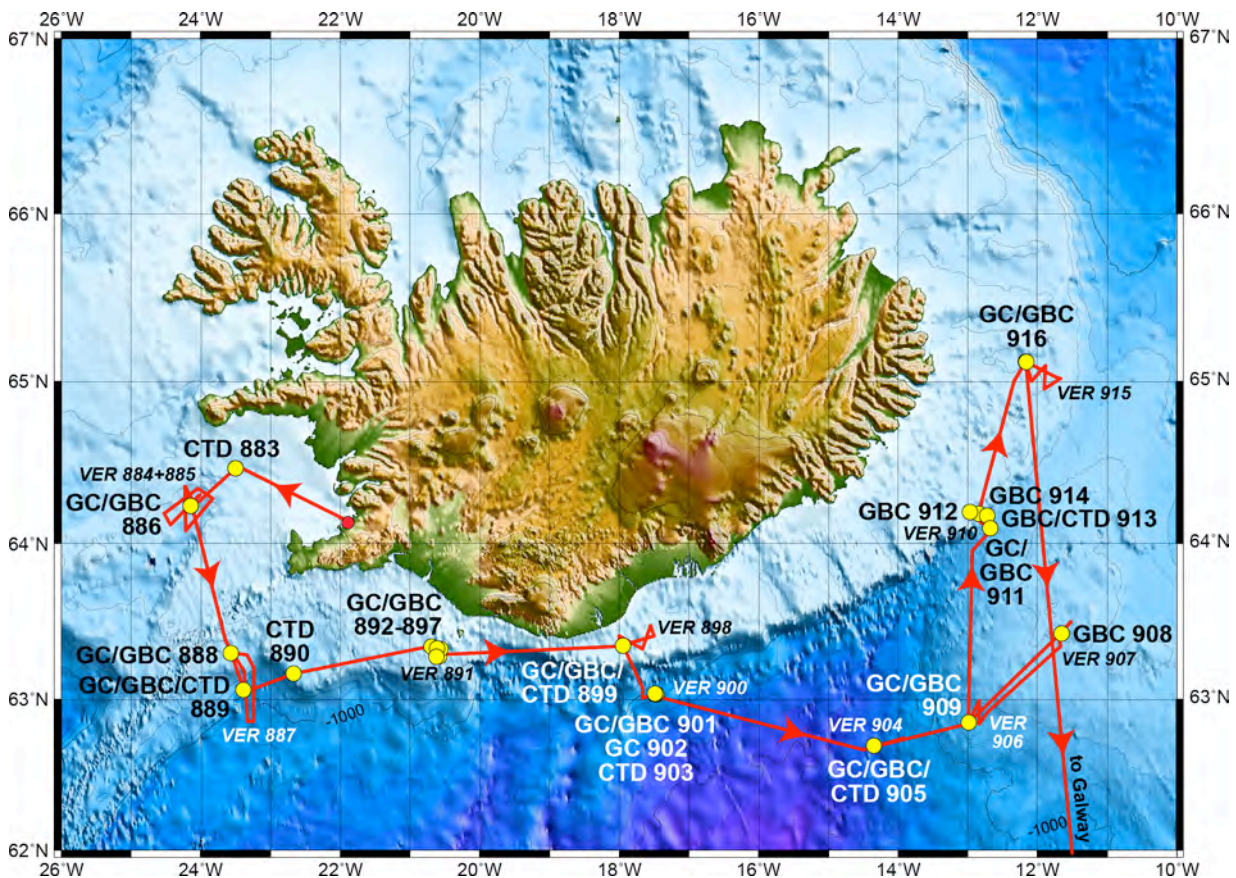


Fig. 4.8: Station map of R/V POSEIDON cruise P457 (VER - sediment echo sounding survey; GC - gravity corer; GBC - giant box corer; CTD - CTD + rosette water sampler).

5. METHODS

5.1. SUB-BOTTOM PROFILING

Chapters 5.1.1. and 5.1.2. are mainly based on the "SES-2000 Technical Background" booklet by INNOMAR Technology GmbH as well as on data and information taken from www.innomar.com/ses2000medium-100.php and www.innomar.com/ses2000software.php.

5.1.1. Basic Requirements of Sub-Bottom Profilers

Sub-bottom profilers (or sediment echo sounding systems) are used to picture sub-seafloor geological structures as, for example, marine sediment successions (Fig. 5.1.). Accordingly the sound waves used for sub-bottom profiling have to penetrate the seafloor and the attenuation in the water and in the sediments should be as low as possible. The attenuation of sound waves increases with frequency, therefore the frequency of the sound wave for sub-bottom profilers should be as low as possible to get the best penetration. Another important property of sub-bottom profilers is the size of the so-called footprint of its sound source, i.e. the size of the sounded area of the seafloor (Fig. 5.1). The narrower the sound beam the smaller is the footprint. The horizontal resolution of the resulting echo print cannot be better than the size of the footprint. Therefore a small footprint and thus a narrow sound beam is essentially needed to receive high-resolution data. on the other hand the pulse length is very important for the vertical resolution. If a target is close beneath another one (e.g. two sediment layers), they can only be separated by evaluable differences in the envelope or phase of the resulting echoes. Accordingly the sound pulse used should have a large frequency bandwidth and hence short pulses should be used for good vertical resolution. Furthermore the pulse repetition rate (ping rate) of sub-bottom profilers should be as high as possible because an object has to be hit by the sound beam as often as possible to receive as surely as possible a signal. Finally heave, roll, and pitch compensation is essential if high-resolution echo prints are required. Beam stabilizing will improve the results especially while using narrow sound beams.

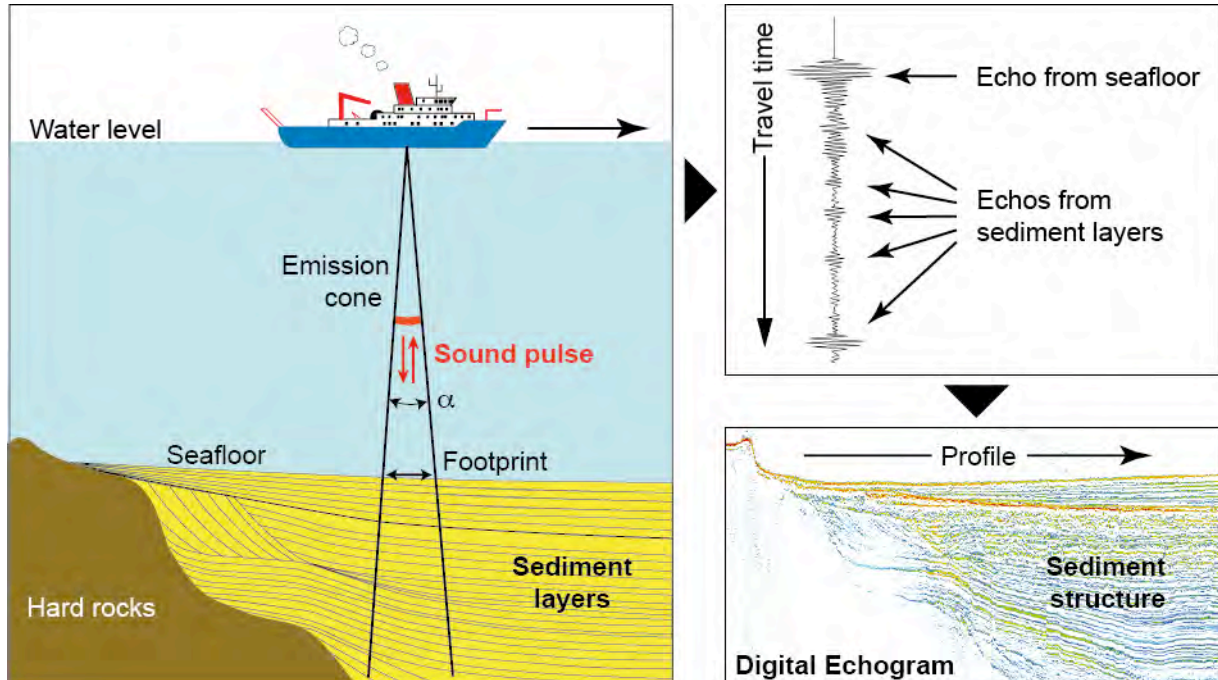


Fig. 5.1: Schematic sketch illustrating the principle mode of operation of sub-bottom profilers (figure modified after the "SES-2000 Technical Background" booklet by INNOMAR Technology GmbH).

5.1.2. The SES-2000 Medium Parametric System

On cruise P457 sub-bottom profiling has been conducted using a SES-2000 medium narrow-beam parametric sub-bottom profiler by INNOMAR Technology GmbH (<http://www.innomar.com>). The SES-2000 system acts as a low-frequency sediment echo sounder and as high-frequency narrow-beam sounder to determine the water depth. It is designed for offshore applications down to 2,000 m water depth and can penetrate the sediment up to 70 m depending on sediment properties and frequency. The system is based on the parametric acoustical effect, which is produced by additional frequencies through nonlinear acoustic interaction of finite amplitude waves. In principle, if two sound waves of similar frequencies f_1 and f_2 (so called primary frequencies with $f_1 < f_2$ and $f_2/f_1 \sim 1$; 94 - 110 kHz for SES-2000 medium) are emitted simultaneously, a signal of the difference frequency $F = |f_2 - f_1|$ (in the range of 4 - 15 kHz for SES-2000 medium) is generated which is low enough to penetrate the seafloor. The reflected primary-frequency signals can be used for exact determination of water depth even in difficult conditions, e.g. seafloor covered by soft sediments. The new (difference) frequency F is traveling within the emission cone of the original high frequency waves, which is limited to an angle (α , Fig. 5.1) of only $\pm 1^\circ$ for the SES-2000 medium system. The resulting footprint size of only $< 3.5\%$ of the water depth is much smaller than for conventional systems and both vertical and lateral resolution is significantly improved. The vertical resolution of the SES-2000 medium system is up to 5 cm depending on pulse settings. The maximal pulse repetition rate is 30/sec. so that it even resolves small-scale bottom structures.

The SES-2000 sub-bottom profiler is equipped with a software package from INNOMAR Technology GmbH for online data acquisition and for converting the SES-2000 data into other data formats. The "SES for Windows" (SESWIN) software supports the operator in running the system properly by system configuration and system control during the survey as well as the visualization of the digital echograms (Fig. 5.1). The SES Convert software is designed to convert the data acquired by the SES-2000 into the SEG-Y or XTF data format to be used with third-party post-processing software. The ISE post-processing software for data acquired using the SES-2000 allows, among others, layer editing and export to ASCII data, extended signal processing capabilities, data conversion and data export filters, tide, water sound velocity and GPS z-level corrections, and enhanced printing modes for data presentation.

5.1.3. Operations

On cruise P457, the SES-2000 medium system was the major tool to identify suitable sites for coring (i.e. undisturbed sediment successions). The shelf and slope south of Iceland is strongly affected by rivers, jökulhlaups, debris flows, etc. Therefore, appropriate coring sites are rare and in many cases their identification requires extensive sub-bottom profiling. Altogether, 11 sediment echo sounding surveys with a total length of c. 425 nm have been conducted during this expedition. The average cruising speed on the surveys was reduced to c. 5 kn to receive data in optimal quality. Whenever possible profiling have been conducted at night-time to save the working time during the day for station work. The SES-2000-medium system worked properly and delivered data in excellent quality during the entire cruise P457, even in poor weather conditions. Survey tracks, waypoints, digital echograms, and locations of the sites selected for the coring stations are shown in Appendix II. Further processing and evaluation of the SES-2000 data and echograms is planned within the next two years to complement the investigations of the sediment cores.

5.2. CTD + ROSETTE

Along the cruise track of P457, seven locations were chosen to obtain large volume (20l) water samples from different water depths for later determination of dissolved neodymium isotopic compositions and rare earth element (REE) concentrations. To achieve this, the ships own rosette equipped with twelve 10 l-Niskin bottles and a CTD profiler (TYPE Seabird SBE) was used. Salinity, temperature and oxygen concentrations were plotted in real-time against water depth and bottles were electronically triggered to close at given depth on the up-casts of the water column profiles. In this mode of operation, 38 water samples (Table 5.1) from depth of interest along the southern coast of Iceland were retrieved.

Tab. 5.1: Water column sampling at CTD stations during P457 of R/V POSEIDON.**883-2CTD at 64°30.017' N/ 23°29.964'W**

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	120	7.5	35.14
3 + 4	75	8.2	35.11
5 + 6	25	10.4	34.60
7 + 8	10	10.6	34.52

889-3CTD at 63°2.303'N / 23°22.546'W

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	952	4.7	35.03
3 + 4	800	5.3	35.06
5 + 6	600	6.5	35.13
7 + 8	350	7.7	35.17
9 + 10	100	8.2	35.17
11 + 12	10	11.1	35.08

890-1CTD at 63°9.983'N / 22°40.002'W

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	287	7.7	35.19
3 + 4	180	8.0	35.19
5 + 6	75	8.6	35.15
7 + 8	25	10.8	35.09
9 + 10	10	11.1	35.08

899-1CTD at 63°20.421'N / 17°56.821'W

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	136	8.0	35.20
3 + 4	75	8.2	35.19
5 + 6	5	11.5	34.84
7 + 8	20	11.1	35.02

903-1CTD at 63°0.790'N / 17°29.228'W

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	1174	4.5	35.06
3 + 4	950	5.0	35.07
5 + 6	700	7.1	35.17
7 + 8	350	8.3	35.22
9 + 10	100	8.7	35.21
11 + 12	10	11.8	35.05

905-1CTD at 62°41.160'N / 14°21.097'W

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	1582	2.4	34.99
3 + 4	1300	4.3	34.97
5 + 6	950	6.5	35.14
7 + 8	500	8.5	35.25
9 + 10	100	9.0	35.23
11 + 12	15	11.5	35.21

913-2CTD at 64°10.681'N / 12°43.355'W

Bottle	Depth (m)	Temperature (°C)	Salinity (psu)
1 + 2	463	1.9	34.92
3 + 4	430	3.4	35.03
5 + 6	360	4.4	34.99
7 + 8	230	8.3	35.25
9 + 10	100	8.8	35.26
11 + 12	15	10.3	35.04

On deck, tubing was attached to the bottom vents of each bottle and water samples were collected in pre-cleaned 20 l-HDPE containers. Subsequently, samples were filtered through 0.45 µm-HDPE containers. Subsequently, samples were filtered through 0.45µm nitrocellulose

filters and acidified to a pH of 2 using 20ml distilled concentrated hydrochloric acid for each 20l seawater sample. After one day, the pH was checked again and eventually adjusted, and samples were finally sealed and stored at room temperatures.

To investigate the various processes and effects that Iceland has on the neodymium isotopic composition of the surrounding waters, sampling locations were chosen to be located on the Icelandic shelf as well as above the continental rise (Fig. 5.2) covering water depth between 130m and 1560m.

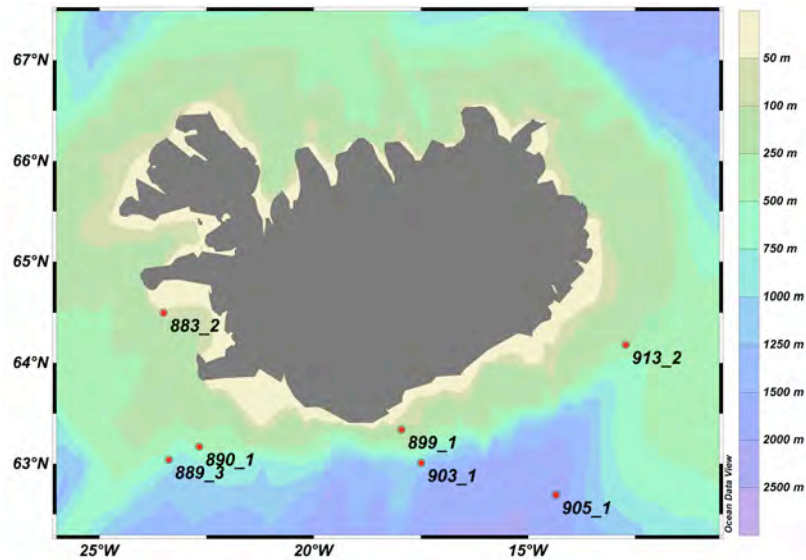


Fig. 5.2: Water sampling stations during P457 of R/V POSEIDON.

5.3. GIANT BOX CORER



Fig. 5.3: Handling of the giant box corer on deck R/V POSEIDON.

Due to potential lost of the top surface sediments by gravity coring, sampling was completed with a giant box corer (Fig 5.3). During research cruise P457, 14 giant box corers were deployed of which 11 were successful. The giant box corer (~1.5 tons) is equipped with a replaceable box and is able to retrieve an undisturbed sediment body of 60 x 60 x 60 cm. The giant box corer was attached to the same winch as the gravity corer. It was lowered with 0.5 - 1.2 m/s and heaved with 1m/s. On deck, documentation started with taking pictures of the top

and the front of the sediment body, and a detailed lithological description (Appendix III). The sampling was carried out with 3x gravity core liner. The overall core recoveries of the different devices in the different working areas are shown in Table 5.2.

5.4. GRAVITY CORER

During research cruise P457 with R/V POSEIDON, 19 gravity corers (Fig. 5.4) with core barrel lengths between 5 and 10 m (GC) were conducted. 9 successful deployments resulted in a total core recovery of 59.52 m. Nine deployments were not successful. The gear types and length of the coring devices were chosen based on detailed acoustic sediment mapping performed with the SES 2000 PARAMETRIC echo sounding system prior to coring. Acoustic patterns such as the strength of characteristic reflectors, their spacing, and the total sub-bottom penetration were taken into account (see Chapter 5.1). The GEOMAR gravity corer onboard R/V POSEIDON can be fitted with a core barrel up to 10 m in length (in 5 m increments). The core diameter is 12.5 cm. On R/V POSEIDON, the gravity corer was deployed with an 18 mm steel cable attached to the ship's winch. The gravity corer applied has a core diameter of 12.5 cm and a barrel of ~2.0 tons. It was lowered with 0.7 – 1.2 m/s to the seafloor. The device remained on the seafloor for about 30 seconds in order to allow for deep penetration, and was then pulled out with a speed of 0.1 m/s. Heave velocity was 1.0 m/s.



Fig. 5.4: *Deployment of the gravity core from R/V POSEIDON*

5.5. CORE HANDLING

The PVC-core liners of the gravity cores and giant box corer were orientated, then labeled, and cut into 1 m sections (gravity coring).. Each section was split into working and archive halves. The sediment surface was cleaned and smoothed before lithological description started. Color reflectance measurements were taken from the archive half. The archive halves were then packed into plastic D-tubes and stored at ~4°C in the reefer (cooling container) onboard R/V POSEIDON. Liners and D-Tube caps contain the following information:

- Core number (e.g., POS457-901-2 GC)
- "A" for archive half, "W" for working half
- Arrow pointing to base with depths of section top and base
- Top and base of each section is marked with "Top" and "Base/Bottom", respectively, and the continuous depth alongside the core.

Sediment cores were opened and partly selected for on-board double sampling. Cores were cut at 1 cm resolution in 1 cm slices (Table 5.2) Then, samples were separated into c.1 cm³ of sediment for the volcanologist and the remaining part for paleoceanographic approaches.

Tab. 5.2: Sediment core recovery during cruise P457 of R/V POSEIDON.

Area	Device	Station	Recovery [cm]	Sampled
1	GC	886-1	414	
1	GC	886-2	1015	
1	GBC	886-3	45.5	
2	GBC	888-1	44 - 52	
2	GC	888-2	376	
2	GC	889-1	888	x
2	GBC	889-2	44	x
3	GBC	892-1	7.5 - 16	
3	GC	892-2	0	
3	GC	892-3	0	
3	GC	892-4	0	
3	GC	893-1	0	
3	GC	894-1	0	
3	GC	895-1	0	
3	GC	896-1	0	
3	GC	897-1	0	
4	GC	899-2	5 (CC)	
4	GBC	899-3	23.5 - 25	
5	GBC	901-1	9	
5	GC	901-2	1014	
5	GC	905-2	886	
5	GBC	905-3	38 - 42	
6	GBC	908-1	21 - 22	
6	GBC	909-1	13- 17	
6	GC	909-2	758	
7	GC	911-1	0	
7	GBC	911-2	13 - 15	
7	GBC	912-2	0	
7	GBC	913-1	0	
7	GBC	914-1	0	
8	GBC	916-1	42 - 43	
8	GC	916-2	18	

5.6. SHIPBOARD CORE LOGGING: MINOLTA COLOR-SCAN

A hand-held Konica Minolta CM 600d spectrophotometer was used to measure the light reflectance of sediment core surfaces immediately after opening of the core (Fig. 5.5). The core surface was covered with plastic foil. Eventually enclosed air-bubbles between the plastic foil and the sediment were carefully removed. Measurements were carried out every 1 cm by placing the device directly on the core surface.

The spectrum of the reflected light is measured by a multi-segment light sensor, measuring at a 20 nm pitch between wavelengths of 400 to 700 nm. A double-beam feedback system automatically compensates variations in the illumination from the CM 600d's pulsed xenon arc lamp. Routine measurements were automatically recorded using Minolta's Software Spectra Magic v. 2.3.

Before each core segment was measured, the spectrophotometer was calibrated for black colors using "zero calibrated" and for white color reflectance. This color calibration was done to avoid variation in color readings due to changes in the laboratory environment (e.g. temperature, humidity, and background light) and instrument variations.

From the reflectance data, the standard color-values X, Y, and Z are automatically calculated by the software Spectra Magic, which are displayed in the L*, a* and b* CIELAB color coordinates. For all cores, the according data records are shown in Appendix V. Most valuable for the interpretation of our sediments were the L*, a*, and b* values. The L* value represents lightness and can be directly correlated to gray value measurements. The b* value reflects the ratio of blue and yellow colors and hence, is most likely indicative for cyclic changes in biogenic silica production. The a* value reflects the ratio of green and magenta.



Fig. 5.5: Core logging with hand color scanner Minolta CM 600d on board R/V POSEIDON.

5.7. NOMENCLATURE

Sediment names consist of a principal name related to the major grain size component. During expedition P457, we only encountered unconsolidated terrigenous, siliciclastic sediments. For siliciclastic sediments, the principal name describes the texture (gravel, sand, mud (silt+clay)) based on the Udden-Wentworth grain-size scale (Wentworth, 1922).

Additional information in the core description logs includes the location and nature of sedimentary structures, the occurrence of ichnofossils, the degree of bioturbation, and accessories (such as pyrite, iron sulfides, laminae, shell fragments, etc.) The symbols used to designate structures found in each core are shown in Appendices III and IV (core description).

Sediment colors were determined with the Minolta spectrophotometer. We included the a*-records (green to magenta) into the lithology logs. Core sections were photographed using a digital camera (Nikon D3100). The single images were arranged for each core.

6. PRELIMINARY RESULTS

6.1. CTD-PROFILING AND ROSETTE

6.1.1. Hydrographic Measurements and Preliminary Results

The surface layer down to c. 40 m water depth consists of relatively warm waters ranging between 10°C and 12°C at all CTD-profiling stations of P457 (Fig. 6.1). The upper 10 m of this layer consist of relatively fresh waters with salinities between 30 and 33, presumably caused by precipitation, melt water, and river runoff. Below this layer, a sharp thermocline is developed and temperatures drop to c. 8°C at 80 m (stations 883-2 and 899-1) and 130 m at station 890-1.

Beneath the thermocline a layer with a mean temperature of $T = 8^\circ\text{C}$ and a mean salinity of $S = 35.2$ is found. According to Van Aken and De Boer (1995) this water type is called Sub-polar Mode Water (SPMW) and is formed by wintertime convection. SPMW has high oxygen values (270 $\mu\text{mol/kg}$) compared to the underlying colder waters. Figures 6.1 and 6.2 show that the lower limit of SPMW is clearly marked by an oxygen decrease of 30–40 $\mu\text{mol/kg}$ to a mean value of 240 $\mu\text{mol/kg}$. With that taken into account, SPMW ranges until a depth of 700 m at station 905-1, whereas at station 889-1 its lower boundary is already found at a water depth of 415 m (Fig. 6.2).

Accompanied by the drop of oxygen concentrations, temperatures and salinity values decrease with increasing water depth. At stations 889-3 and 903-1, water mass characteristics above the seafloor are $\theta \approx 4.7^\circ\text{C}$ and $S \approx 35.04$. Referring to Van Aken and De Boer (1995), this water mass can be called Icelandic Slope Water (ISW) and is mainly a mixture of SPMW and Iceland Scotland Overflow Water (ISOW) (Fig. 6.3). ISW can be encountered at intermediate and deep water levels over the Icelandic and Reykjanes slopes.

