Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

Open Access Earth System Science Data Discussions

The GIK-Archive of sediment radiography

Hannes Grobe[1], Kyaw Winn[2], Friedrich Werner[2], Amelie Driemel[1], Stefanie Schumacher[1], Rainer Sieger[1]

[1]Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, 27515 Bremerhaven, Deutschland
[2]Institut für Geowissenschaften, Christian-Albrechts Universität, 24118 Kiel, Deutschland

Correspondence to: Hannes Grobe (hannes.grobe@awi.de)

Abstract. The GIK-Archive of radiographs is a collection of X-ray negative images from sediment cores, prepared and exposed since the early 1960s. During four decades of marine geological work at the University of Kiel, Germany, some thousand hours of sampling, careful preparation and x-raying were spent to produce a unique archive of sediment radiographs from several parts of the world ocean. The archive consists of more than 18500 exposures on chemical film that were digitized, geo-referenced, supplemented with metadata and archived in the data library PANGAEA®. With this publication, the images become available in Open Access for use by the scientific community at doi:10.1594/PANGAEA.854841.

1 Introduction

During the late 1950s, the new field of marine geology was developed in Germany at the "Geologisch-Paläontologisches Institut und Museum" an der Christian-Albrechts-Universität zu Kiel (GIK), since 1998 named "Institut für Geowissenschaften". With the commission of the new German research vessel "Meteor" in 1965, GIK developed new and assimilated existing techniques to recover sediments from the ocean floor (a.o. Seibold, 1958; Werner, 1998). A simple but efficient gravity corer with a 12 cm diameter barrel and up to 1.5 t lead weight (Schwerelot) was constructed by the company ”Hydrowerkstätten Kiel”. Piston coring technique was applied in the 1970s with the Kiel version of the former Kullenberg corer (Kullenberg, 1947). A vibro corer supplemented the set of devices for sampling harder sediments. High volume coring technology was extended with the Kastenlot (Kögler, 1963) with a rectangular size of 15 cm x 15 cm and length of 6.4 m for clayey sediments. In the seventies, a larger version recovered cores of 30 cm x 30 cm, and lengths 12-15 m, weighing up to 3.5 t. Besides the mostly deployed gravity and piston corers, the Kastenlot is still in use due to its well known capability not only of recovering undisturbed and continuous sedimentary sequence, but also for providing sufficient material to fulfil the numerous interdisciplinary sampling demands.

To obtain an undisturbed sediment surface from the sea-bottom for the investigation of the sediment-water interface, the box corer was added to the suite of sampling devices (Reineck, 1963). The corer ensures that the pristine sediment succession from the utmost top of the sea-floor surface is collected. The extended large version of the corer with a box size of 50 cm x 50 cm x 55 cm was developed by Scripps and USNEL (United States Naval Electronic Laboratory) (Farris and Crezée, 1976). This type was modified and rebuilt by Wuttke GmbH, Henstedt-Ulzburg to become the German Großkastengreifer (GKG). Since its first deployment in 1980 on RV “Meteor” during cruise M60 (Thiel, 1982) it is in use on all expeditions of German marine research vessels.

Schwerelot, Kastenlot and Großkastengreifer became valuable devices recovering large volumes of high quality sediments, always providing sufficient material for X-ray sample preparation even with multiple sets. They have been in continuous use for more than five decades. Doctoral dissertations and publications of GIK including radiograph interpretations were contributed notably among others by Exon (1972), Werner (2002), Winn (1974, 2006), Wetzel (1979), and Löwemark

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

(2001). Also the inpretation of large scale structures of sedimentary environments was supported by x-ray technology of the sediments Hinz et al. (1971), Whitaker and Werner (1981), Winn and Averdieck (1984).

2 Application of X-ray techniques in sedimentology

In radiography, the structural heterogeneity or homogeneity of an object is made visible by the different attenuation of X-rays on a photographic negative film. The resulting image is referred to as “radiograph” with the key quality parameters blackening, contrast and resolution. In the late nineties, positive films were also exposed and interpreted. Applications of radiography are mostly known in medical and industrial, for example to verify the welding quality of steel products.

X-ray imaging on marine sediment cores commenced at GIK around 1960 with a self-constructed device, which simply consisted of an X-ray source located in a shielded cabinet. In the early 1970s, the Faxitron cabinet X-ray system was invented by physicist Joseph Edmonds Henderson at the Applied Physics Laboratory, University of Washington (Faxitron 2017). In 1974 Hewlett Packard took over the product for use in manufacturing silicon chips. GIK applied this professional technology for sediment slabs taken from marine sediment cores by the use of the Faxitron model type 43855 (10 to 110 kV, 3 mA, size 84 x 55 x 51 cm, weight 176 kg), finally resulting in a comprehensive collection of large format radiography (Werner, 1998). In marine geology, the Faxitron became the most frequently used device in X-ray imaging. The technology and preparation procedures of GIK as described below were subsequently adopted by some other sedimentology laboratories in Germany.