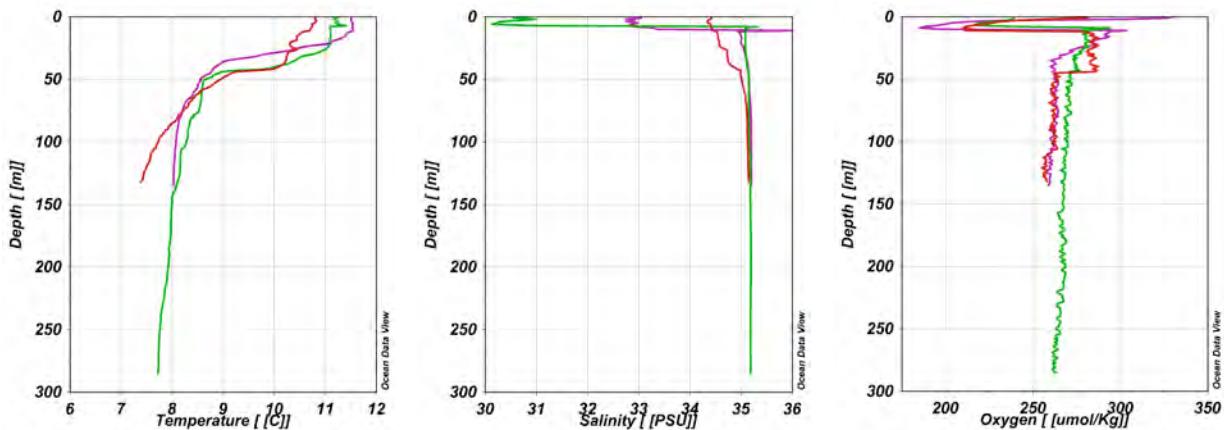


Fig. 6.1: Temperature (left), salinity (middle) and oxygen (right) versus water depth from the shallow stations 883-2 (red), 890-1 (green) and 899-1 (purple) of P457.

Bottom waters at stations 905-1 and 913-2 show different characteristics and indicate the presence of ISOW. ISOW is a mixture of different types of Arctic Intermediate Water that entrain overlying SPMW while overflowing the Iceland-Faroe Ridge into the Iceland Basin. At Station 913-2, located above a depression at the western end of the Iceland-Faroe Ridge, bottom waters with $\theta \approx 1.95^\circ\text{C}$ and $S \approx 34.9$ were observed at a water depth of 455 m. At the deeper Station 905-1 (1,560 m), located in the northeastern Iceland basin, bottom waters with only slightly altered characteristics are present. Temperature and salinity are altered to $\theta \approx 2.30^\circ\text{C}$ and $S \approx 35.0$, which indicates a further mixing with the overlying SPMW.

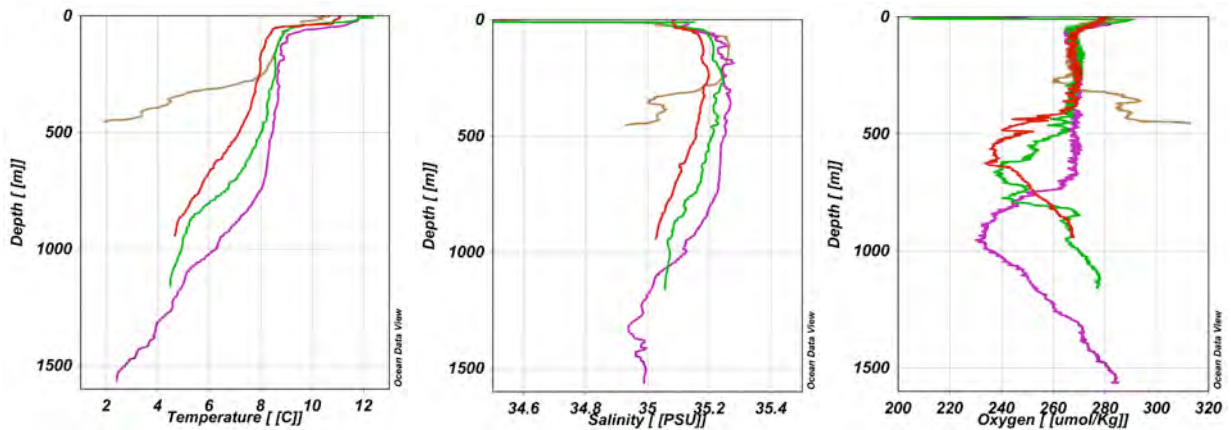


Fig. 6.2: Temperature (left), salinity (middle) and oxygen (right) versus water depth from the stations 889-3 (red), 903-1 (green), 905-1 (purple) and 913-2 (brown) of P457.

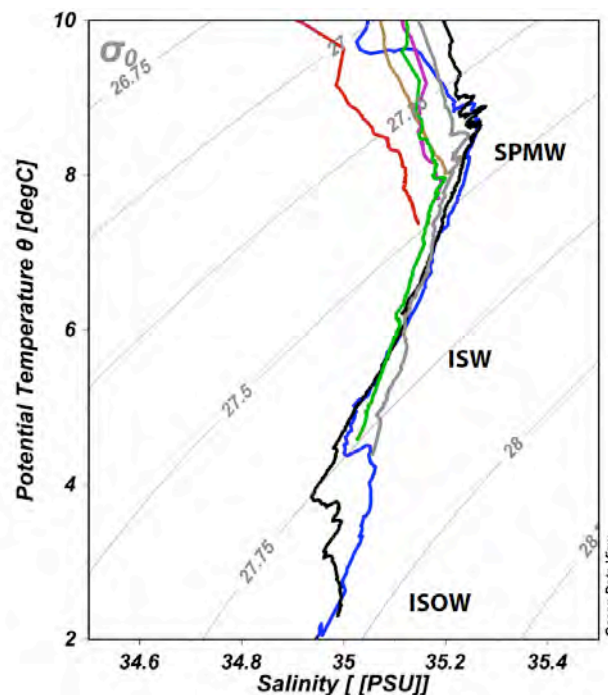


Fig 6.3: Temperature versus salinity from all P457 CTD stations: 883-2 (red), 889-3 (green), 890-1 (purple), 899-1 (brown), 903-1 (grey), 905-1 (black), and 913-2 (blue). Different water masses are indicated: SPMW = Subpolar Mode Water; ISW = Iceland Slope Water; ISOW = Iceland Scotland Overflow Water.

6.2. SEDIMENT FACIES AND RESULTS

Preliminary interpretations of the sediment facies are based on sedimentological properties, as well as color-scan data and visual inspection of the cores. The graphical core descriptions (lithology strip logs performed with AppleCORE version 10.1t by Mike Ranger, 2011) and photographs (Nikon D3100) can be found in the Appendix III and IV.

We retrieved sediment cores (gravity cores) and surface sediment samples (giant box cores) from the southern part of Iceland from seven working areas (Figs. 4.1. and 4.8):

- Area I: West of Iceland / south of Snæfellness (886)
- Area II: Southeast of Reykjanes Ridge (889), south of Reykjanes Ridge (888)
- Area III: Surtsey, south, northwest, and north
- Area IV: South of the central Icelandic south coast, deep (902, 901) and shallow (899)
- Area V: South of the Icelandic shelf/west of Iceland-Färöer-Ridge, deep (905)
- Area VI: South of Iceland on Iceland-Färöer-Ridge, deep (909) and shallow offshore (908)

Area VII: SE-Icelandic shelf and shelf slope, deep (913, 911) and shallow station (914, 912)

Area VIII: Eastern Icelandic shelf, southern flank of small “Channel” (916)

6.2.1. Sediment facies

We basically differentiated between 4 major siliciclastic lithologies present in our P457 sediment cores: Sand, clayey silt, clayey sandy silt, sandy clayey silt, and volcanic ashes. The formation of these sediment types is either in dependence of bottom currents, climatic changes and/or volcanic eruptions.

Siliciclastic sediments

Most distinct at core locations 889, 901, 905 and 909, the sediment surface consists of a dark greyish brown sandy silt enriched in shell fragments (snails, foraminifera, mussels) and rusty (Fe-, Mn-oxides) particles. Partly, the surface sediment is formed in elongated ripples. In addition to these ripples, the missing fine fraction points to a restsediment, which is indicative of strong currents in water depths of ~720 to ~1,600 m along the Iceland margin.

Below the sediment surface, the strongly bioturbated sandy silt remains light brown down to 20–40 cm core depth, changing downcore into the typical dark olive grey sandy clayey silt. The light colors imply oxygenated conditions and higher biogenic carbonate concentrations. According to the preliminary stratigraphy (see Chapter 6.2.2), these sediments belong to the Holocene. Color scan a^* values commonly increase to 2 to 4.

Similar interglacial sediments occur in core 909 at ~470 - 500 cm core depth, with light brown sandy clayey silt intercalated by many dark greyish brown sand layers, pointing also to restsediment formation and strong bottom currents. The preliminary stratigraphy (see Chapter 6.2.2) relates these sediment to Marine Oxygen Isotope Stage 5. Core 909 apparently is the only core recovered during P457, which reaches to below MIS 5.

Below the interglacial sediments, the typical glacial sediment found in our cores is clayey silt and silty clay with varying portions of (volcanic) sand, with colors from blackish grey to dark olive grey. It is relatively soft in the upper core sections, while becoming stiff and increasingly dry downcore. Bioturbation is mostly strong, with large burrows (centimeter in diameter) filled with sediment from above leading to an often patchy appearance of the sediment. Bioturbation implies an intensive benthic life and oxygenated conditions at the seafloor. Calcitic biogenic fragments and benthic foraminifera (found by visual inspection with a binocular) are common. The upper and lower contacts of these glacial-type sediments are commonly gradational, changing to a „transitional“ type of sediment, which becomes less dark and less bioturbated and changing into the typical interglacial sediment. The lightness L^* (D65)-values commonly range between 25 and 40, b^* values (blue to yellow) are around 5, and the a^* values (green to magenta) are between 0 and -2. The sediments are often intercalated by black volcanic sand and gravel layers up to a few centimeter in thickness. In many cases, the basal contact is sharp and even, while the upper contact is wavy and mostly bioturbated. The differentiation into slumps originating from downslope mass transport and volcanic fallout could not be made in most instances. Only in a few cases, volcanic tephra layers could be identified doubtlessly, due to composition and internal structures like upward fining sequences. Partly, the glacial sediment is diagenetically overprinted, indicated by stiff layers of bluish black to dark olive grey clay.

Large gravel and stones up to 8 cm in diameter entrained in the fine hemipelagic sediment are common in all cores. These “dropstones” are granitic and metamorphic (gneiss, schist) rocks, and most presumably iceberg-transported from Fennoscandia, Greenland and/or North America. Most prominent boulders leave prominent color-scan signals (e.g., cores 905 and 909), which according to our preliminary age model (see below) belong to Heinrich Events 2 and 6.

Notably, gravity core 889 from east of Reykjanes Ridge at 925 m water depth exhibits fine-layered to laminated sediment sequences from ~3 to ~9 m core depth. These sediments are most likely of glacial age pointing to calm and suboxic to anoxic bottom water conditions.

6.2.2. Correlation of lightness records along the Iceland margin

In particular the Minolta color scan L^* (D65), b^* (blue to yellow), and a^* (green to magenta) data (Appendix V) allowed for the detailed correlation of selected sediment cores along the Iceland margin. We tentatively assigned L^* (D65), b^* , and a^* maxima to warm (interglacial)

marine isotope stages. Conversely, low L^* (D65), b^* , and a^* intervals indicate the carbonate-low, most likely cool climatic phases.

Core correlation is an important step towards the establishment of a reliable core chronostratigraphy in the Iceland area. Figures 6.4 and 6.5 demonstrate our tentative attempt to correlate selected sedimentary records along the Iceland margin from ca. 24°W to 12°W. Initially, the correlation of cores is based on the assumption that the thick sediment sequences characterized by maximum a^* -values followed by two distinct peaks found in cores P457-886, -888, -889, -901, and -902 formed synchronously, an assumption that needs to be verified later. The prominent peaks and lows in the remaining data records could then be easily matched. As we still have no age control on our records, cores P457-886, -888, -901, and -902 were related to core P457-889 in the depth scale only (Figs. 6.4 and 6.5). As a^* -values generally remain low, we may speculate that these cores mainly cover glacial periods. Only the top sections of cores 889 and 901 may have reached the earliest Holocene. The correlation of a^* data from the different working areas implies that sedimentation rates vary highly along the Iceland margin, with deep sites often exhibiting higher sedimentation rates than shallower sites and *vice versa*. Interestingly to note is that distinct volcanic ash layers can apparently be traced in our cores across the entire working areas.

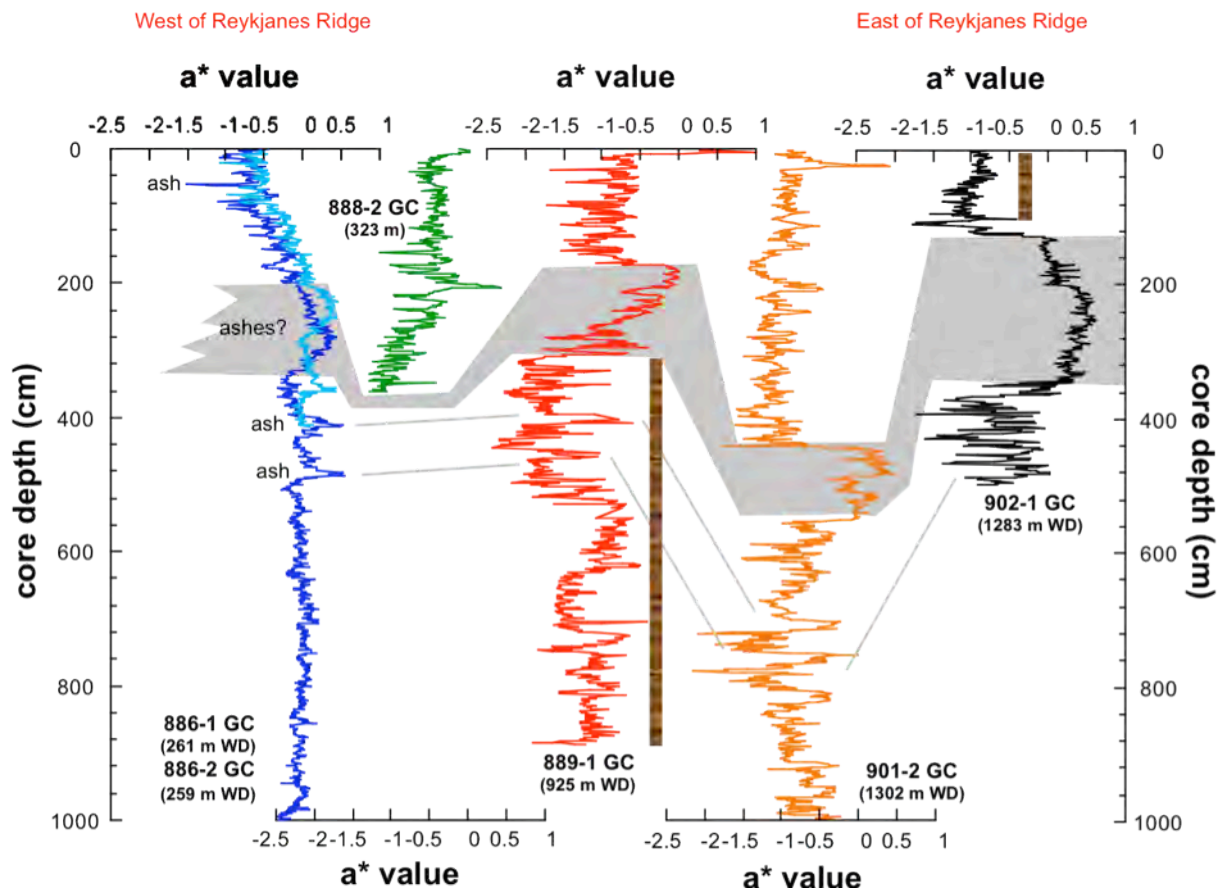


Fig. 6.4: Preliminary core correlation along the Iceland margin from west (~24°W, left) to east (~12°E, right). The Minolta color a^* data, which reflect the varying green to magenta portions of the sediments, appeared valuable for correlation purposes, as downcore patterns were rather similar at core locations POS457-886, -888, -889, -901, and -902 (from west to east). The shaded area and gray lines mark the prominent a^* -excursions used for core correlation. The vertical bars indicate fine layering/lamination.

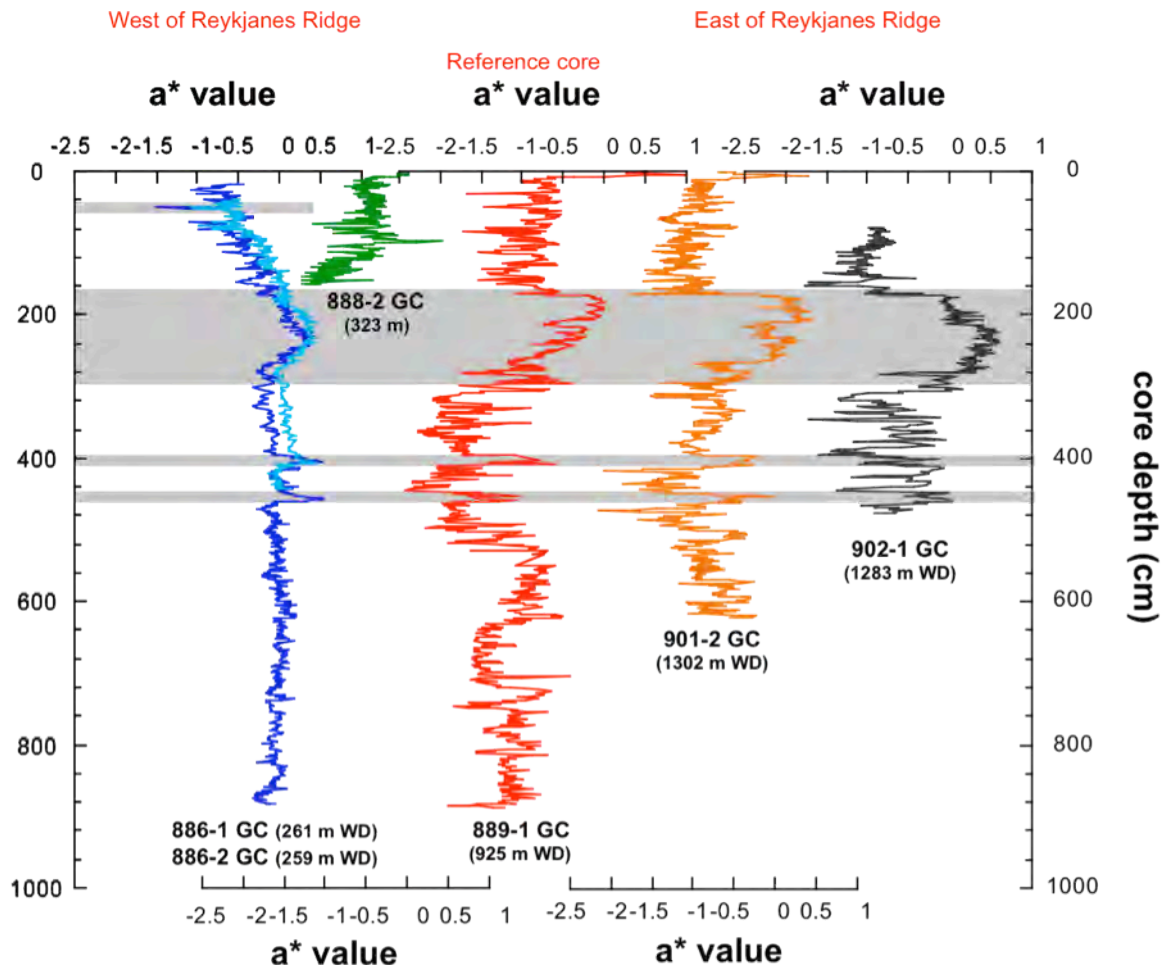


Fig. 6.5: Correlation of a^* -records from the southern Iceland margin, using *AnalySeries2.1* (Paillard et al., 1996). All records were tuned to sediment core 889-1 in the depth scale. The shaded areas mark the prominent a^* -excursions used for initial core correlation.

In particular, gravity core 909-2 shows distinct lithological variations, volcanic tephra and sand layers, as well as large dropstones, expressed in pronounced changes in color. As described above, this core most likely extends back in time the most, with a light brown interglacial sediment sequence at ~5 m core depth. In a tentative approach, we related the color b^* -record of core 909-2 to the North Greenland Icecore Record NGRIP (North Greenland Ice Core Project Members, 2004). The NGRIP climate record serves as a dated reference record to which the core 909 b^* -record was tuned and hence, allowed to convert core depth into age (Fig. 6.6). According to this stratigraphical attempt, the 5 m depth level in core 909, described as light brown interglacial sediment, relates to ~120,000 years BP (Marine Oxygen Isotope Stage 5.5).

In a further step, we related the b^* -record of core 905 to the dated b^* -record of core 909. The close match allowed to establish similarly an age model for core 905. According to this approach, the sedimentation rates of the deeper core 905 from ~1,600 m water depth has twice as high sedimentation rates as the shallower core 909 from ~750 m water depth, possibly due to pronounced downslope mass transport on the one hand and severe erosion at shallow water depths due to bottom currents on the other hand.

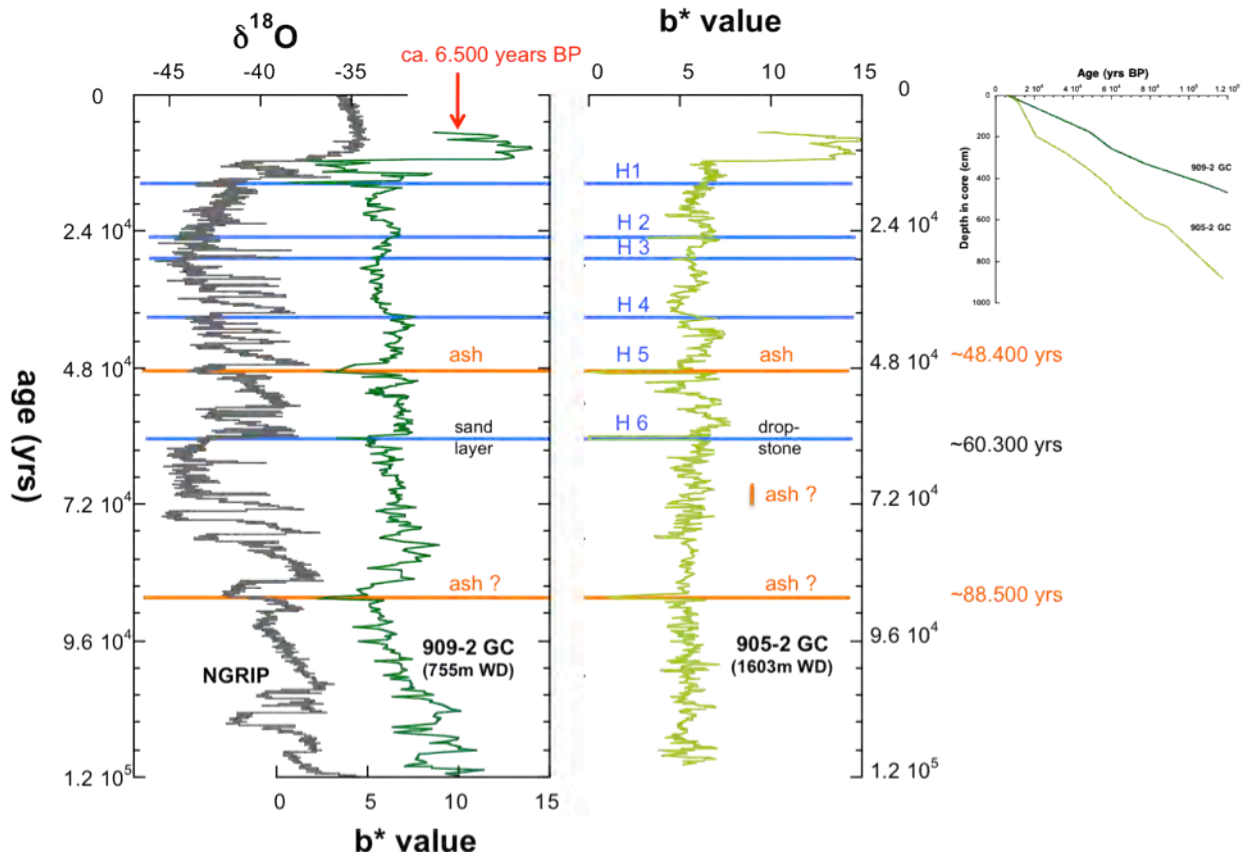


Fig. 6.6: Tentative age models for gravity cores 909 and 905 from south and southeast of Iceland. The age models were established by relating the b^* -record of core 909 to the NGRIP reference record (North Greenland Ice Core Project Members, 2004), and subsequently by relating the b^* -record of core 909 to that of core 905. Distinct ash and sand/gravel layers occurring in both records are indicated, Heinrich Events 1 to 6 are marked. The upper right diagram is the according depth/age diagram allowing to assess the sedimentation rates.

From the preliminary age models it becomes clear that the latest Holocene sediment sequences are not preserved in the gravity cores, but are present in the according GBCs. The distinct tephra layers seen in both cores date to ~48,400 yrs BP, which corresponds to Heinrich Event 5, and ~88,500 years BP. Distinct minima in the b^* -records of both cores reflecting sand and dropstone layers often appear synchronous, and can be correlated to Heinrich Events 6, 2, and 1. At selected locations, the formation of restsediment, ripple structures, and dead fauna at sediment surfaces imply that the latest Holocene is not preserved.

7. REFERENCES

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Appendix I:

Sampling Summary / Station List

Appendix I (Station list)

Station no.	Device	Location	Recovery	depth (m)	lat °N dec.	long °W dec.	lat °N deg min	long °W deg min
CTD883/1	CTD	Area I - south of Snaæfellsnes	failed	-155	64,500	-23,499	64 30,03	23 29,92
CTD883/2	CTD	Area I - south of Snaæfellsnes	8 bottles	-156	64,500	-23,499	64 30,02	23 29,95
VER884/1	SES	Start Area I - south of Snaæfellsnes		-160	64,483	-23,500	64 29,00	23 30,00
VER884/1	SES	End Area I - south of Snaæfellsnes		-260	64,245	-24,086	64 14,71	24 5,17
VER885/1	SES	Start Area I - south of Snaæfellsnes		-215	64,364	-24,231	64 21,87	24 13,84
VER885/1	SES	End Area I - south of Snaæfellsnes		-240	64,310	-24,020	64 18,62	24 1,18
GC886/1	GC 5m	Area I - south of Snaæfellsnes	414 cm	-259	64,255	-24,141	64 15,30	24 8,46
GC886/2	GC 10m	Area I - south of Snaæfellsnes	1015 cm	-259	64,255	-24,141	64 15,32	24 8,47
GBC886/3	GBC	Area I - south of Snaæfellsnes	45 cm	-258	64,255	-24,140	64 15,28	24 8,41
VER887/1	SES	Start Area II - southeast of Reykjanes Ridge		-225	63,370	-23,650	63 22,20	23 39,00
VER887/1	SES	End Area II - southeast of Reykjanes Ridge		-315	63,278	-23,342	63 16,70	23 20,50
GBC888/1	GBC	Area II - southeast of Reykjanes Ridge	52 cm	-323	63,292	-23,567	63 17,50	23 33,99
GC888/2	GC 5m	Area II - southeast of Reykjanes Ridge	376 cm	-324	63,291	-23,570	63 17,44	23 34,17
GC889/1	GC 10m	Area II - southeast of Reykjanes Ridge	888 cm	-923	63,051	-23,387	63 3,04	23 23,19
GBC889/2	GBC	Area II - southeast of Reykjanes Ridge	44 cm	-922	63,051	-23,386	63 3,04	23 23,18
CTD889/3	CTD	Area II - southeast of Reykjanes Ridge	12 bottles	-970	63,038	-23,376	63 2,30	23 22,55
CTD890/1	CTD	Area II - southeast of Reykjanes Ridge	10 bottles	-312	63,158	-22,667	63 9,48	22 40,00
VER891/1	SES	Start Area III - Surtsey		-123	63,331	-20,739	63 19,88	20 44,36
VER891/1	SES	End Area III - Surtsey		-105	63,308	-20,658	63 18,50	20 39,50
GBC892/1	GBC	Area III - north of Surtsey	16 cm	-107	63,268	-20,620	63 16,07	20 37,20
GC892/2	GC 5m	Area III - north of Surtsey	empty	-107	63,319	-20,619	63 19,12	20 37,15
GC892/3	GC 5m	Area III - north of Surtsey	empty	-107	63,319	-20,620	63 19,11	20 37,22
GC892/4	GC 5m	Area III - north of Surtsey	empty	-107	63,319	-20,620	63 19,11	20 37,21
GC893/1	GC 5m	Area III - north of Surtsey	empty	-107	63,322	-20,611	63 19,34	20 36,68
GC894/1	GC 5m	Area III - north of Surtsey	empty	-111	63,319	-20,561	63 19,13	20 33,65
GC895/1	GC 5m	Area III - northwest of Surtsey	empty	-116	63,334	-20,691	63 20,05	20 41,48
GC896/1	GC 5m	Area III - south of Surtsey	empty	-138	63,270	-20,580	63 16,20	20 34,81
GC897/1	GC 5m	Area III - south of Surtsey	empty	-133	63,280	-20,590	63 16,77	20 35,40
VER898/1	SES	Start Area IV - off the central Icelandic south coast		-149	63,333	-18,022	63 20,00	18 1,29
VER898/1	SES	End Area IV - off the central Icelandic south coast		-150	63,332	-18,001	63 19,94	18 0,03
CTD899/1	CTD	Area IV - off the central Icelandic south coast	8 bottles	-156	63,340	-17,947	63 20,42	17 56,82
GC899/2	GC 5m	Area IV - off the central Icelandic south coast	empty	-157	63,340	-17,945	63 20,42	17 56,72
GBC899/3	GBC	Area IV - off the central Icelandic south coast	25 cm	-157	63,341	-17,946	63 20,44	17 56,78
VER900/1	SES	Start Area IV - off the central Icelandic south coast		-935	63,067	-17,666	63 4,03	17 39,95
VER900/1	SES	End Area IV - off the central Icelandic south coast		-1280	63,000	-17,666	63 0,00	17 39,95
GBC901/1	GBC	Area IV - off the central Icelandic south coast	53 cm	-1292	63,027	-17,488	63 1,61	17 29,27
GC901/2	GC 10m	Area IV - off the central Icelandic south coast	998 cm	-1299	63,021	-17,488	63 1,28	17 29,25
GC902/1	GC 5m	Area IV - off the central Icelandic south coast	500 cm	-1288	63,022	-17,466	63 1,31	17 27,98
CTD903/1	CTD	Area IV - off the central Icelandic south coast	12 bottles	-1186	63,013	-17,487	63 0,79	17 29,23
VER904/1	SES	Start Area V - south of the Icelandic shelf/west of Iceland-Färöer-Ridge		-1672	62,667	-14,498	62 40,00	14 29,85
VER904/1	SES	End Area V - south of the Icelandic shelf/west of Iceland-Färöer-Ridge		-1235	62,742	-13,917	62 44,50	13 55,03
CTD905/1	CTD	Area V - south of the Icelandic shelf/west of Iceland-Färöer-Ridge	12 bottles	-1602	62,686	-14,352	62 41,16	14 21,10
GC905/2	GC 10m	Area V - south of the Icelandic shelf/west of Iceland-Färöer-Ridge	886 cm	-1610	62,686	-14,353	62 41,13	14 21,15
GBC905/3	GBC	Area V - south of the Icelandic shelf/west of Iceland-Färöer-Ridge	42 cm	-1610	62,686	-14,352	62 41,13	14 21,09
VER906/1	SES	Start Area VI - south of Iceland on Iceland-Färöer-Ridge		-755	62,833	-13,000	62 50,00	13 0,00
VER906/1	SES	End Area VI - south of Iceland on Iceland-Färöer-Ridge		-665	62,908	-12,717	62 54,50	12 43,00
VER907/1	SES	Start Area VI - south of Iceland on Iceland-Färöer-Ridge		-415	63,333	-11,667	63 20,00	11 40,00
VER907/1	SES	End Area VI - south of Iceland on Iceland-Färöer-Ridge		-375	63,492	-11,519	63 29,49	11 31,15
GBC908/1	GBC	Area VI - south of Iceland on Iceland-Färöer-Ridge	22 cm	-411	63,420	-11,661	63 25,18	11 39,64
GBC909/1	GBC	Area VI - south of Iceland on Iceland-Färöer-Ridge	47 cm	-755	62,838	-12,993	62 50,28	12 59,56
GC909/2	GC 10m	Area VI - south of Iceland on Iceland-Färöer-Ridge	758 cm	-755	62,837	-12,991	62 50,20	12 59,47
VER910/1	SES	Start Area VII - southeastern Icelandic shelf and shelf slope		-676	63,950	-12,933	63 57,00	12 56,00
VER910/1	SES	End Area VII - southeastern Icelandic shelf and shelf slope		-565	64,095	-12,677	64 5,70	12 40,60
GC911/1	GC 5m	Area VII - southeastern Icelandic shelf and shelf slope	empty	-570	64,091	-12,685	64 5,47	12 41,08
GBC911/2	GBC	Area VII - southeastern Icelandic shelf and shelf slope	15 cm	-571	64,091	-12,687	64 5,45	12 41,19
GBC912/1	GBC	Area VII - southeastern Icelandic shelf and shelf slope	stones	-165	64,198	-12,974	64 11,85	12 58,44
GBC913/1	GBC	Area VII - southeastern Icelandic shelf and shelf slope	empty	-482	64,174	-12,729	64 10,41	12 43,73
CTD913/2	CTD	Area VII - southeastern Icelandic shelf and shelf slope	12 bottles	-481	64,178	-12,723	64 10,68	12 43,36
GBC914/1	GBC	Area VII - southeastern Icelandic shelf and shelf slope	stones	-261	64,186	-12,849	64 11,13	12 50,94
VER915/1	SES	Start Area VIII - eastern Icelandic shelf		-166	65,000	-12,333	65 0,00	12 20,00
VER915/1	SES	End Area VIII - eastern Icelandic shelf		-230	65,026	-11,733	65 1,56	11 44,00
GBC916/1	GBC	Area VIII - eastern Icelandic shelf	43 cm	-245	65,126	-12,166	65 7,54	12 9,94
GC916/2	GC 5m	Area VIII - eastern Icelandic shelf	30 cm	-253	65,124	-12,166	65 7,46	12 9,98

P457 deployments:

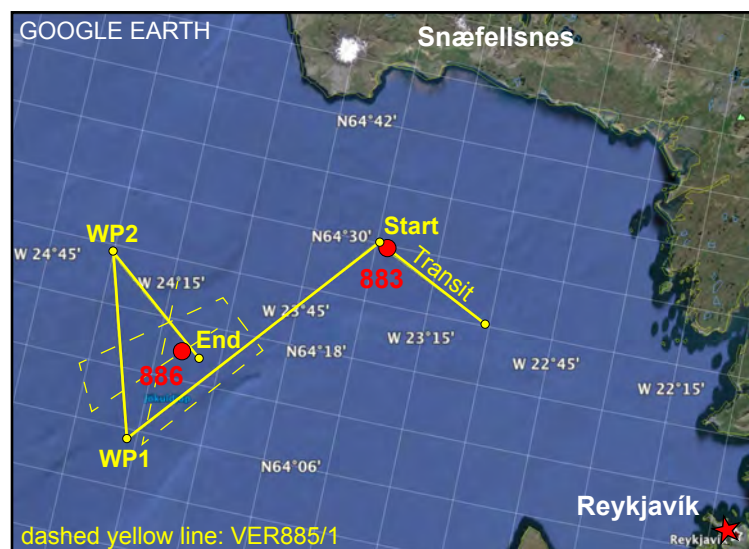
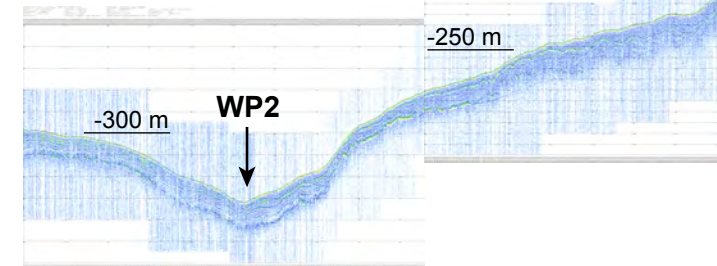
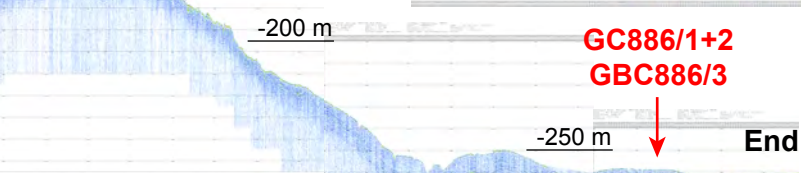
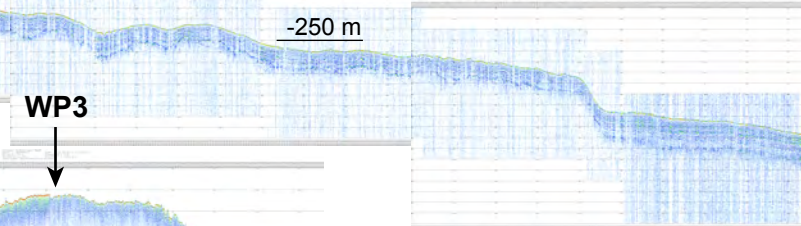
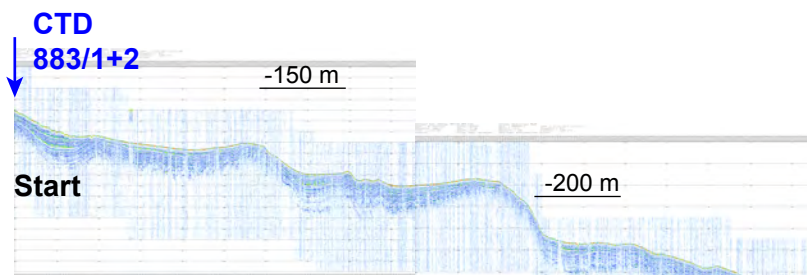
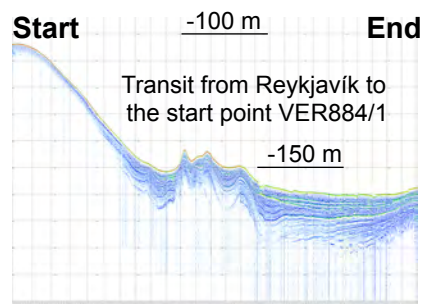
- 19 Gravity corer
- 14 Giant box corer
- 7 CTD
- 11 SES-2000 surveys (total c. 425 nm)

Abbreviations:

- GC Gravity corer
- GBC Giant box corer
- CTD Conductivity, temp., density + rosette water sampler
- SES Parametric sediment-echosounder SES 2000 medium

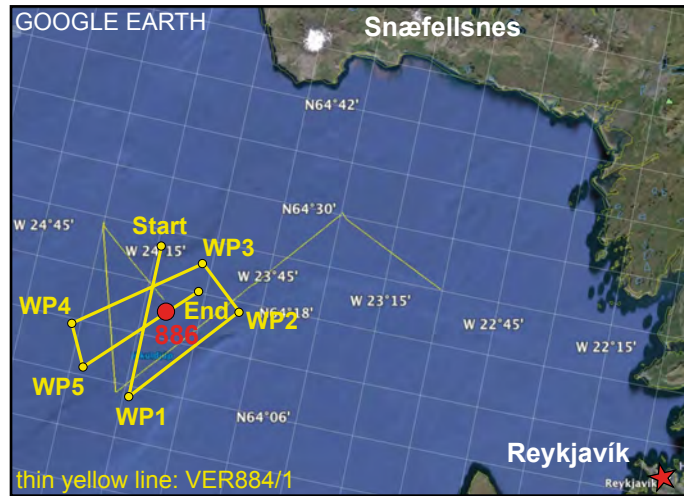
Appendix II:

Sediment Echosounding Surveys

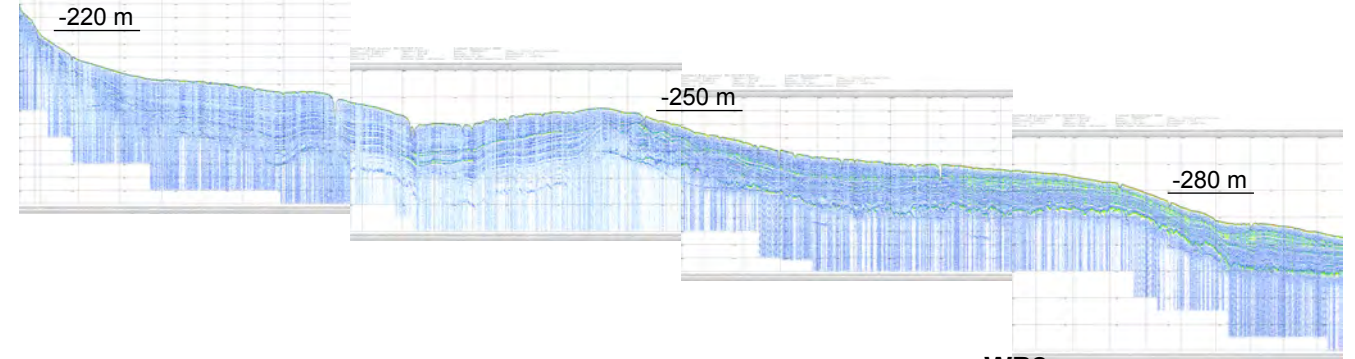


Survey interrupted due to bad weather conditions

VER 885/1 2nd Survey in Area I (south of Snæfellsnes)

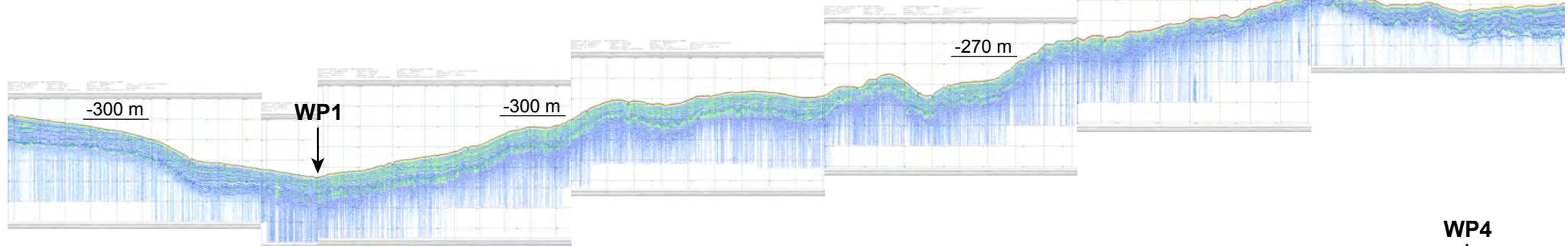


Start



WP2

-240 m



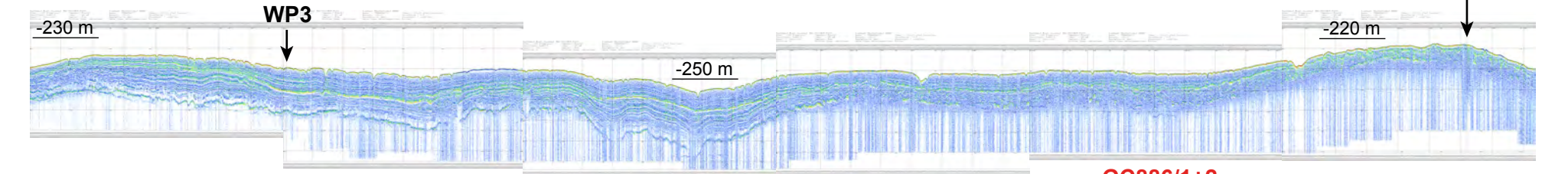
WP3

-230 m

-250 m

-220 m

WP4



GC886/1+2
GBC886/3

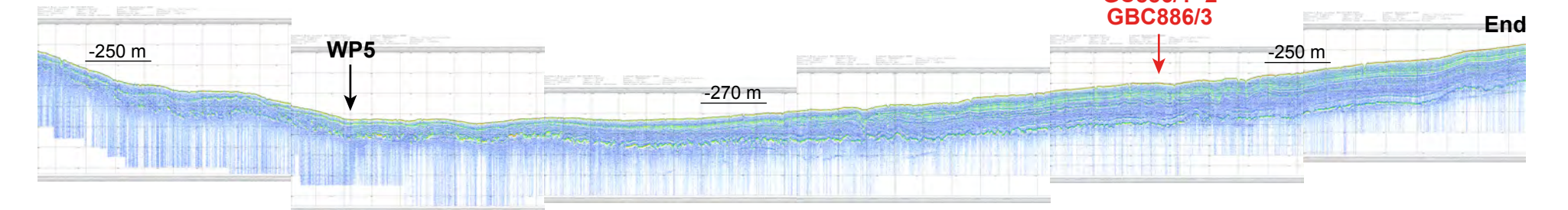
End

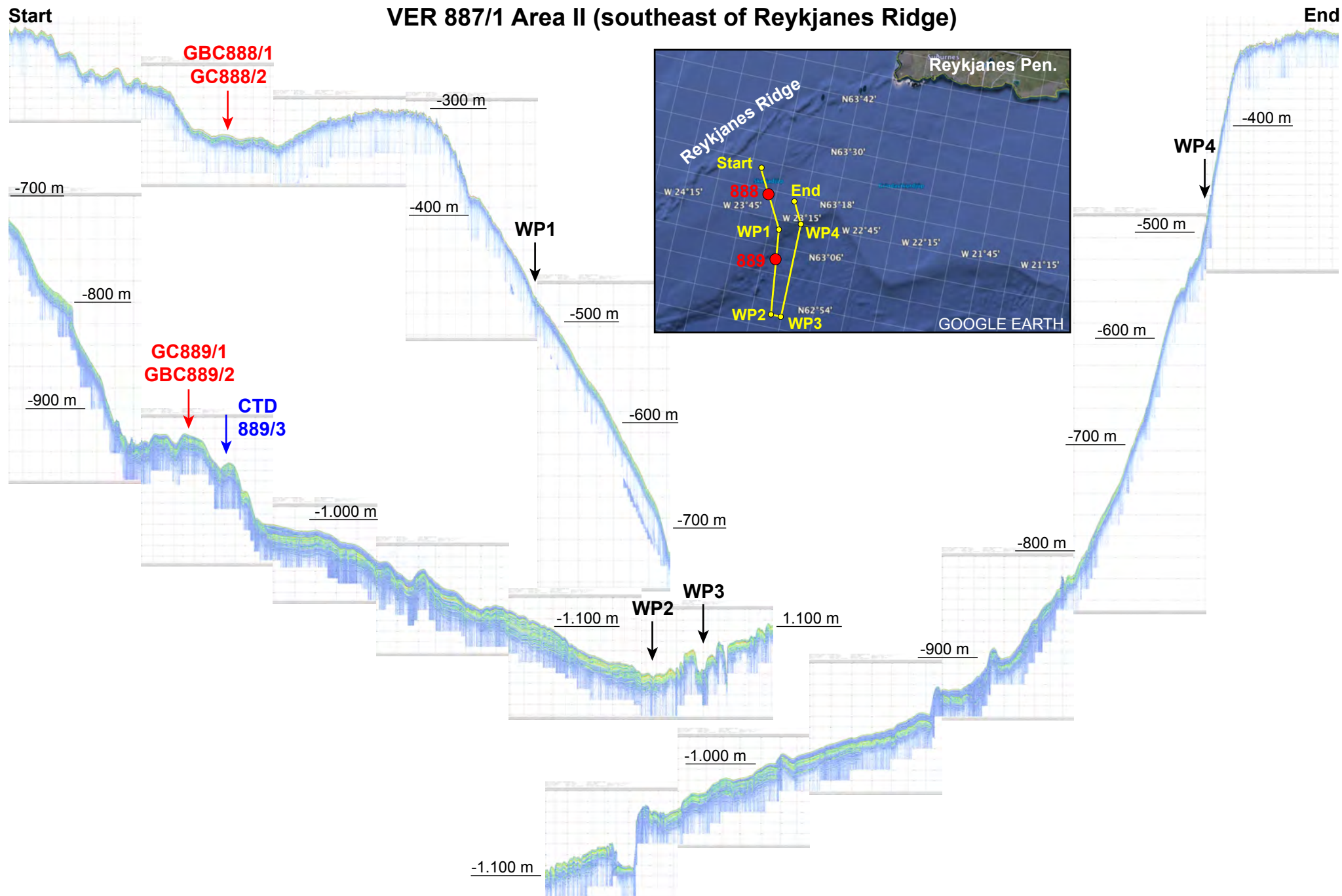
-250 m

-270 m

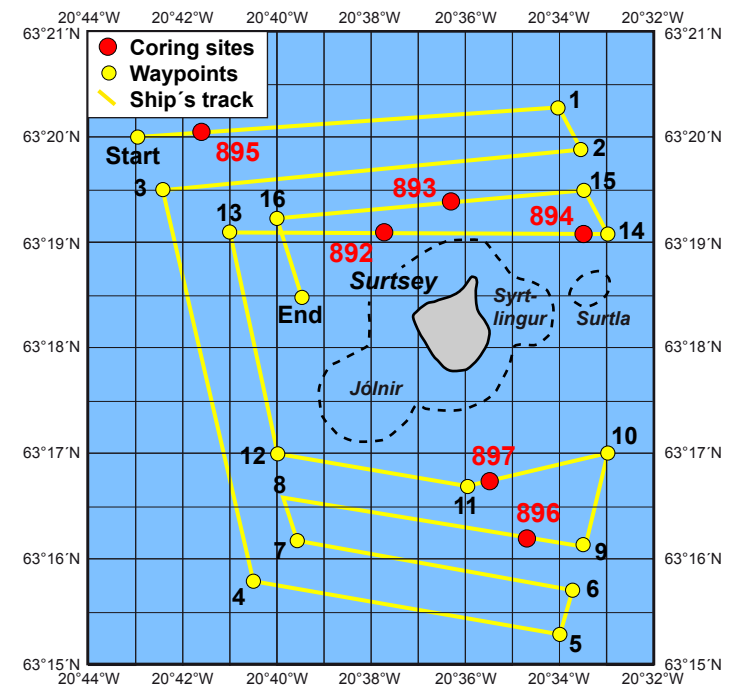
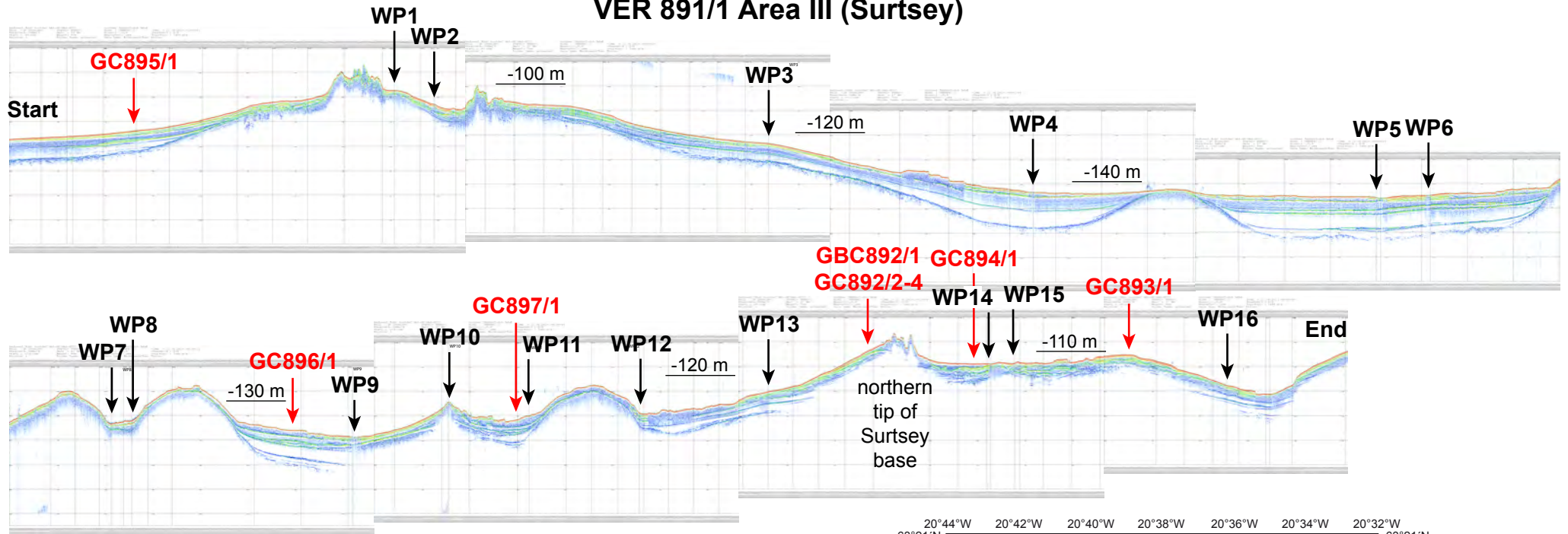
WP5

-250 m

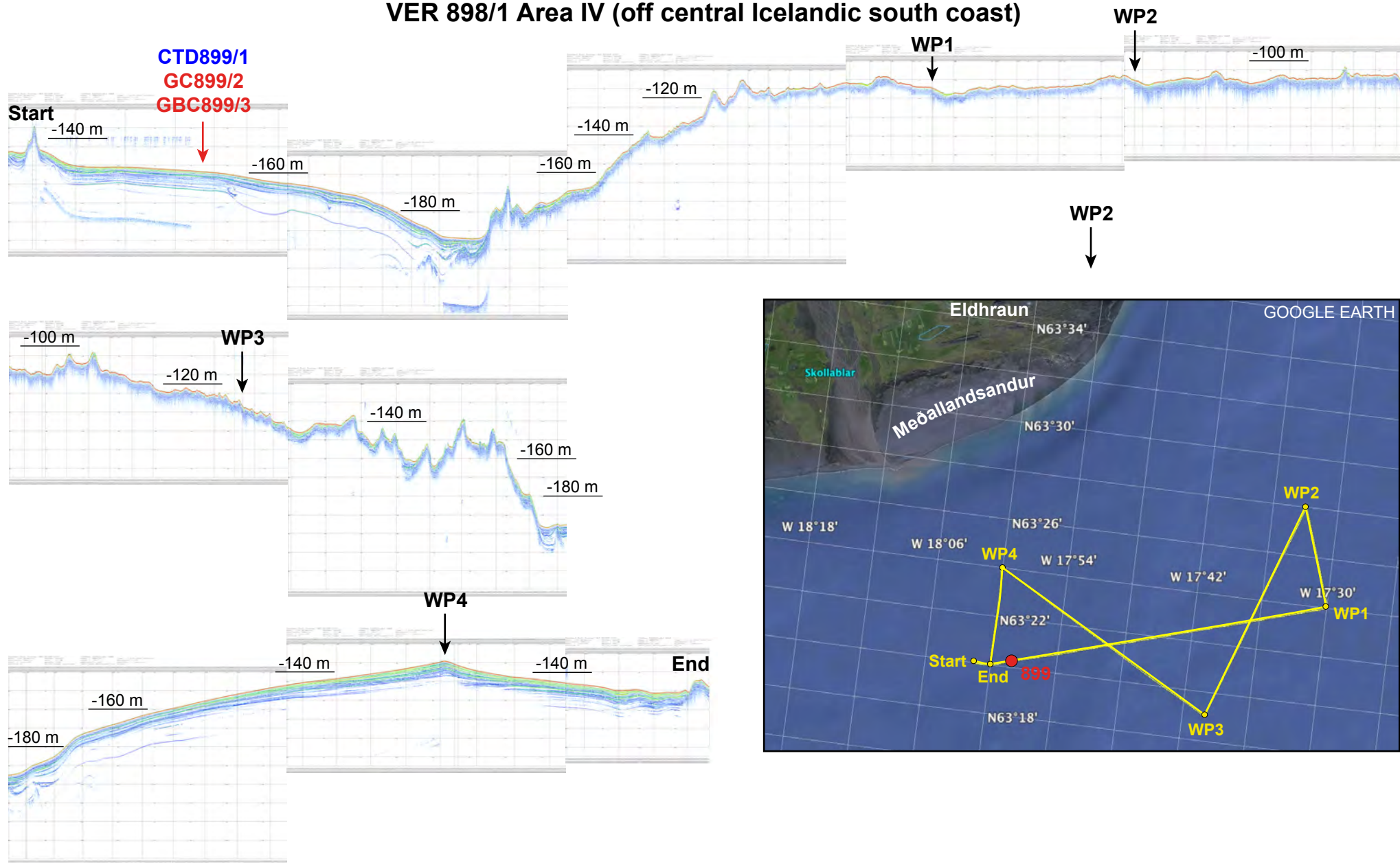




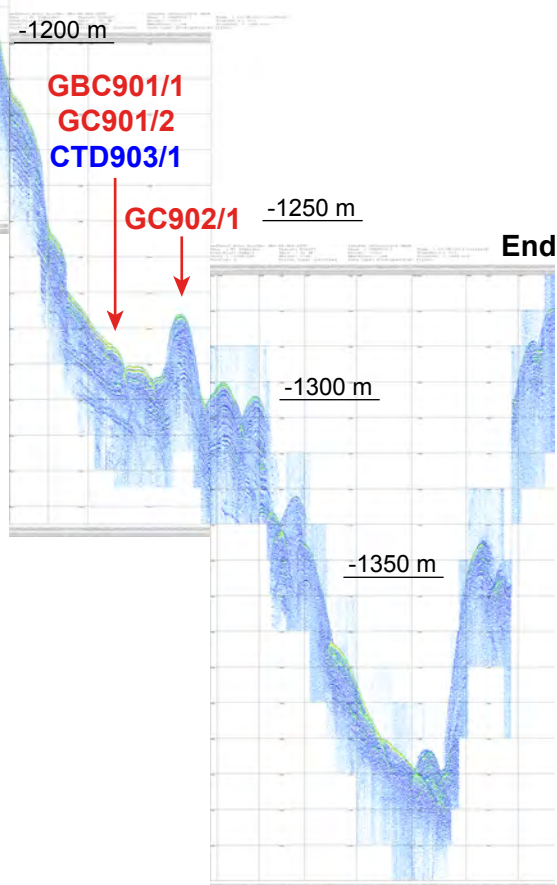
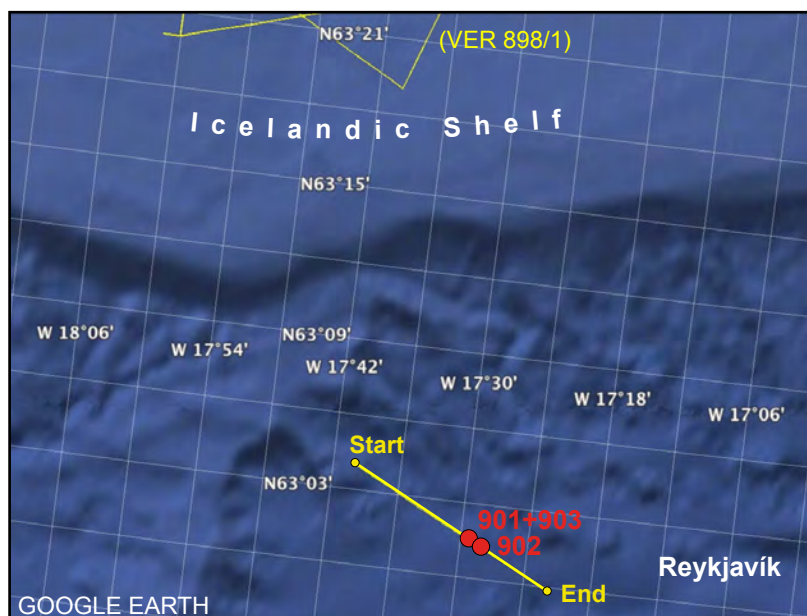
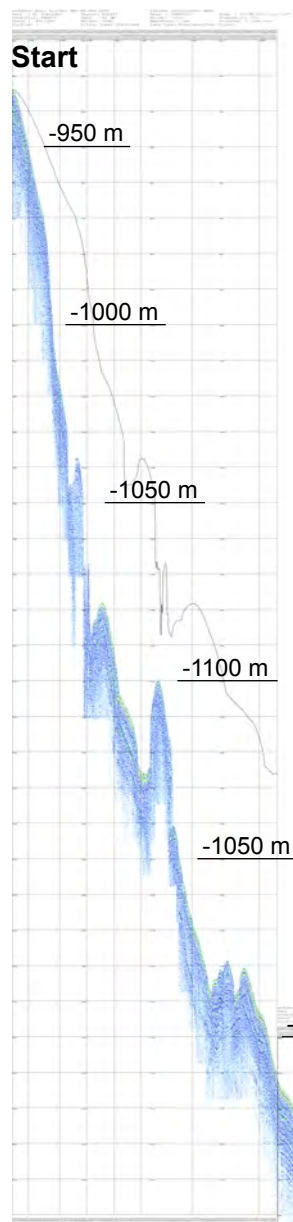
VER 891/1 Area III (Surtsey)



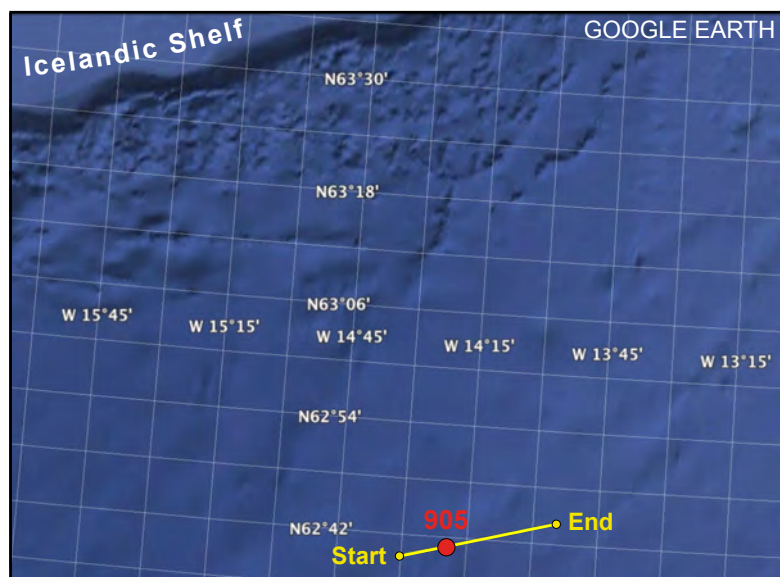
VER 898/1 Area IV (off central Icelandic south coast)



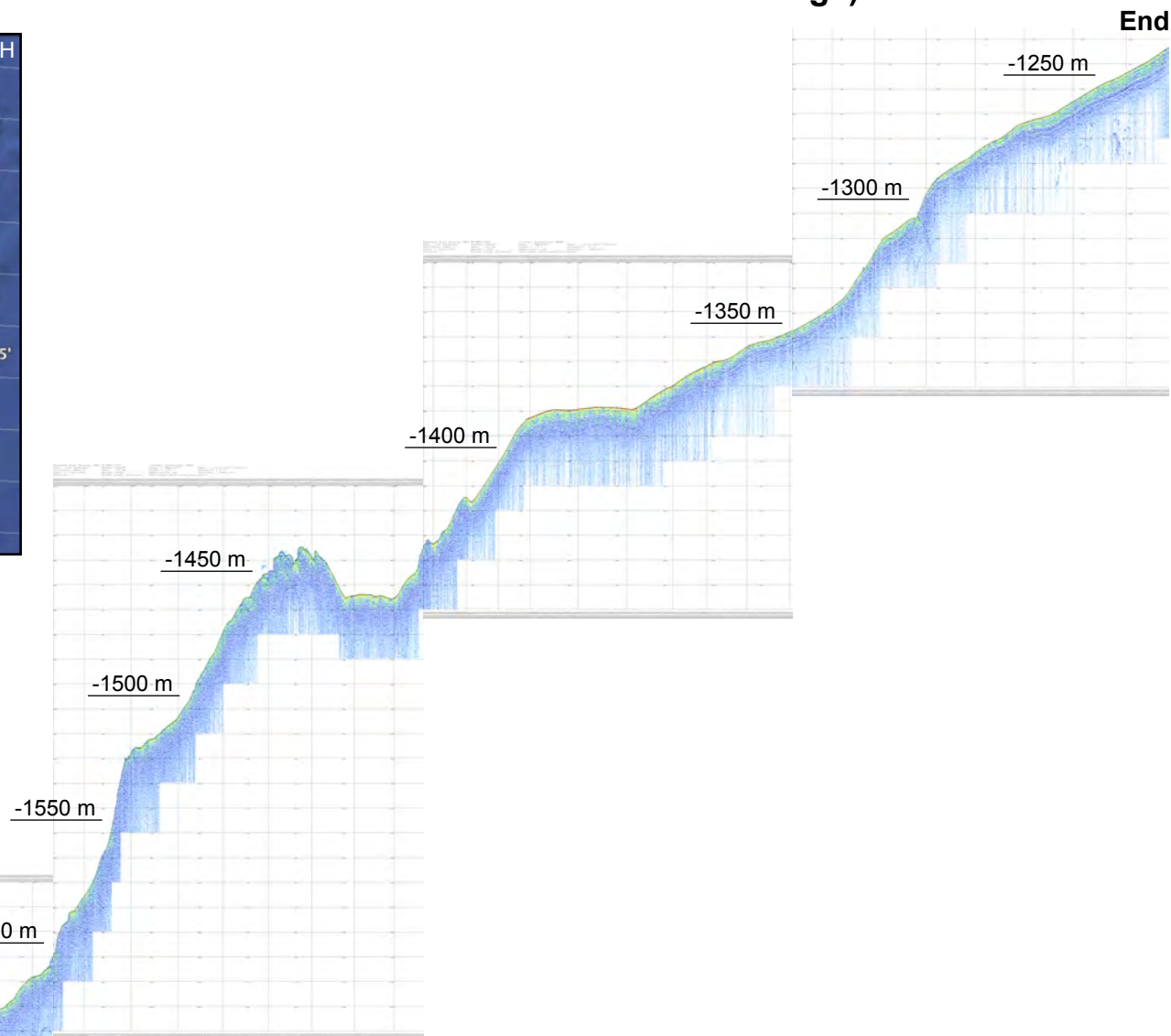
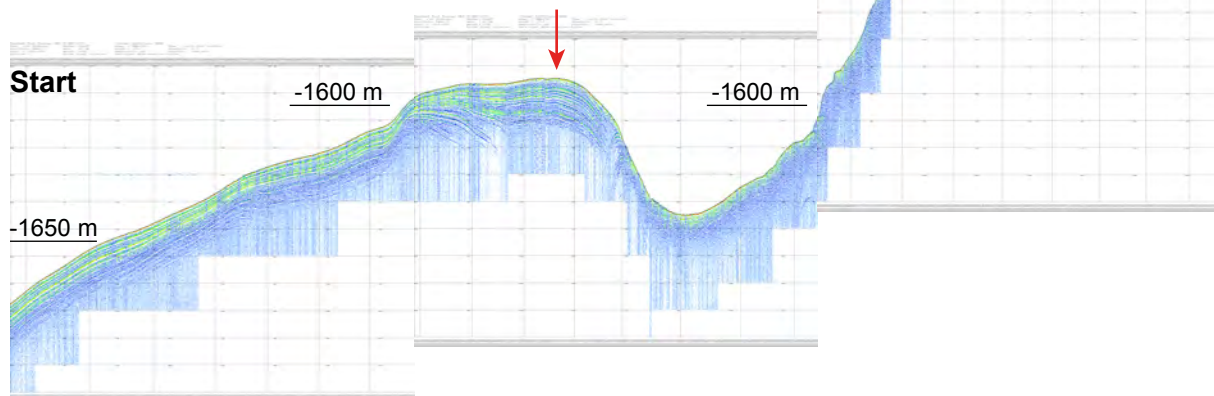
VER 900/1 Area IV (off central Icelandic south coast)



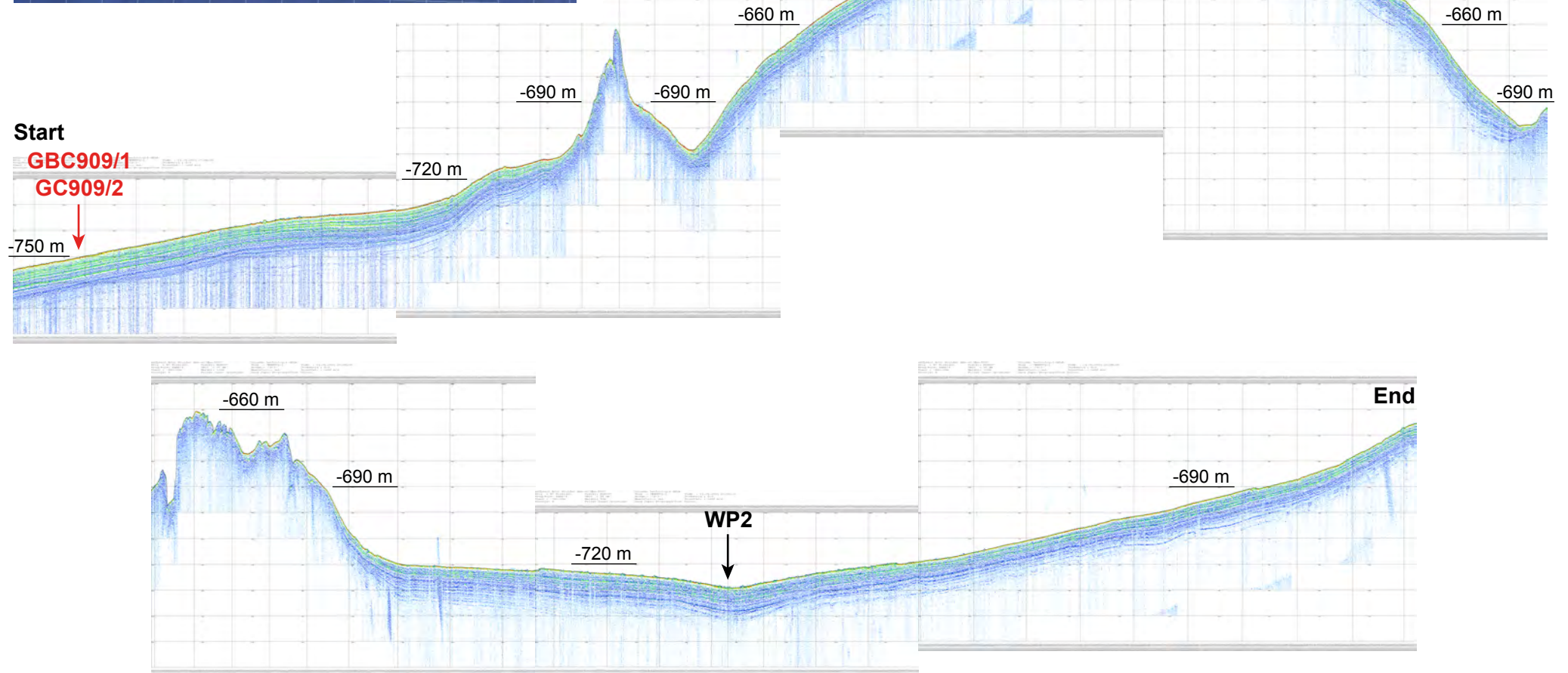
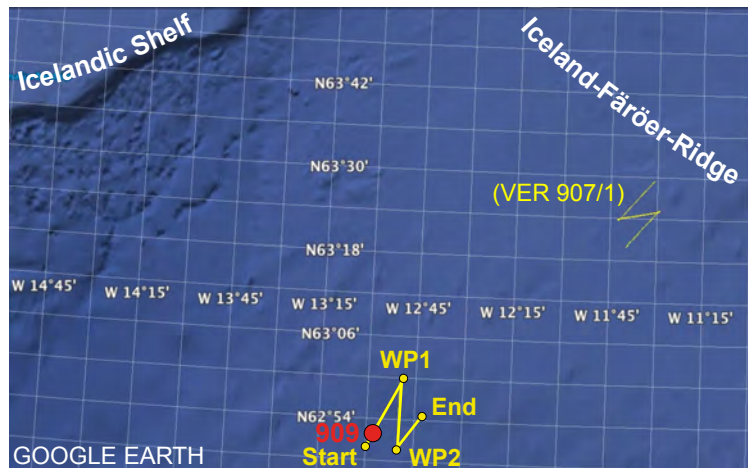
VER 904/1 Area V (south of the Icelandic shelf/west of Iceland-Färöer-Ridge)



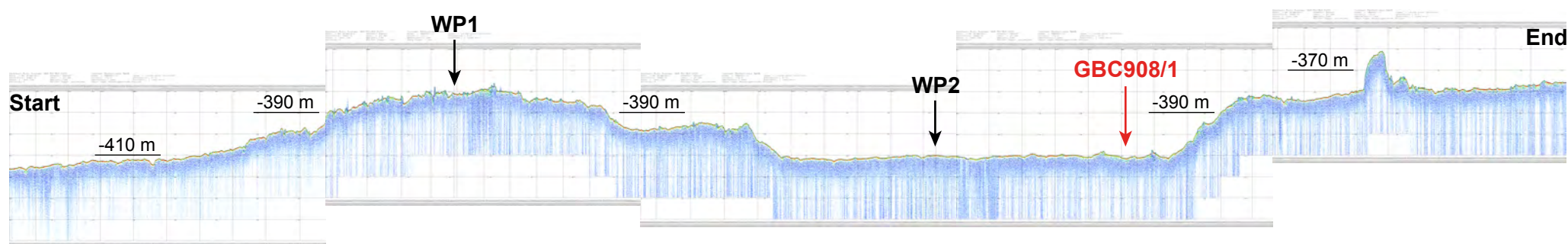
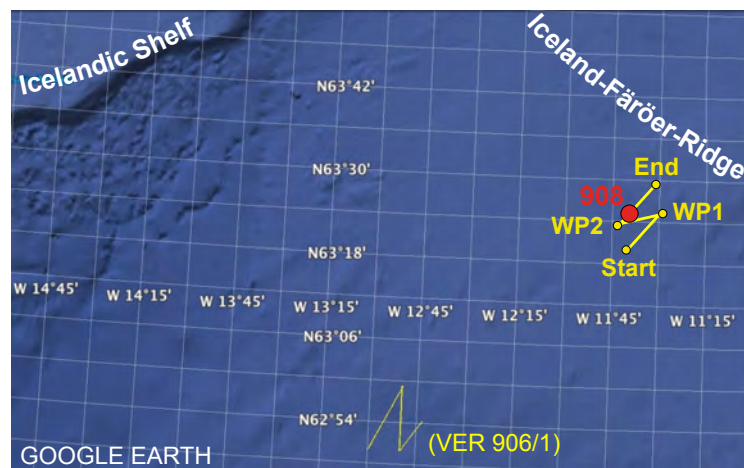
CTD905/1
GC905/2
GBC905/3



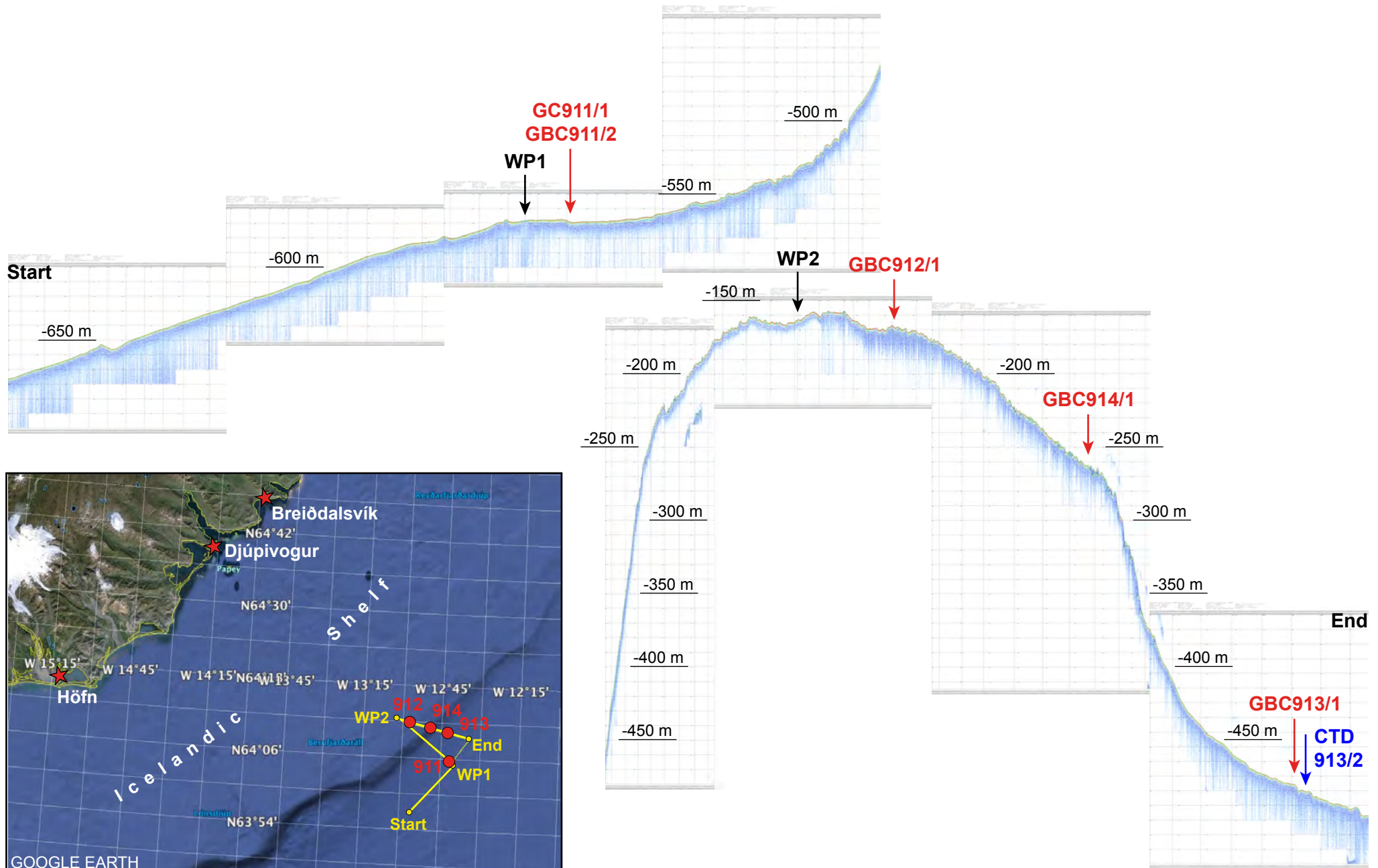
VER 906/1 Area V
(south of the Icelandic shelf/west of Iceland-Färöer-Ridge)



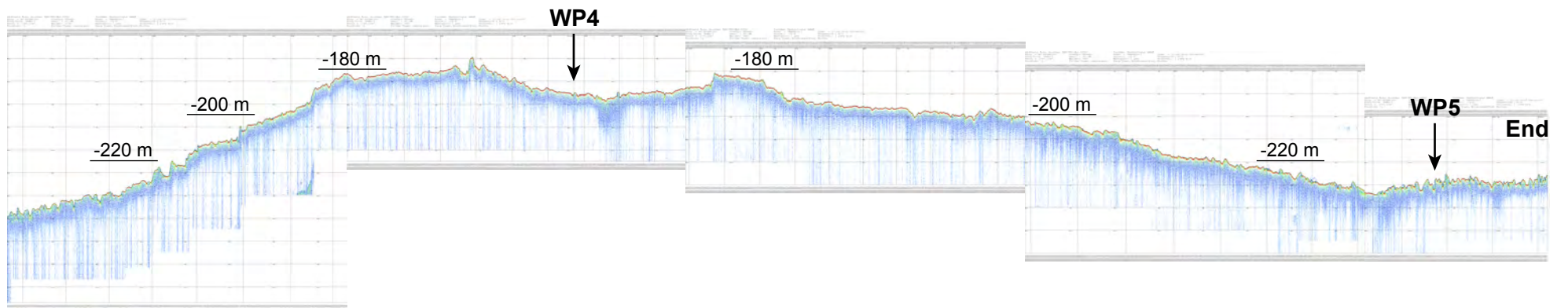
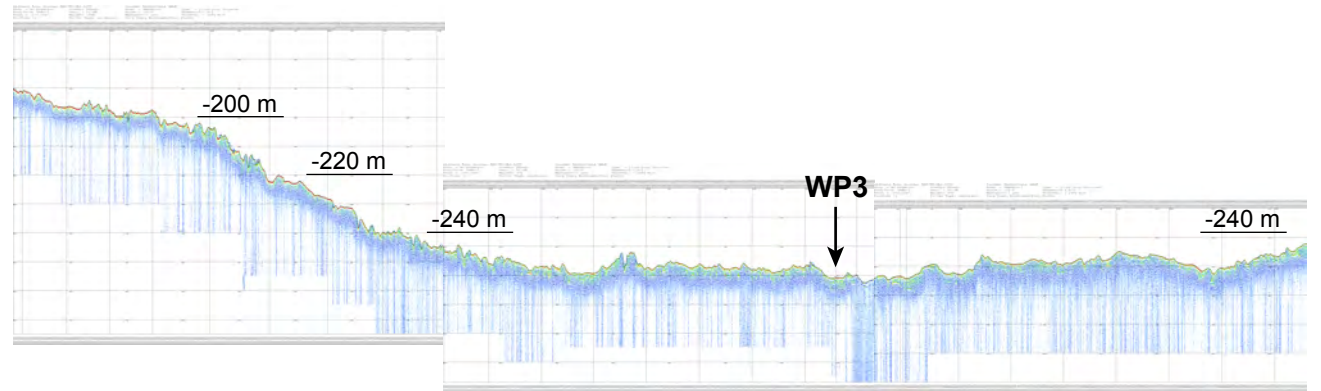
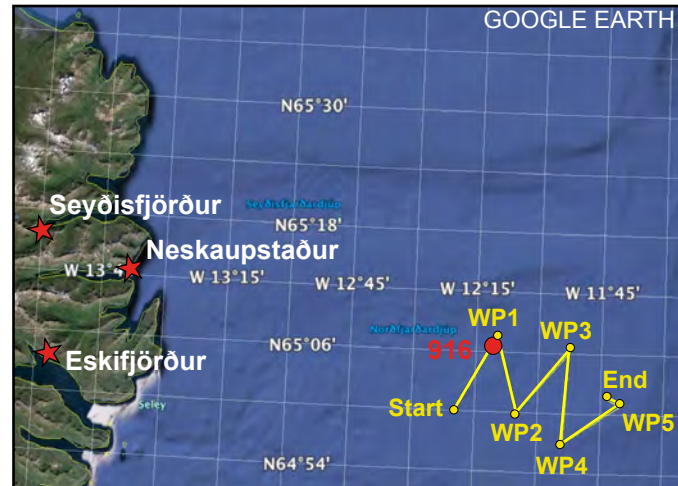
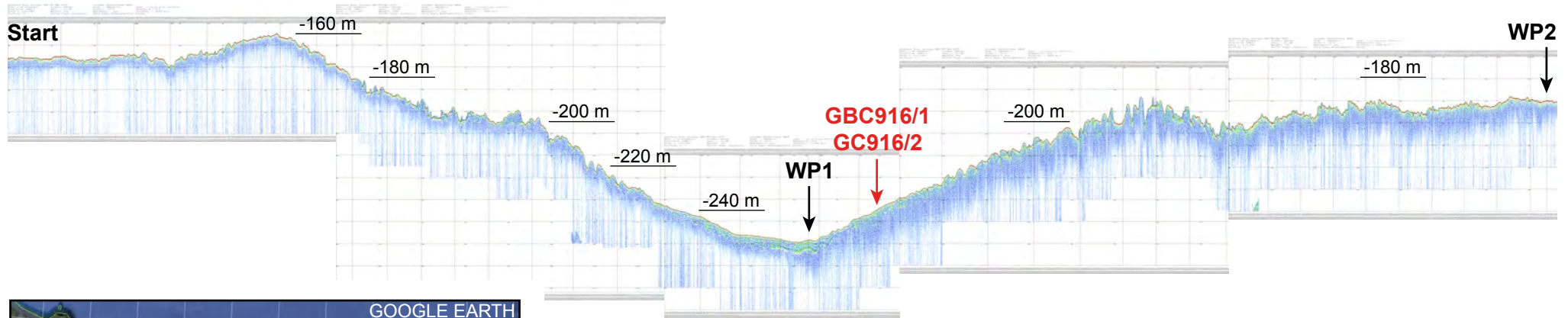
VER 907/1 Area VI (south of the Icelandic shelf/on the Iceland-Färöer-Ridge)



VER 910/1 Area VII (southeastern Icelandic shelf and shelf slope)



VER 915/1 Area VIII (eastern Icelandic shelf)

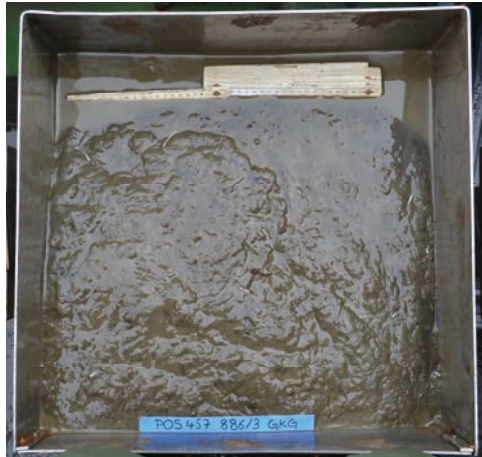


Appendix III:

Giant Box Corer: Core Photos and Descriptions

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
64°15.28'	24°8.41'	258	10.08.2013	10:57	45

Sediment surface



Sediment colour

Olive-gray with black ash deposition on top

Sample preservation

Undisturbed surface, dipping towards one side

General aspects

-

Vertical section



Dominating feature

-

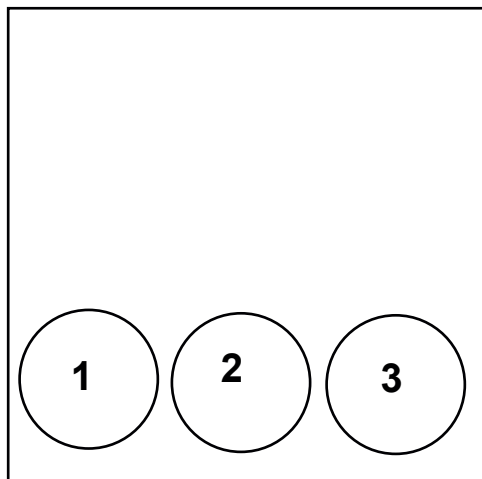
Grain size and sediment type

Sandy silt

Corals

-

Core sampling



Fauna

Scaphopoda, foraminifers

Samples taken

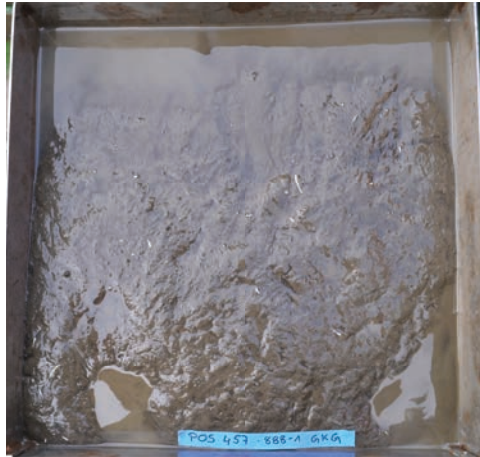
3 cores, surface sample

Operator

Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
63°17.50'	23°33.99'	323	11.08.2013	08:35	52

Sediment surface



Sediment colour

Olive-gray with black ash deposition on top

Sample preservation

Undisturbed surface, minimal angular to one side

General aspects

-

Vertical section



Dominating feature

-

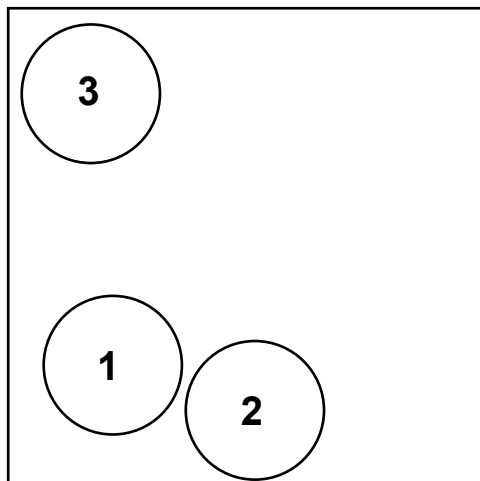
Grain size and sediment type

Silty sand

Corals

-

Core sampling



Fauna

Scaphopoda (3cm), worms, grass like structures (seaweed?)

Samples taken

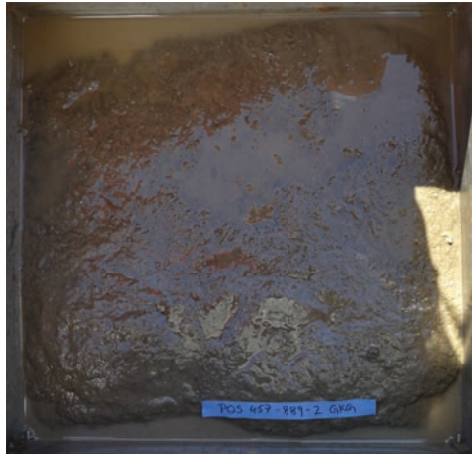
3 cores, surface sample

Operator

Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
63°3.04'	23°23.18'	922	11.08.2013	14:04	44

Sediment surface



Sediment colour

Olive-gray, less black ash deposition on top compared to station 888-1

Sample preservation

Undisturbed surface, dipping towards one side

General aspects

-

Vertical section



Dominating feature

-

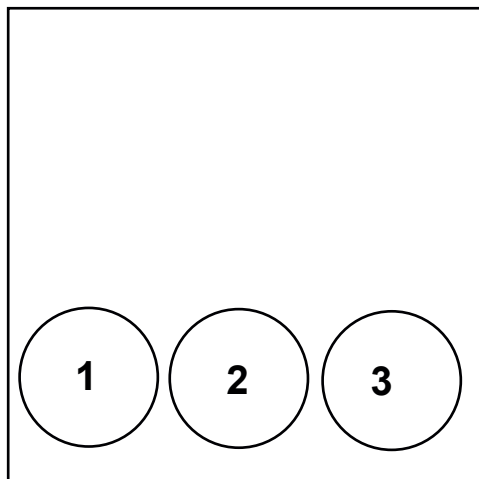
Grain size and sediment type

Sandy silt, slightly finer material compared to station 886/3

Corals

-

Core sampling



Fauna

-

Samples taken

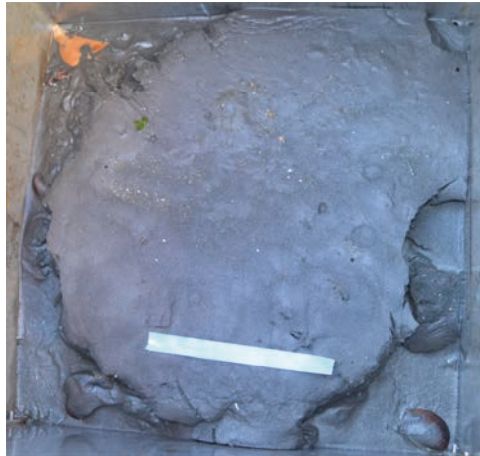
3 cores, surface sample

Operator

Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
63°16.07'	20°37.20'	107	12.08.2013	09:34	16

Sediment surface



Sediment colour

Gray-black with white deposition on top (small shells)

Sample preservation

Mostly undisturbed surface, disturbed at the sides

General aspects

Only few sediment

Vertical section



Dominating feature

-

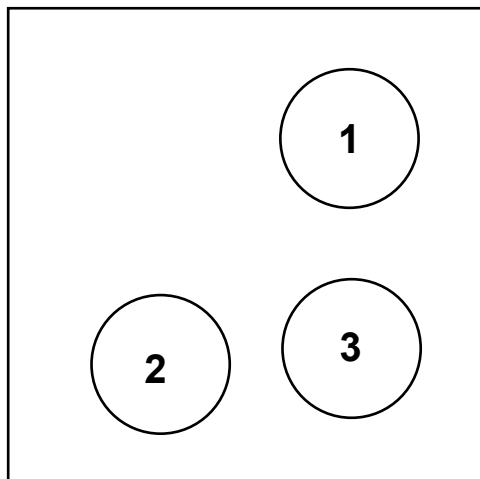
Grain size and sediment type

Fine to medium grained sand

Corals

-

Core sampling



Fauna

Big mussels (6-8cm), shrimps, worms

Samples taken

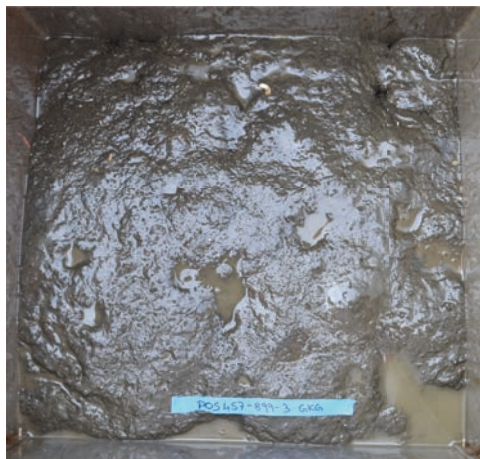
3 cores, surface samples of upper mm and cm

Operator

Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
63°20.44'	17°56.78'	157	13.08.2013	08:59	25

Sediment surface



Sediment colour

Olive-gray with black ash deposition on top

Sample preservation

Undisturbed uneven surface

General aspects

-

Vertical section



Dominating feature

-

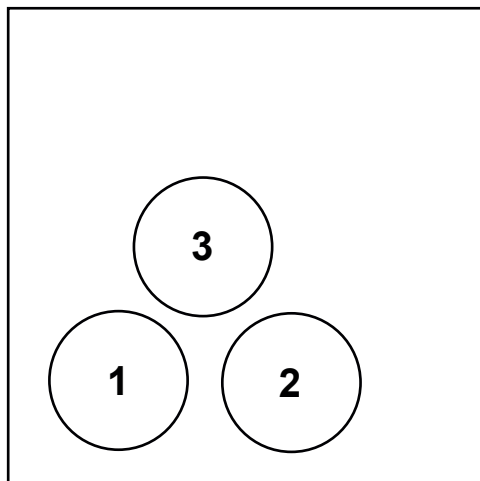
Grain size and sediment type

Sandy silt

Corals

-

Core sampling



Fauna

Scaphopoda, shells on top

Samples taken

3 cores, surface sample

Operator

Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
63°1.61'	17°29.27'	1292	13.08.2013	14:13	53

Sediment surface



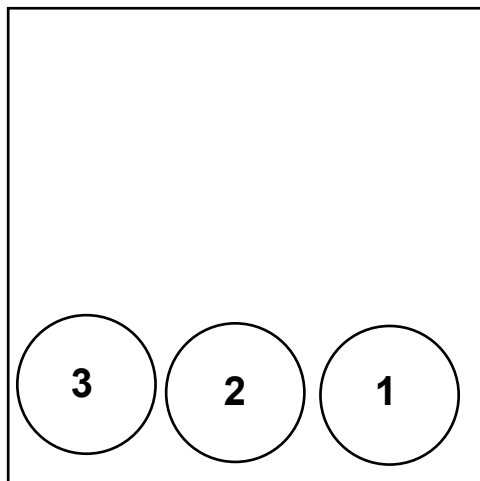
Sediment colour	Olive-gray
Sample preservation	Undisturbed uneven surface
General aspects	Homogenous, fine material

Vertical section



Dominating feature	-
Grain size and sediment type	Fine silty clay
Corals	-

Core sampling



Fauna	Worms, seaweed, mussels, shrimps
Samples taken	3 cores, surface sample
Operator	Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
62°41.13'	14°21.09'	1610	14.08.2013	13:17	42

Sediment surface



Sediment colour

Light brownish yellow
with black ash deposition
on topSample
preservationUndisturbed uneven
surface with ripples and
traces of wormsGeneral
aspectsIn parts covered with
sand and remains of
shells

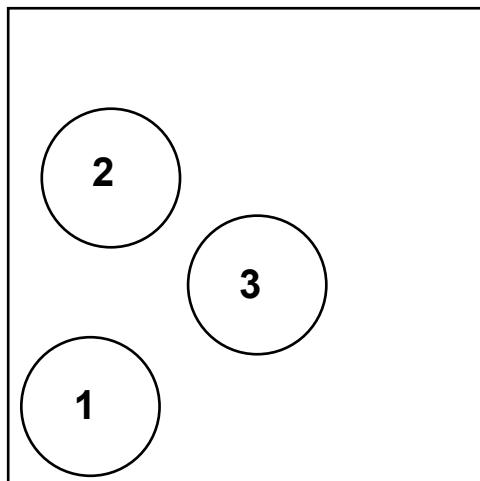
Vertical section

Dominating
featureSurface with ripples
partly covered by
medium grained sandGrain size and
sediment typeSilty sand - medium
grained sand

Corals

-

Core sampling



Fauna

Shell fragments, worms,
snails

Samples taken

3 cores, surface
samples (silty sand/
sand)

Operator

Bonanati, Friðriksson,
Portnyagin

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
63°25.18'	11°39.64'	411	15.08.2013	08:23	22

Sediment surface



Sediment colour

Olive-gray

Sample preservation

Undisturbed uneven surface

General aspects

-

Vertical section



Dominating feature

-

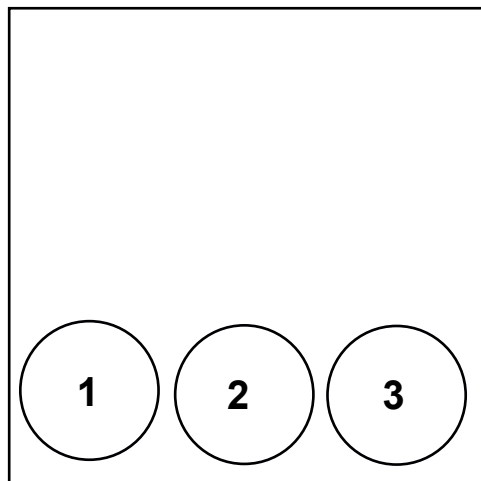
Grain size and sediment type

Fine sand

Corals

-

Core sampling



Fauna

Shell fragments, sca-phopoda

Samples taken

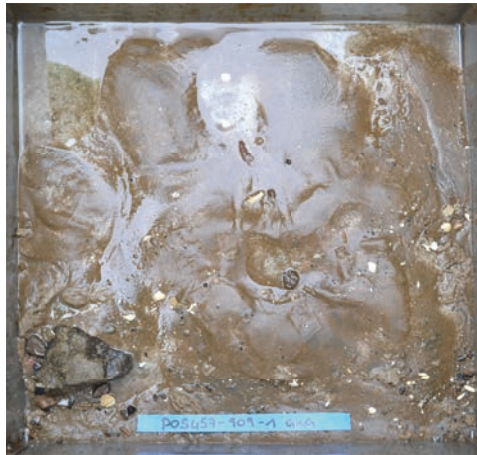
3 cores, surface samples of upper mm + cm, dropstones

Operator

Bonanati, Friðriksson, Portnyagin, Schattel

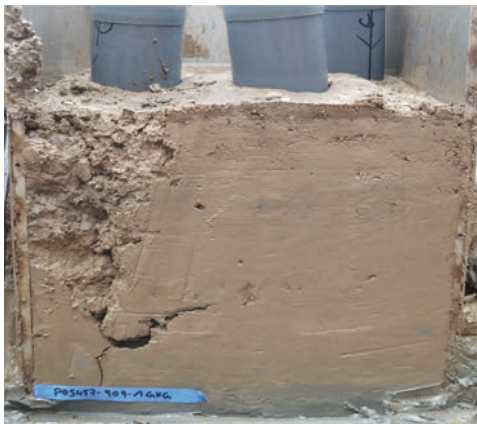
Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
62°50.28'	12°59.56'	755	15.08.2013	16:05	22

Sediment surface



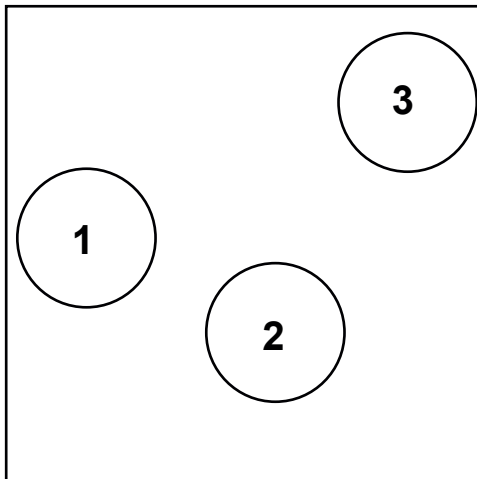
Sediment colour	Brown to yellowish brown sediment with black ash deposition on top
Sample preservation	Undisturbed uneven surface
General aspects	Different sizes of shell fragments and dropstones on top

Vertical section



Dominating feature	-
Grain size and sediment type	Medium grained sand
Corals	-

Core sampling



Fauna	Shell fragments, shrimps, seastar, snails
Samples taken	3 cores, surface samples, dropstones
Operator	Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
64°5.45'	12°41.19'	571	16.08.2013	10:33	15

Sediment surface



Sediment colour brown to olive-gray with minor deposition of light particles on top

Sample preservation Disturbed surface fewer sediment on one side

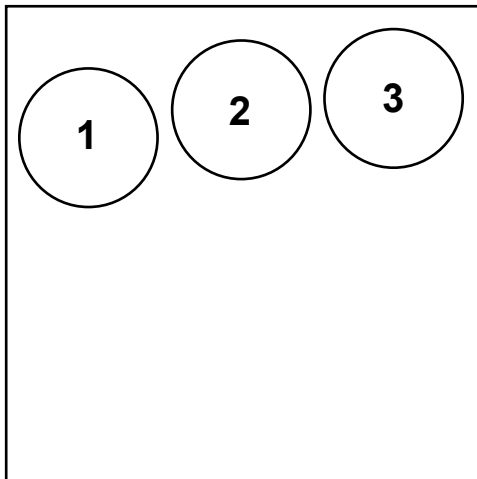
General aspects Many dropstones in various sizes

Dominating feature -

Grain size and sediment type Medium grained sand

Corals -

Core sampling



Fauna Worms, scaphopoda

Samples taken 3 cores, surface samples, dropstones

Operator Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
64°11.85'	12°58.44'	165	16.08.2013	12:24	-

Sediment surface



Sediment colour	Brownish to yellowish-gray
Sample preservation	No surface preserved
General aspects	Disturbed sediment with many shell fragments and dropstones
Dominating feature	-
Grain size and sediment type	Coarse grained sand, mixed with clay
Corals	-
Fauna	Shell fragments
Samples taken	Sediment sample
Operator	Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
64°10.41'	12°43.73'	482	16.08.2013	13:47	-

Sediment surface



Sediment colour	-
Sample preservation	No sediment preserved
General aspects	Stones with up to 20cm in diameter
Dominating feature	Insitu aphyric/cpx phyric basalts, angular, fresh to moderately altered
Grain size and sediment type	Coarse grained sand, mixed with clay
Corals	calcitic coral
Fauna	Sea star, serpent star, sponges, worm, spider crab
Samples taken	All fragments over 5cm in diameter
Operator	Bonanati, Friðriksson, Portnyagin, Schattel

Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
64°11.13'	12°50.94'	261	16.08.2013	15:40	-

Sediment surface



Sediment colour	Olive-gray
Sample preservation	Only few disturbed sediment without clear surface
General aspects	-
Dominating feature	Rocks are basalts similar to those from station 913-1, but more rounded
Grain size and sediment type	Medium grained sand
Corals	-
Fauna	-
Samples taken	Sediment sample, stones
Operator	Bonanati, Friðriksson, Portnyagin, Schattel

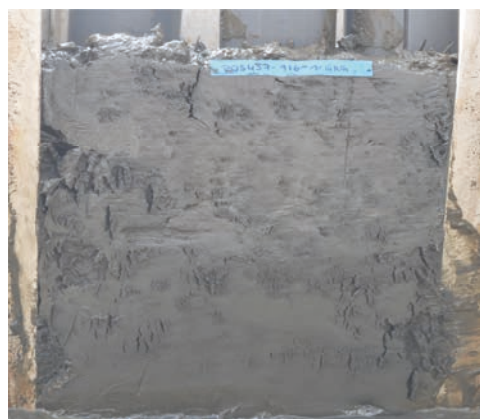
Latitude	Longitude	Depth (m)	Date	Time	Core recovery (cm)
65°7.54'	12°9.94'	245	17.08.2013	08:31	43

Sediment surface



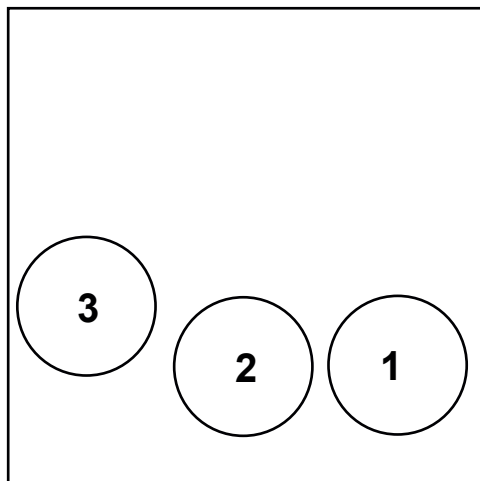
Sediment colour	Brownish to olive-gray
Sample preservation	Mostly undisturbed surface with ripples
General aspects	-

Vertical section



Dominating feature	-
Grain size and sediment type	Homogenous sandy silt
Corals	-

Core sampling



Fauna	Worms, worm tubes
Samples taken	3 cores, surface samples of upper cm and mm
Operator	Bonanati, Friðriksson, Portnyagin, Schattel

Appendix IV:

Gravity Corer: Core Descriptions

POS457-886-1 GC

Area I South of Snaefellsnes

Date Logged: August 20, 2013

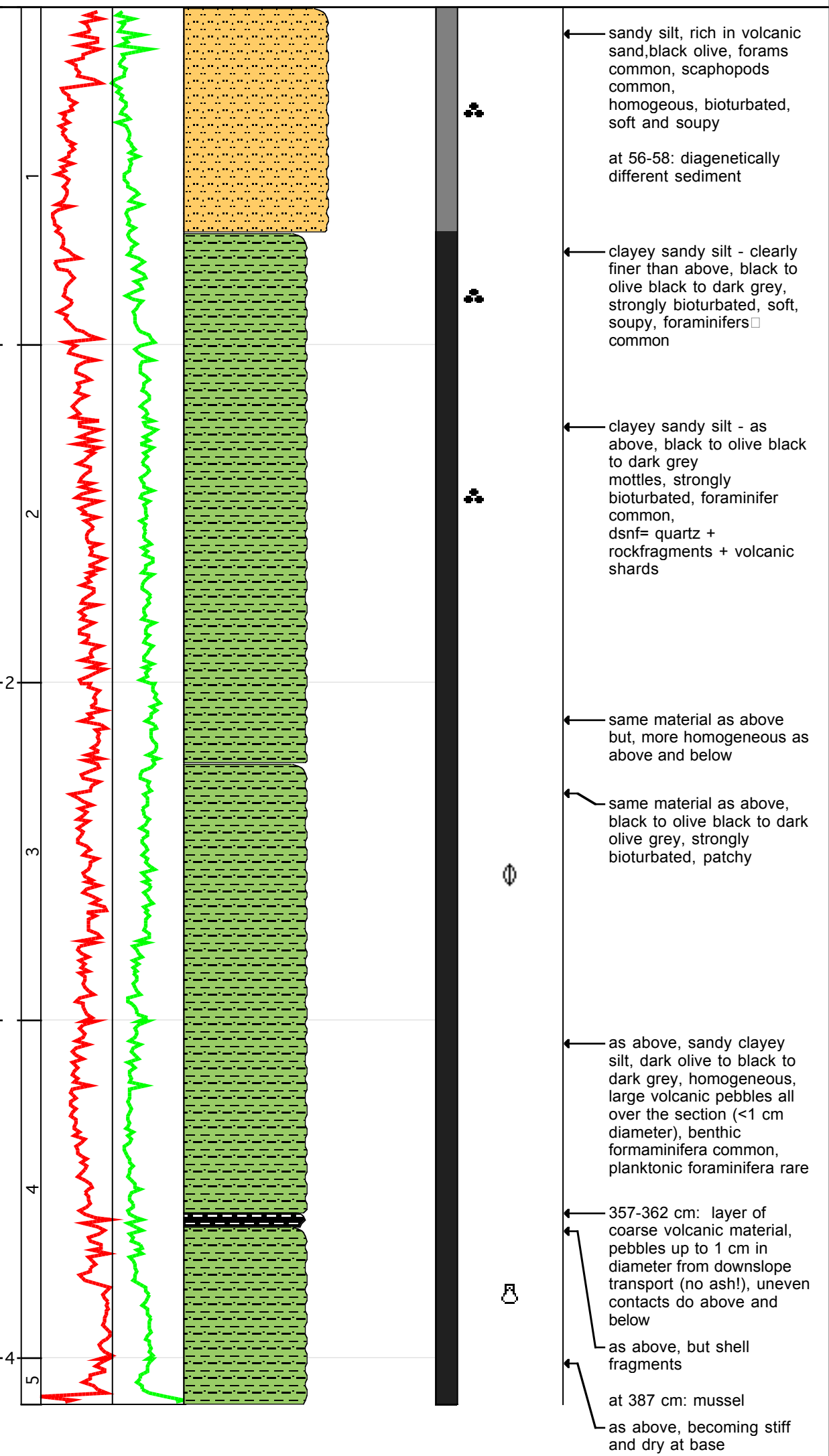
Logged by: D. Nuernberg / C. Bogaard

Ground: 260.00 m KB: 4.14 m

Remarks: 64°15,30' N 24°08,46' W



METERS	BOX	L* (D65) Minolta CM600d	b* (D65) Minolta CM600d	GRAIN SIZE sand silt clay	BIOTURBATION INDEX v f m c v	FOSSILS	REMARKS
17.9	6.5	6.3	-0.3				



LEGEND

LITHOLOGY			
	sandy silt		sandy shale
	organic shale		Lost Core
CONTACTS			
	Incised		
FOSSILS			
	Foraminifera (undifferentiated)		Foraminifera (benthonic)
	Pelecypods		

POS457-886-2 GC

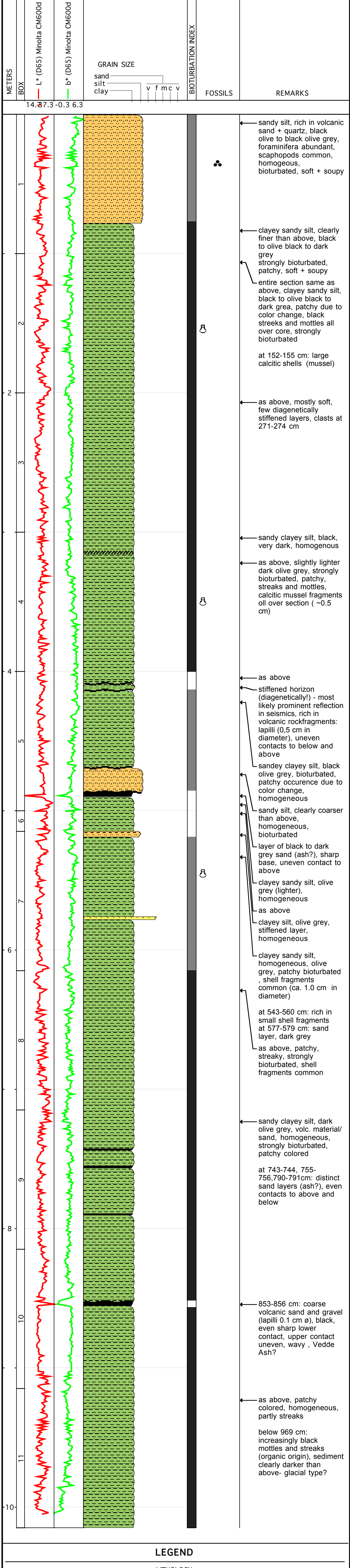
Area I South of Snaefellsnes

Date Logged: August 20, 2013

Logged by: D. Nuernberg / C. Bogaard

Ground: 259.00 m KB: 10.15 m

Remarks: 64°15,32'N 24°08,47'W



LEGEND

LITHOLOGY

SAND/SANDSTON

sandy silt

clayey silty

sandy shale

coal

Lost Core

CONTACTS

Gradational

Undulating

FOSSILS

Foraminifera (undifferentiated)

Pelecypods

POS457-888-2 GC

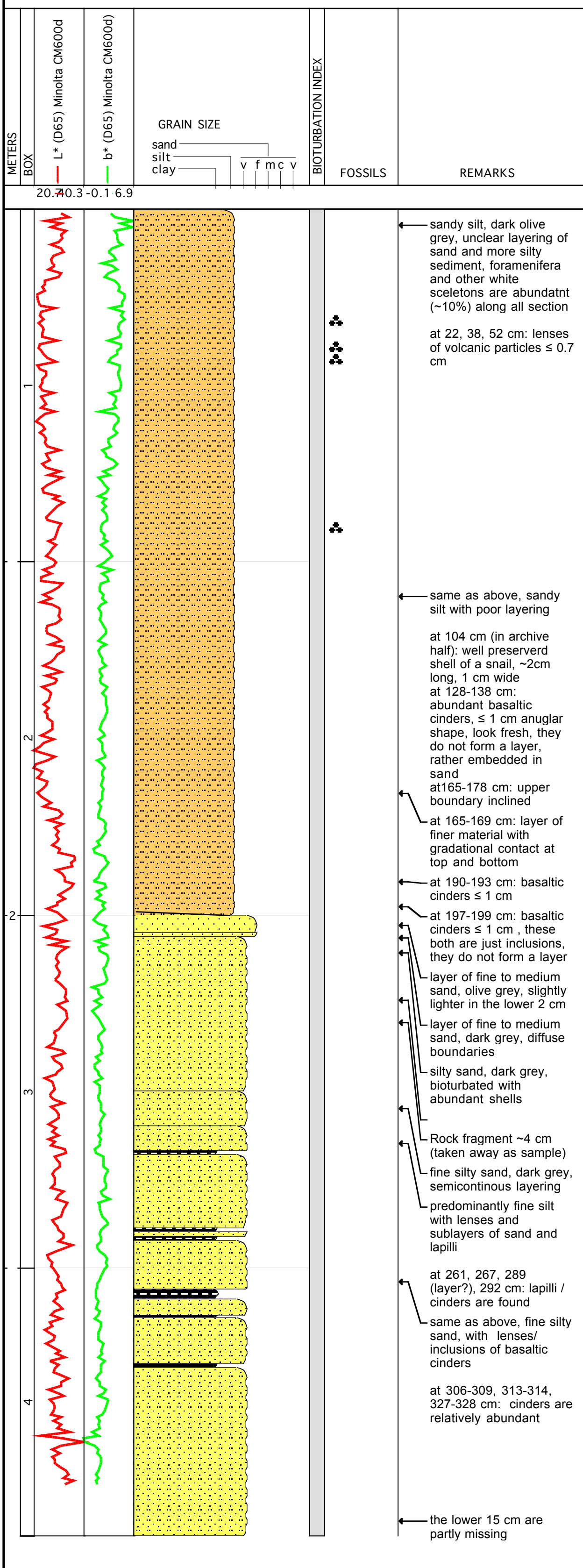
Area I South of Snaefellsnes

Date Logged: August 20, 2013

Logged by: D. Nuernberg / C. Bogaard

Ground: 324.00 m KB: 3.76 m

Remarks: 63°17,44' N 23°34,17' W



LEGEND

LITHOLOGY

	SAND/SANDSTON		sandy silt		organic shale		Lost Core
	silty sand						

CONTACTS

Inclined

FOSSILS

Foraminifera (undifferentiated)

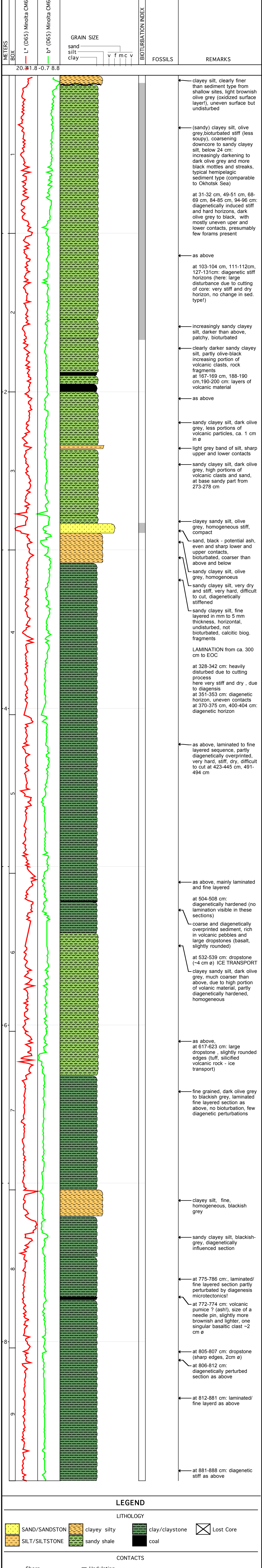
Date Logged: August 20, 2013

Logged by: D. Nuernberg / C. Bogaard

Ground: 923.00 m KB: 8.88 m

Remarks: 63°03,04' N 23°23,19' W

Lamination!



POS457-901-2 GC

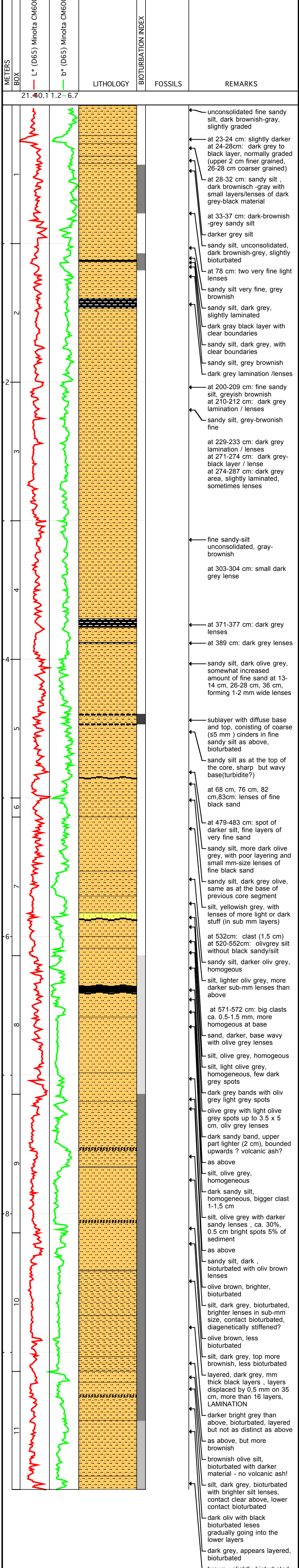
Area VI (deep)

Date Logged: August 20, 2013

Logged by: D. Nuernberg / C. Bogaard

Ground: 1302.00 m KB: 0.00 m

Remarks: 63°01,28 'N 17°29,25 'W



LEGEND

LITHOLOGY

	SAND/SANDSTONE		clayey silty		coal
	SILT/SILTSTONE		organic shale		Lost Core
	sandy silt				

CONTACTS

	Bioturbated		Uncertain		Undulating
--	-------------	--	-----------	--	------------

Date Logged: August 20, 2013

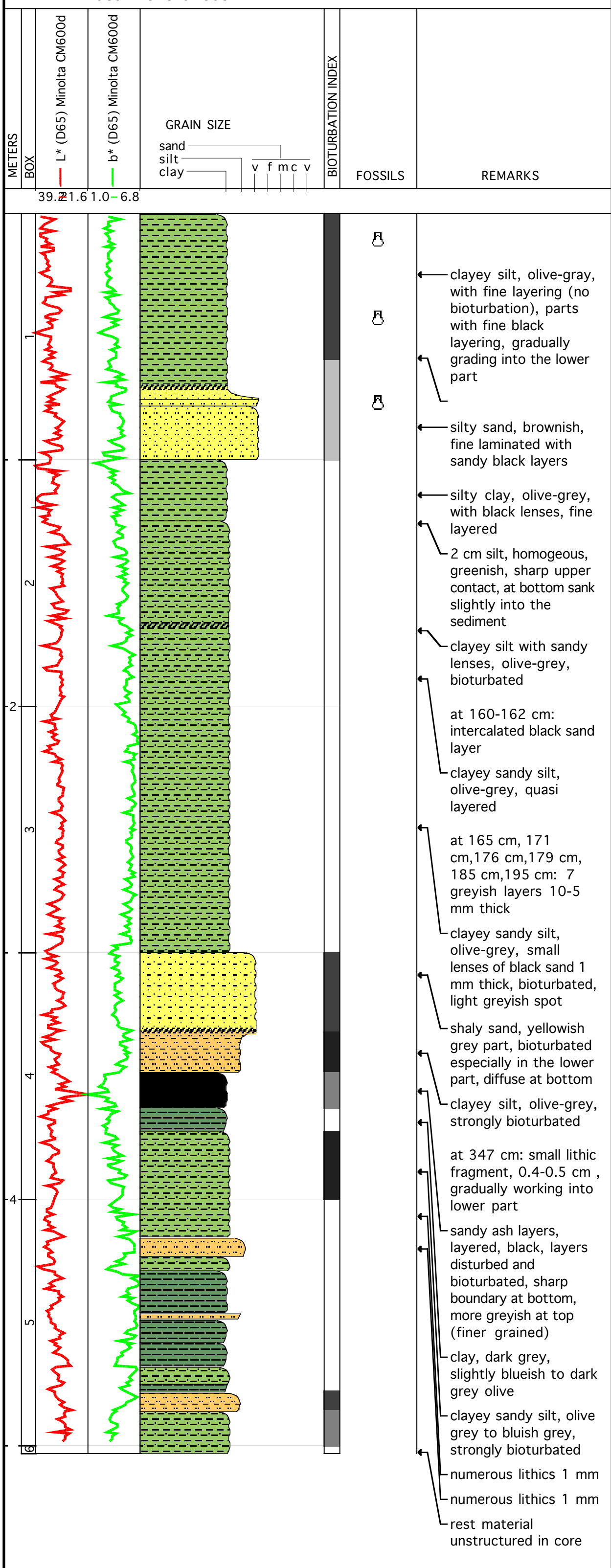
Logged by: D. Nuernberg / C. Bogaard

Ground: 1288.00 m KB: 5.00 m

Remarks: 63°01,31' N 17°27,98' W



Core overpenetrated, uppermost ~1.5 m of sediment is lost



LEGEND

LITHOLOGY

	silty sand		clayey silty		sandy shale		coal
	shaly sand		SHALE/MUDSTON		clay/claystone		Lost Core
	sandy silt						

CONTACTS

//// Gradational

FOSSILS

Pelecypods

POS457-905-2 GC

Area V (deep)

Date Logged: August 20, 2013

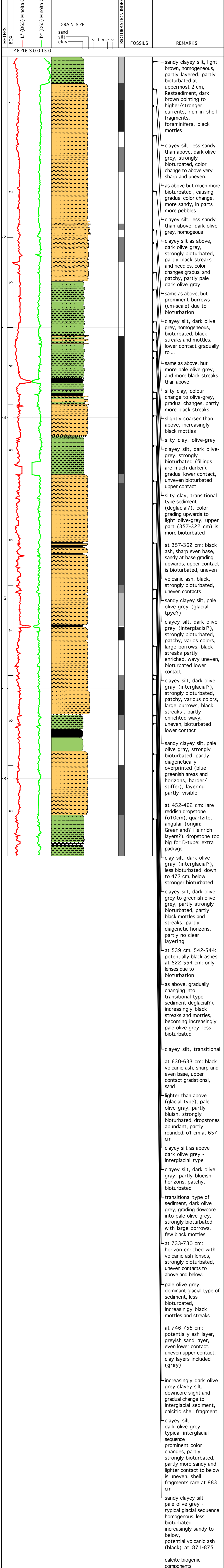
Logged by: D. Nuernberg / C. Bogaard

Ground: 1610.00 m KB: 8.86 m

Remarks: 62°41,13' N 14°21,15' W



GEOMAR



LEGEND

LITHOLOGY

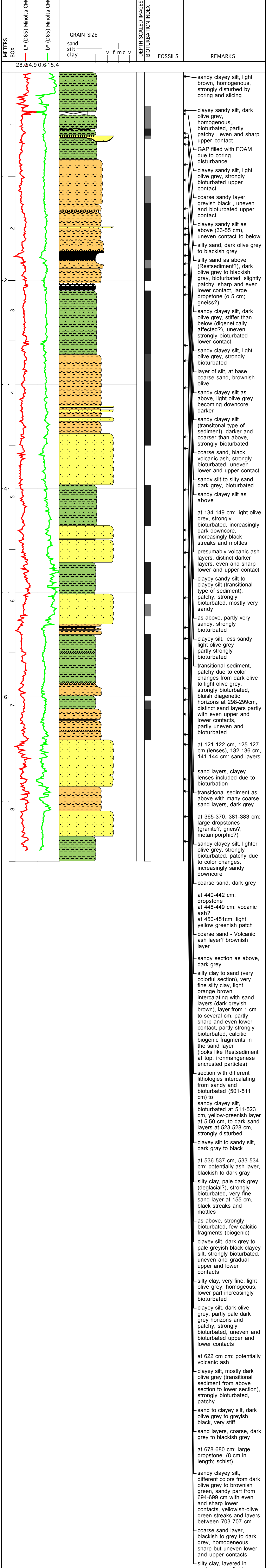
	sandy silt		SHALE/MUDSTON		sandy shale		coal
	clayey silty		silty shale		organic shale		Lost Core

CONTACTS

***** Bioturbated

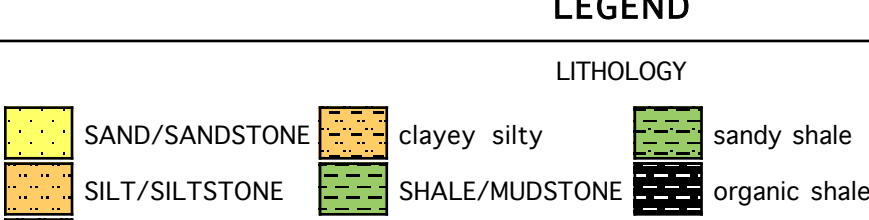
POS457-909-2 GC
Area VI (deep)

Date Logged: August 20, 2013
Logged by: D. Nuernberg / C. Bogaard
Ground: 755.00 m KB: 7.58 m
Remarks: 62°50,20' N 12°59,47' W



LEGEND

LITHOLOGY



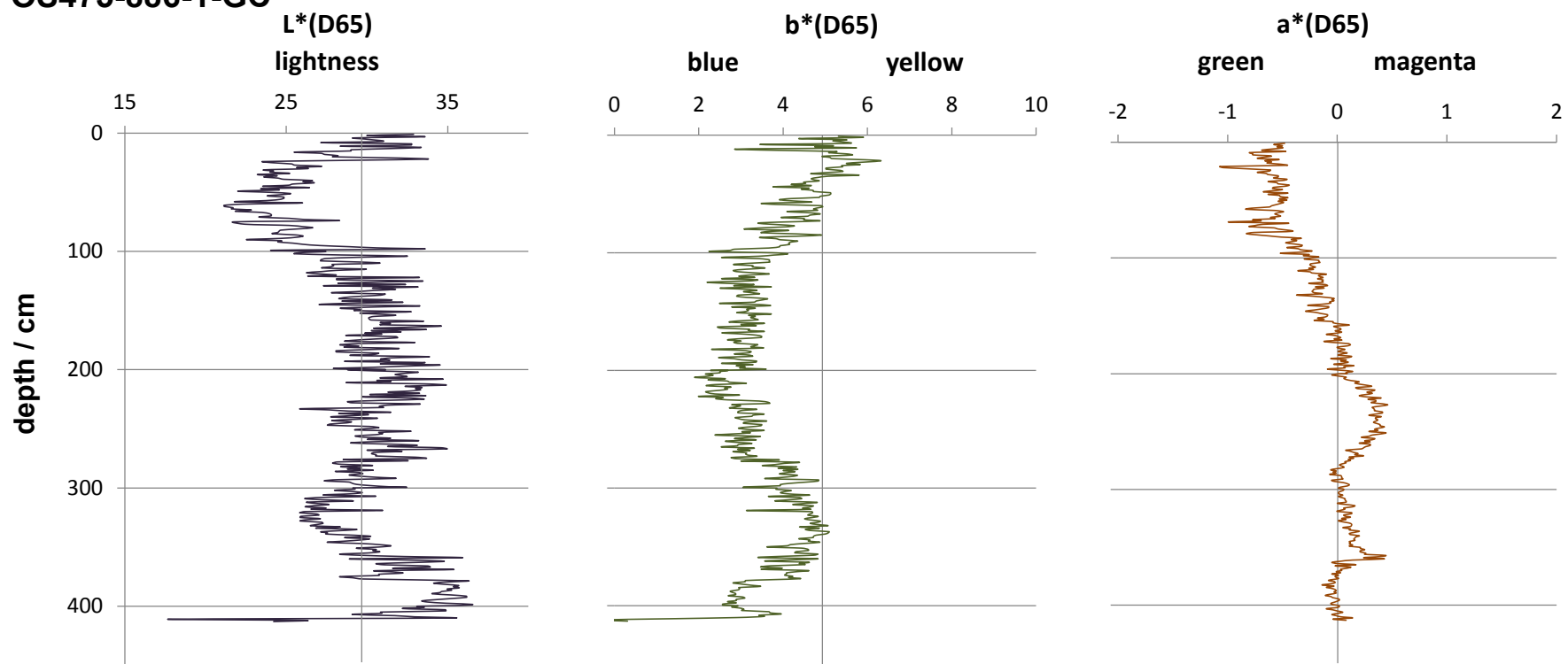
CONTACTS



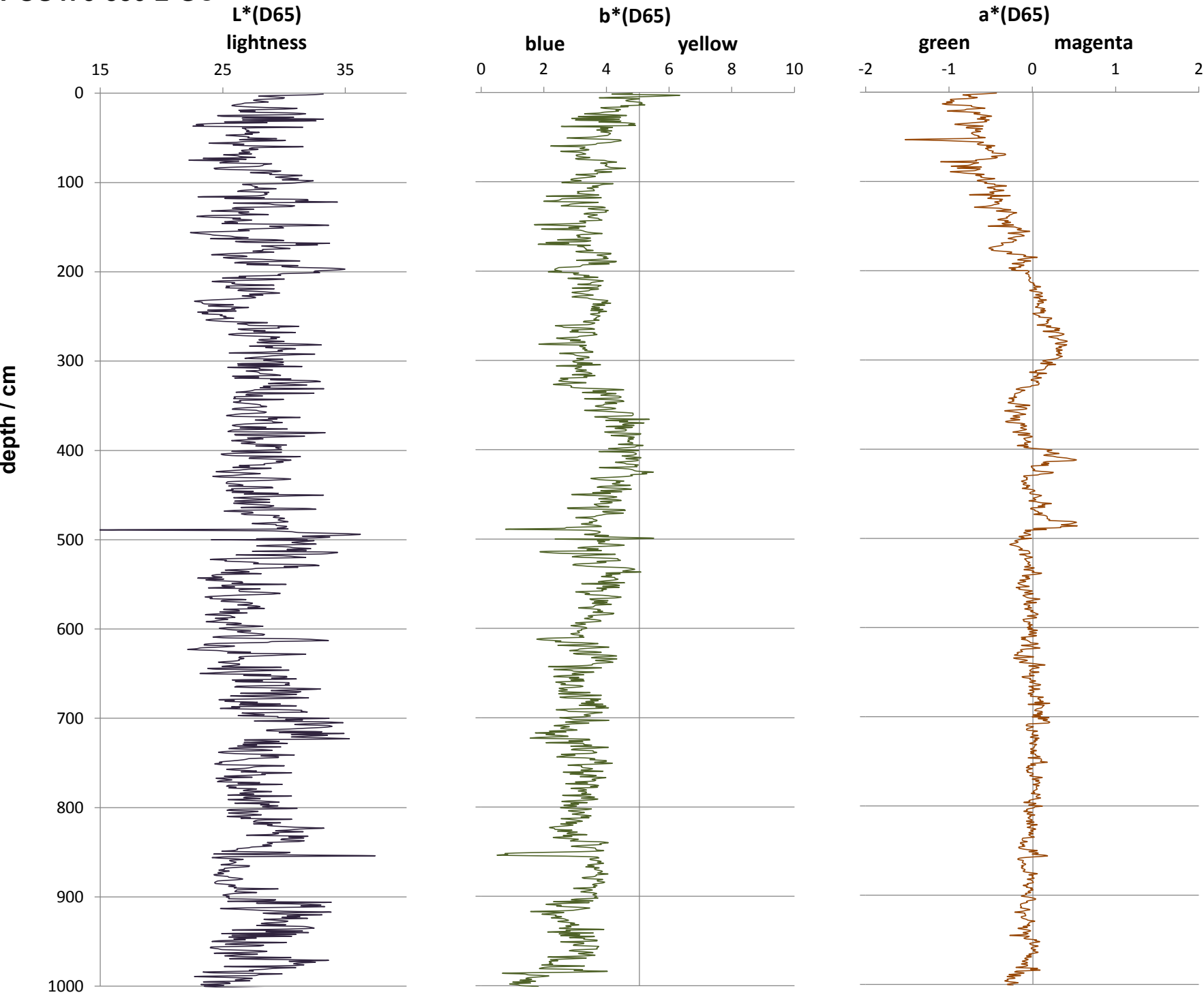
Appendix V:

Core Logging (Color Scans)

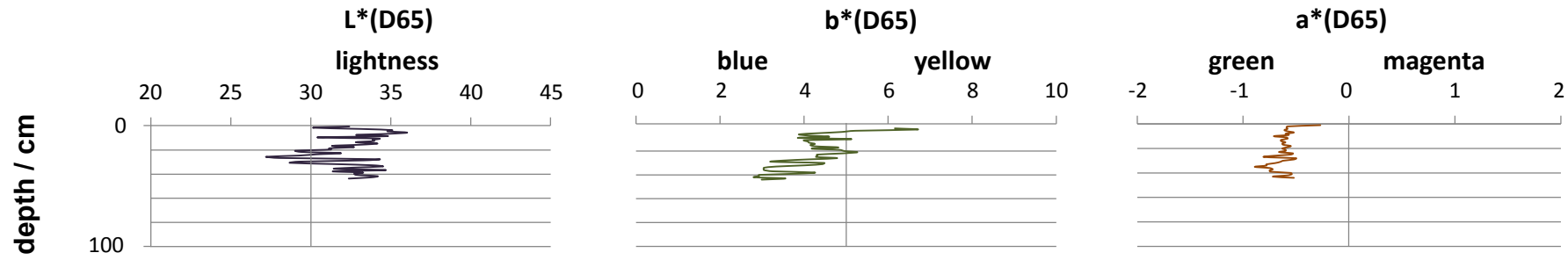
POS475-886-1-GC



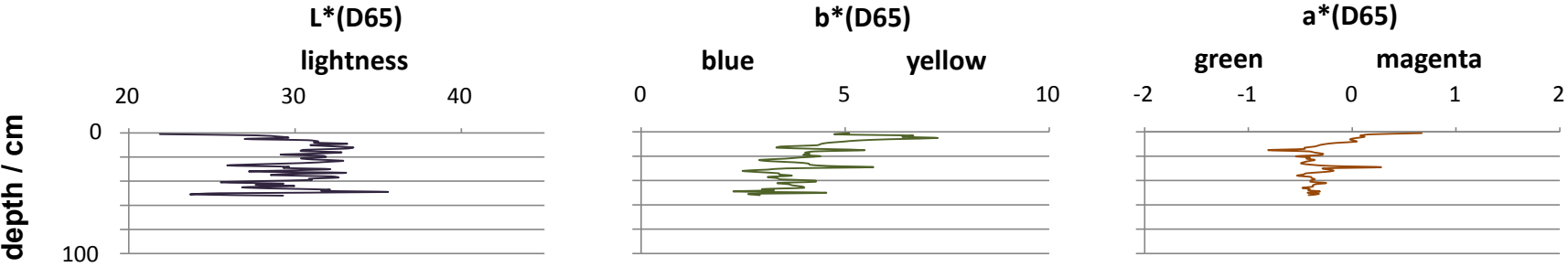
POS475-886-2-GC



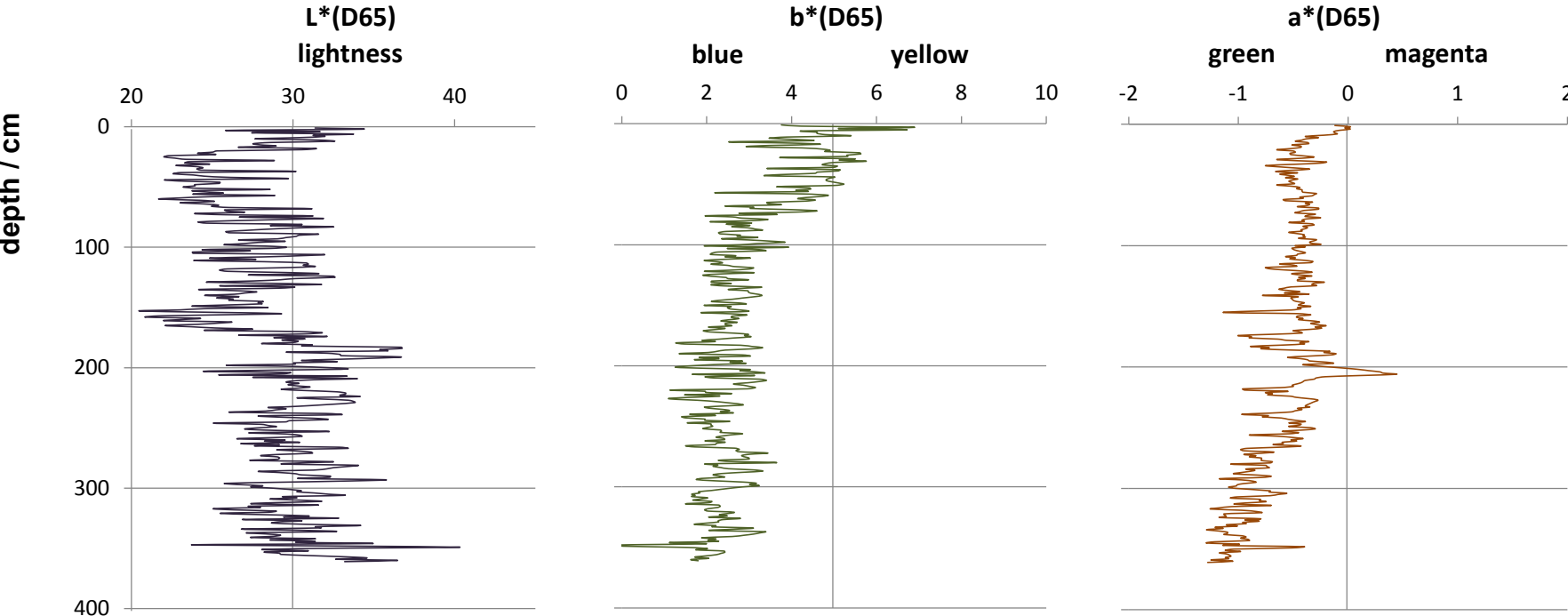
POS475-886-3-GBC



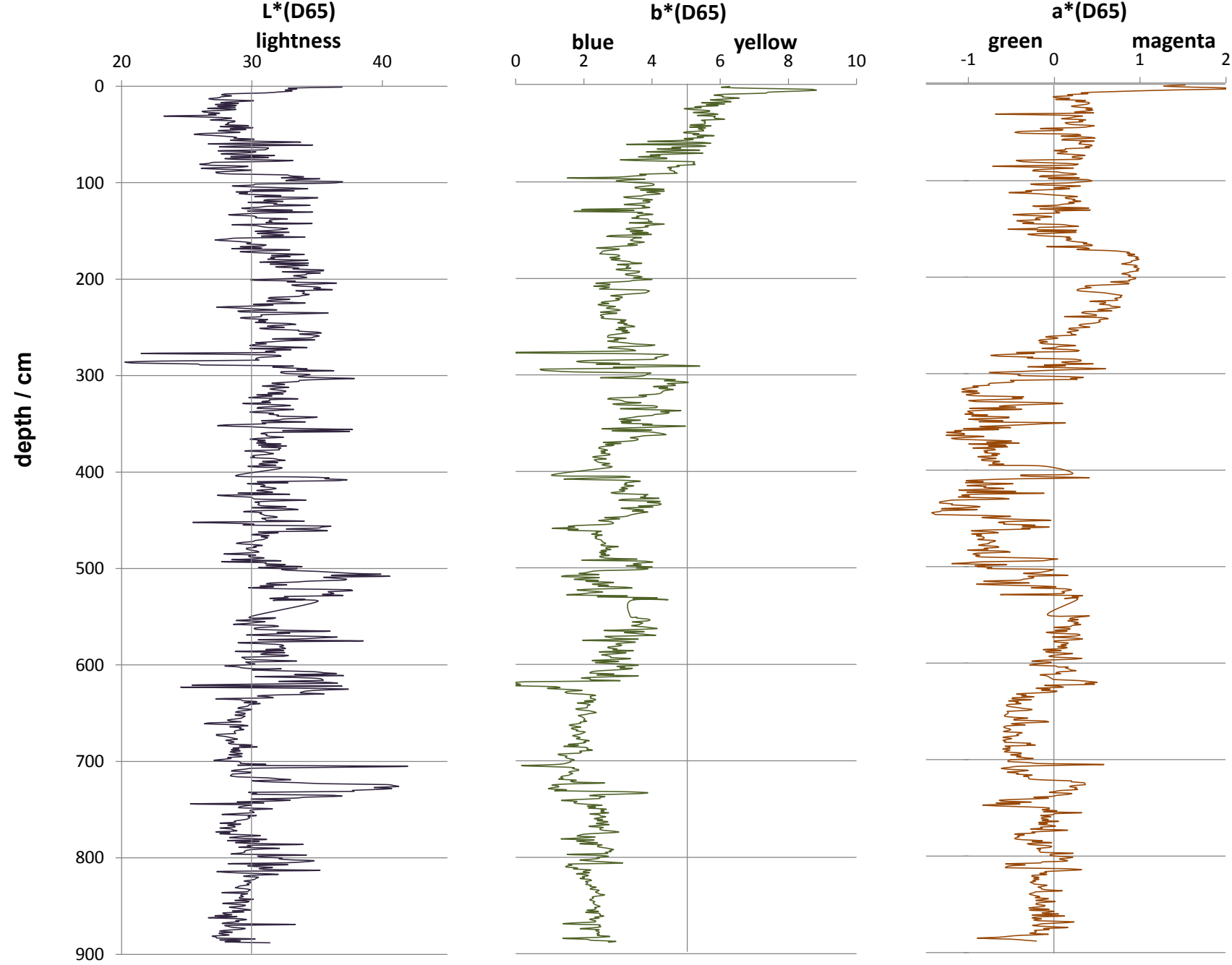
POS475-888-1-GBC



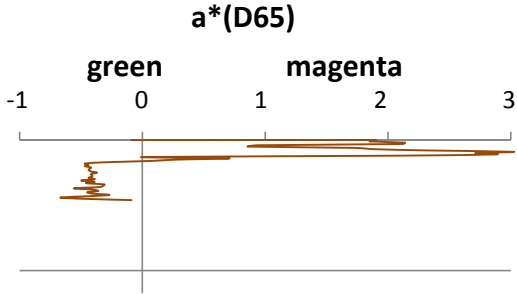
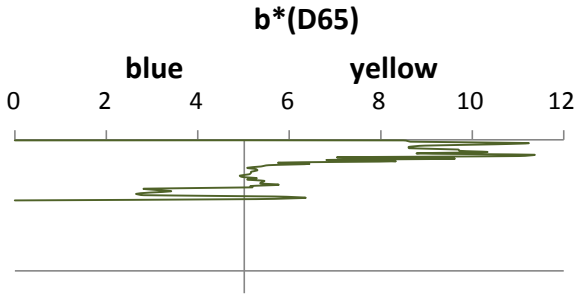
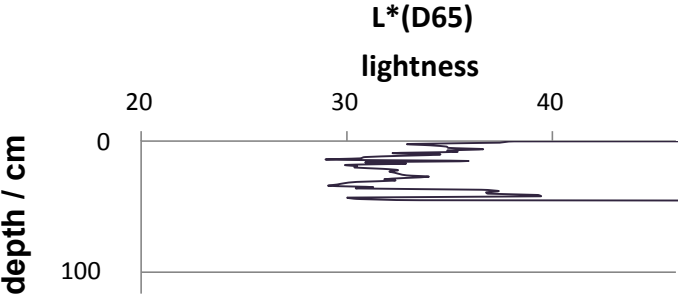
POS475-888-2-GC



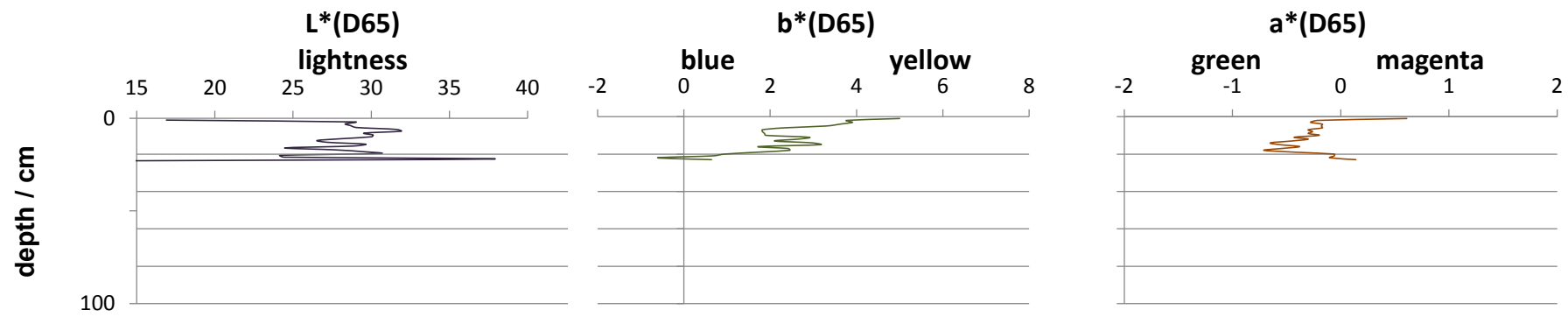
POS475-889-1-GC



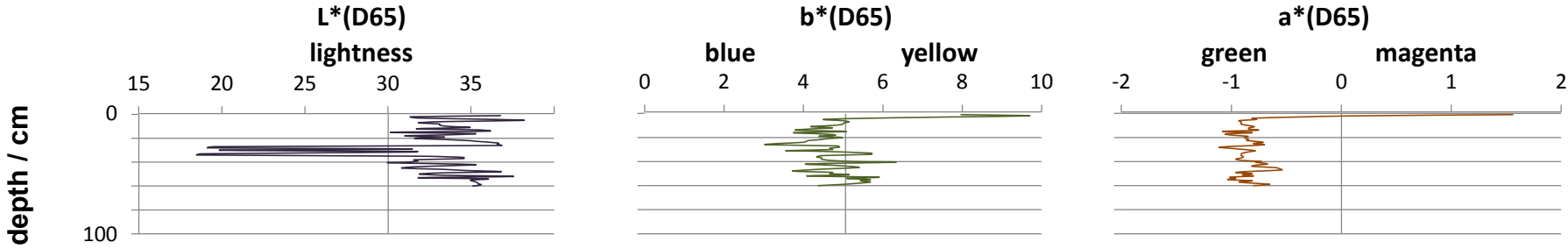
POS475-889-2-GBC



POS475-899-3-GBC

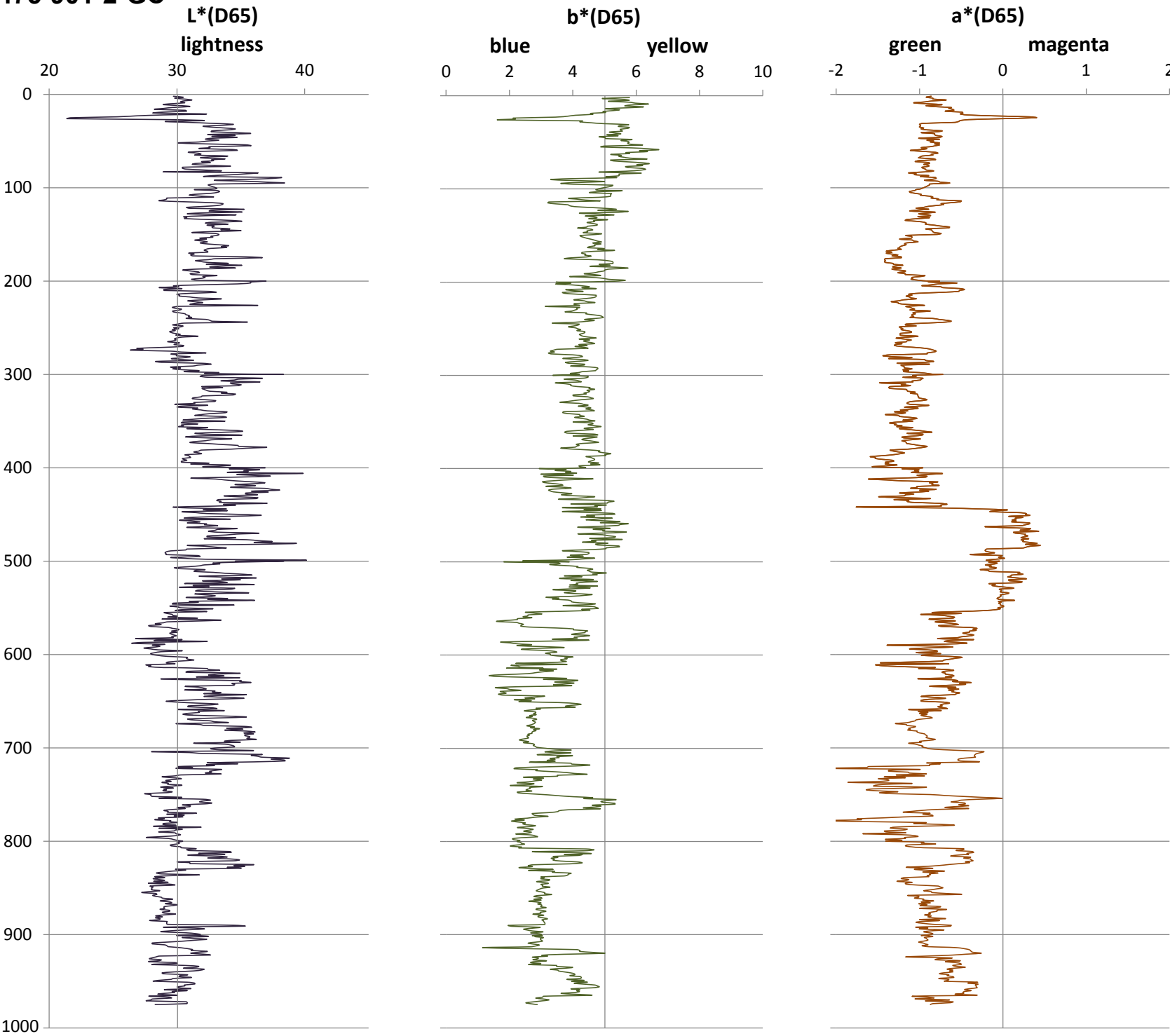


POS475-901-1-GBC

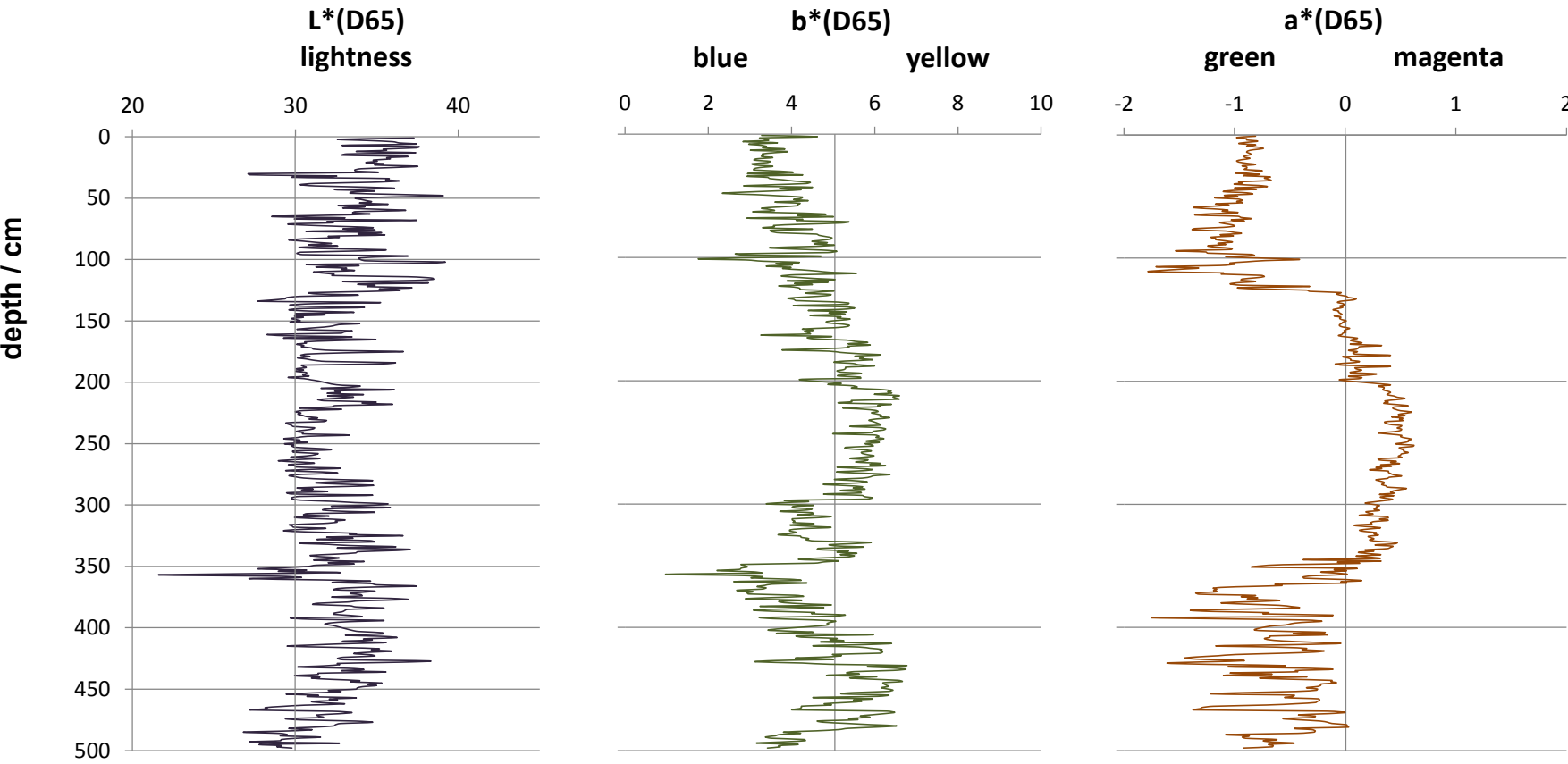


POS475-901-2-GC

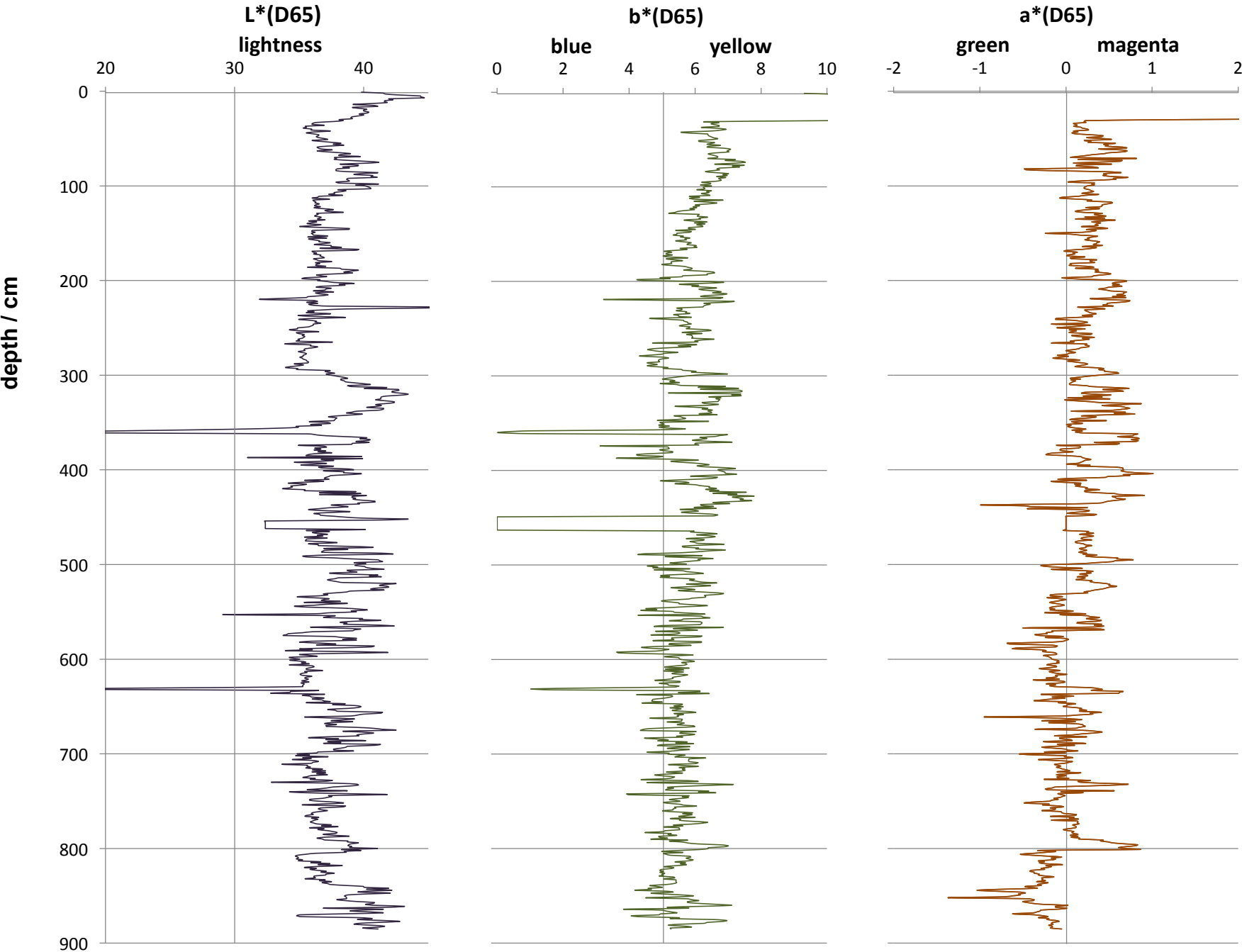
depth / cm



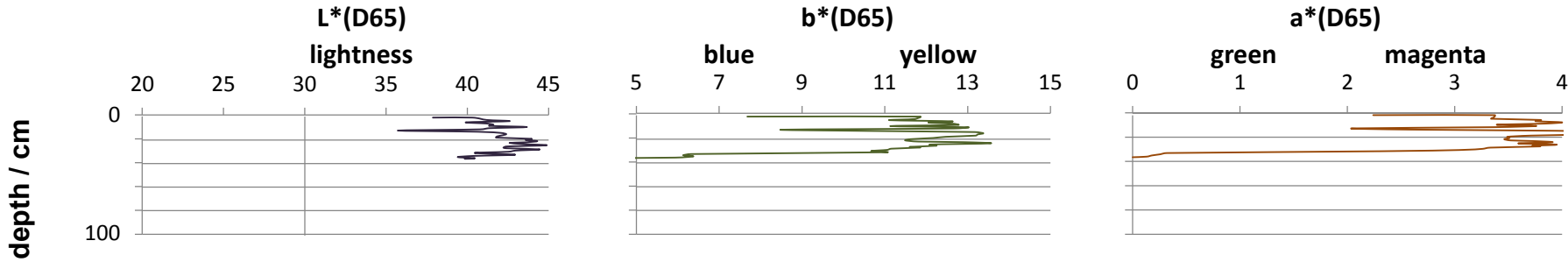
POS475-902-1-GC



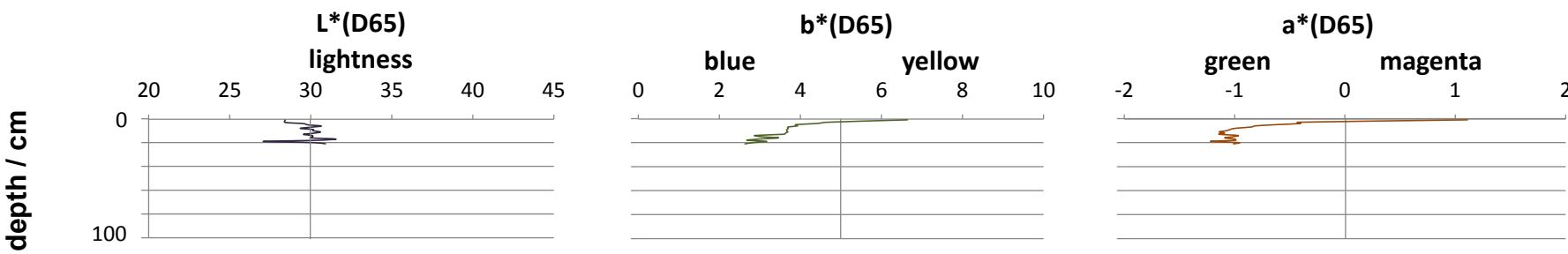
POS475-905-2-GC



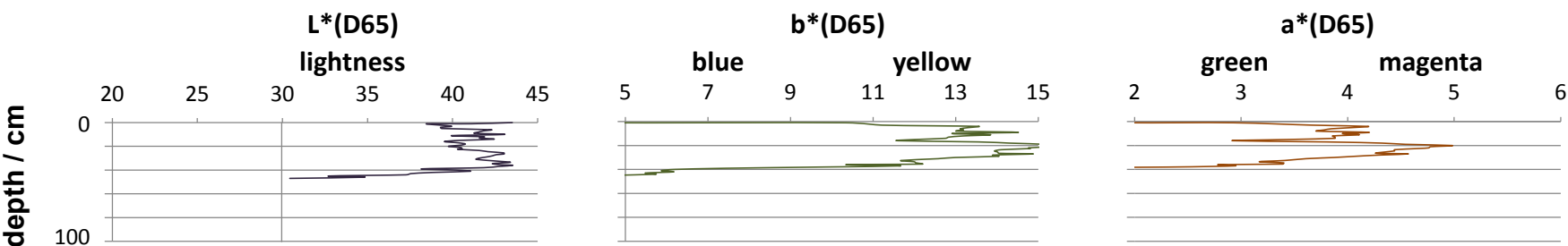
POS475-905-3-GBC



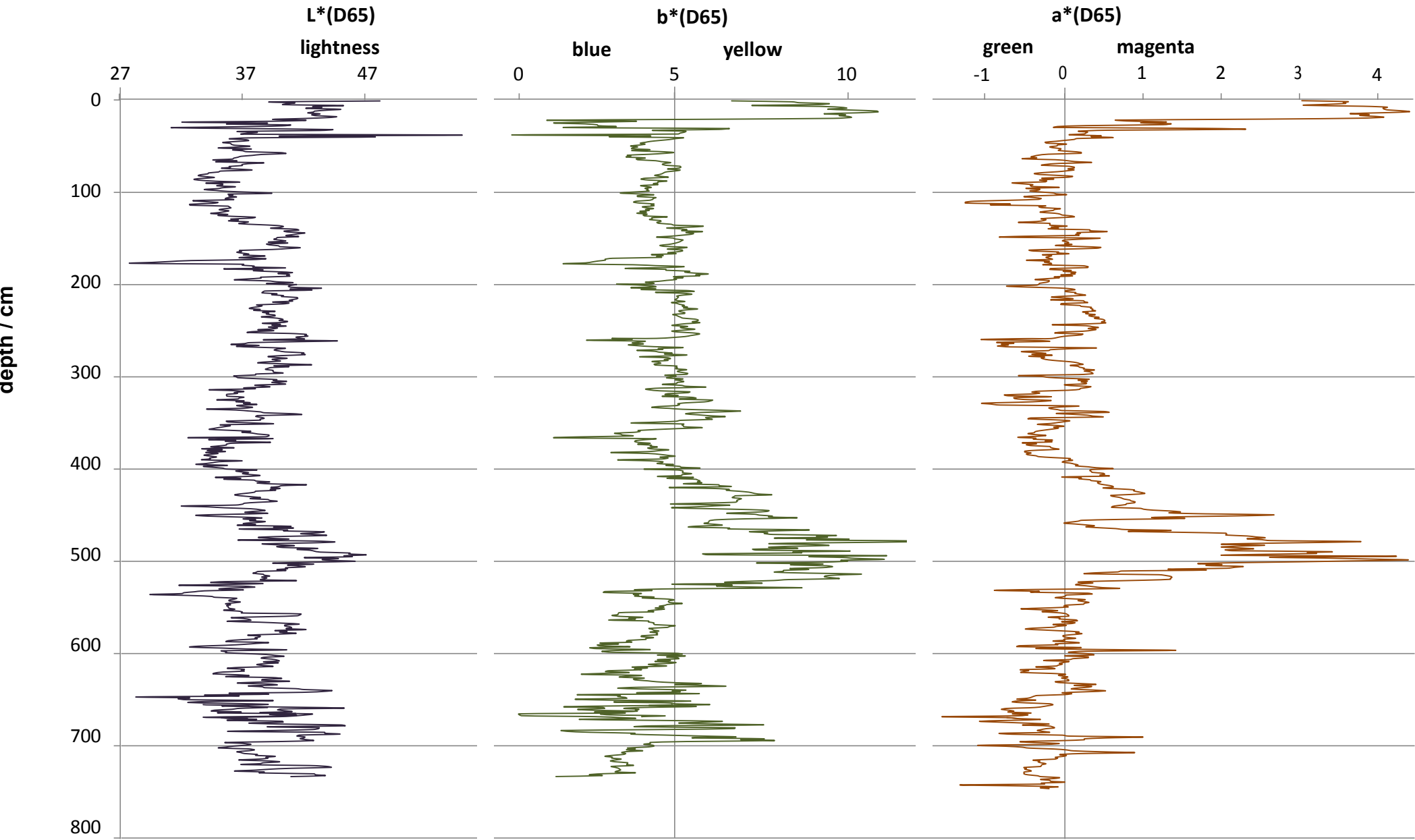
POS475-908-1-GBC



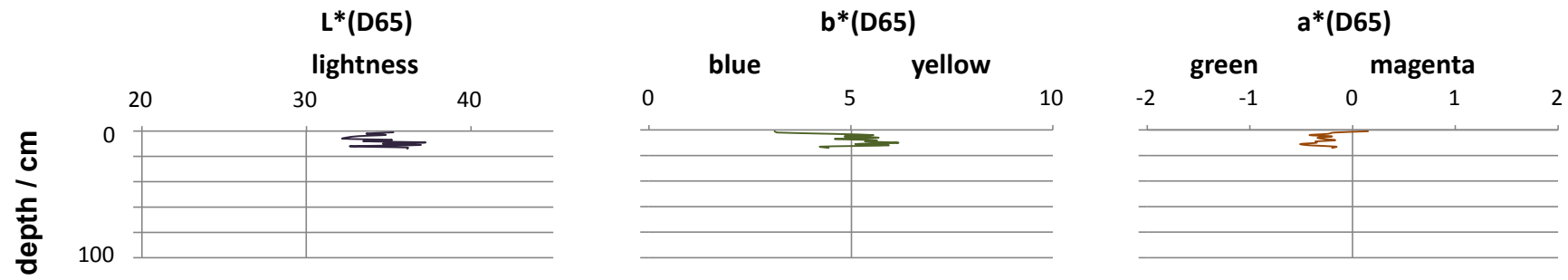
POS475-909-1-GBC



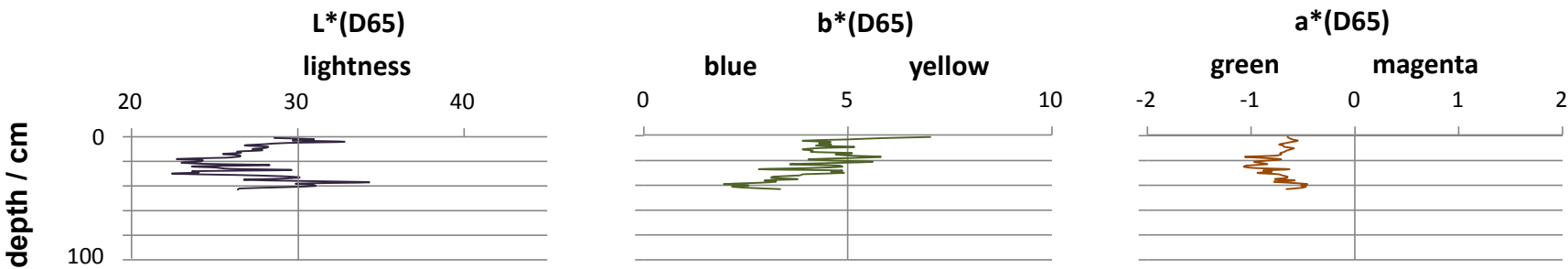
POS475-909-2-GC



POS475-911-2-GBC



POS475-916-1-GBC



GEOMAR Reports

No.	Title
1	FS POSEIDON Fahrtbericht / Cruise Report POS421, 08. – 18.11.2011, Kiel - Las Palmas, Ed.: T.J. Müller, 26 pp, DOI: 10.3289/GEOMAR_REP_NS_1_2012
2	Nitrous Oxide Time Series Measurements off Peru – A Collaboration between SFB 754 and IMARPE –, Annual Report 2011, Eds.: Baustian, T., M. Graco, H.W. Bange, G. Flores, J. Ledesma, M. Sarmiento, V. Leon, C. Robles, O. Moron, 20 pp, DOI: 10.3289/GEOMAR_REP_NS_2_2012
3	FS POSEIDON Fahrtbericht / Cruise Report POS427 – Fluid emissions from mud volcanoes, cold seeps and fluid circulation at the Don-Kuban deep sea fan (Kerch peninsula, Crimea, Black Sea) – 23.02. – 19.03.2012, Burgas, Bulgaria - Heraklion, Greece, Ed.: J. Bialas, 32 pp, DOI: 10.3289/GEOMAR_REP_NS_3_2012
4	RV CELTIC EXPLORER EUROFLEETS Cruise Report, CE12010 – ECO2@NorthSea, 20.07. – 06.08.2012, Bremerhaven – Hamburg, Eds.: P. Linke et al., 65 pp, DOI: 10.3289/GEOMAR_REP_NS_4_2012
5	RV PELAGIA Fahrtbericht / Cruise Report 64PE350/64PE351 – JEDDAH-TRANSECT –, 08.03. – 05.04.2012, Jeddah – Jeddah, 06.04 - 22.04.2012, Jeddah – Duba, Eds.: M. Schmidt, R. Al-Farawati, A. Al-Aidaros, B. Kurten and the shipboard scientific party, 154 pp, DOI: 10.3289/GEOMAR_REP_NS_5_2013
6	RV SONNE Fahrtbericht / Cruise Report SO225 - MANIHIKI II Leg 2 The Manihiki Plateau - Origin, Structure and Effects of Oceanic Plateaus and Pleistocene Dynamic of the West Pacific Warm Water Pool, 19.11.2012 - 06.01.2013 Suva / Fiji – Auckland / New Zealand, Eds.: R. Werner, D. Nürnberg, and F. Hauff and the shipboard scientific party, 176 pp, DOI: 10.3289/GEOMAR_REP_NS_6_2013
7	RV SONNE Fahrtbericht / Cruise Report SO226 – CHRIMP CHatham RIse Methane Pockmarks, 07.01. – 06.02.2013 / Auckland – Lyttleton & 07.02. – 01.03.2013 / Lyttleton – Wellington, Eds.: Jörg Bialas / Ingo Klauke / Jasmin Mögeltönder, 126 pp, DOI: 10.3289/GEOMAR_REP_NS_7_2013
8	The SUGAR Toolbox - A library of numerical algorithms and data for modelling of gas hydrate systems and marine environments, Eds.: Elke Kossel, Nikolaus Bigalke, Elena Piñero, Matthias Haeckel, 168 pp, DOI: 10.3289/GEOMAR_REP_NS_8_2013
9	RV ALKOR Fahrtbericht / Cruise Report AL412, 22.03.-08.04.2013, Kiel – Kiel. Eds: Peter Linke and the shipboard scientific party, 38 pp, DOI: 10.3289/GEOMAR_REP_NS_9_2013
10	Literaturrecherche, Aus- und Bewertung der Datenbasis zur Meerforelle (<i>Salmo trutta trutta</i> L.) Grundlage für ein Projekt zur Optimierung des Meerforellenmanagements in Schleswig-Holstein. Eds.: Christoph Petereit, Thorsten Reusch, Jan Dierking, Albrecht Hahn, 158 pp, DOI: 10.3289/GEOMAR_REP_NS_10_2013
11	RV SONNE Fahrtbericht / Cruise Report SO227 TAIFLUX, 02.04. – 02.05.2013, Kaohsiung – Kaohsiung (Taiwan), Christian Berndt, 105 pp, DOI: 10.3289/GEOMAR_REP_NS_11_2013

No.	Title
12	RV SONNE Fahrtbericht / Cruise Report SO218 SHIVA (Stratospheric Ozone: Halogens in a Varying Atmosphere), 15.-29.11.2011, Singapore - Manila, Philippines, Part 1: SO218- SHIVA Summary Report (in German), Part 2: SO218- SHIVA English reports of participating groups, Eds.: Birgit Quack & Kirstin Krüger, 119 pp, DOI: 10.3289/GEOMAR_REP_NS_12_2013
13	KIEL276 Time Series Data from Moored Current Meters. Madeira Abyssal Plain, 33°N, 22°W, 5285 m water depth, March 1980 – April 2011. Background Information and Data Compilation. Eds.: Thomas J. Müller and Joanna J. Waniek, 239 pp, DOI: 10.3289/GEOMAR_REP_NS_13_2013

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