2.1 Preparation and exposure

Marine sediment cores are archived in segments of one meter length for convenient handling, and cut longitudinally in two halves for processing. After photography and a visual lithological description of the sediment sequence (structure, texture, colour), the ”working” half is sampled for various analyses, with the preparation of X-ray slabs being the first step of the sampling workflow (Grobe, 1986; Fig. 1). It was common practice first to prepare sediment slices for radiographs, and use the exposure as a guide for further sampling, in particular through strongly bioturbated sections. The remaining ”archive” half is sealed airtight in D-tubes for future investigations. As a common practice in geological repositories worldwide, the core segments are archived in cold stores at +4°C.

To ensure the best quality of the X-radiograph, sediment slices have to be prepared with utmost care, so as not to destroy the original structures, and also not to add artefacts. The surface of the longitudinal core cut is evened with a wet glass plate. Grooves or furrows on the surface, usually caused by large particles, have to be avoided. A hard Plexiglas® lid of 25 x 10 x 1 cm size is pushed gently into the smoothened surface of the working half to provide support and stability for the sediment slab (Fig. 2). Core label, depth interval and an arrow pointing downwards in the direction of penetration of the coring device (backwards in time, opposite to Ocean Drilling Program standard) are then marked on the lid. A Kastenlot sediment core with a typical preparation of sampling of X-ray slabs is shown in Fig. 3. The slab within the lid is separated from the remaining core by pulling a nylon line up-core behind the plastic lid, thereby using the two sides of the lid orientated parallel to the core axis as guides. The slab is carefully lifted with a cheese knife and removed from the core. The slit might be wetted if the slab tends to adhere to the main core. The slices in the lids are vacuum sealed in polyethylene lay-flat tubing after removing the enclosed air. Equipment used for the preparation is shown in Fig. 4.

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

X-ray film is coated on both sides and thus has higher sensitivity and contrast compared to film used in light photography. For exposure the film type ”Structurix D 4“ manufactured by Agfa-Gevaert was chosen. The film is not sensitive to red light and thus can easily be handled in a dark room under low light conditions. The film was cut into 25 x 10 cm stripes and stored in black film covers. Each 25 cm-long slab was exposed to the X-ray beam with the slab surface not covered by the lid facing the X-ray source (Fig. 5).

The characteristics of the X-radiation determine the quality of the sediment images with the wave length being the most important factor. High energy will produce ”harder” radiation with shorter wavelength while lower energy will result in radiation with longer wavelength. Due to the soft composition of unconsolidated sediments, a spectrum of longer wavelengths and thus ”weaker” radiation is preferred to produce images with a moderate contrast (Werner 1975).

Exposure times depend on sediment type and are mostly controlled by grain size and compaction, the thickness of the slab and the strength of the radiation. A 1-centimetre thick slice has to be exposed for a time span between 3 (soft clay) and 20 minutes (high sand content) when a voltage of 30-35 kV and a current of 3 mA are applied. Identification of the core ID and the depth interval on the negative is assured by putting corresponding lead letters and numbers on the film during exposure. The film is developed in a dark room for 3 minutes by using the developer G124 and the fixer G335 (Agfa), washed for 20 minutes in distilled water and dried. For a detailed description of the procedure see Werner (1975).

During 50 years of marine geological research at GIK, a suite of 1355 sediment cores with a total length of 3547 m was investigated (Fig. 6). More than 18500 sediment slices were prepared for X-ray imaging and exposure. Between 2010 and 2014 the images were transferred to the PANGAEA department at the Alfred Wegener Institute for Polar and Marine Research, Bremerhaven (AWI). They were digitised with a resolution of 600 dpi by a transmitting light scanner (Microtek ScanMaker 9800XL). Images were supplemented with the metadata of the corresponding cores including position, water depth, sampling device, expedition, date/time, ship etc. The resulting collection of 1355 data sets was combined in a single parent dataset which is available at doi:10.1594/PANGAEA.854841.

2.2 Analysis of images

Besides the documentation by light photography, the X-radiography became a standard imaging technique in marine geology to complement and support the visual description of sediment profiles, which comprises the detailed logging of the lithological composition of the sediment, its texture and sedimentary structures (Bouma, 1969). In particular, radiographs reveal details of structures, such as bioturbation and graded bedding, diagenetic modifications and large internal components (e.g. fossils or drop-stones) that are not discernible on normal light photography.

The dominant control on beam attenuation is bulk sediment density (Holyer et al. 1996), which in turn is affected by grain size, mineralogical composition, abundance of biogenic components and physical parameters as water content, porosity, and compaction. Thus radiographs can be used to determine a whole range of various sediment properties. During examination of the images some specific points need to be considered which are described in brief in the following, examples of typical sedimentary textures are shown in Fig. 7.

Structures that may be unrecognisable to the naked eye are, e.g. boundaries of strata, unconformities, graded bedding and most important - bioturbation (Werner 1968; Winn 1974, Wetzel 1979). “Lebenspuren” are the most common structures in marine sediments allowing the identification of the species and the reconstruction of palaeoecological and palaeoenvironmental conditions (Löwemark 2001). The resulting taxonomy of palichnology is the basis for its identification and classification (Bromley 1999, Seilacher 2007). Sedimentological sequences formed by distinct processes, e.g. deposition by turbidity or contour currents, and their evolution over time are also part of this structural group. Features like base and top boundaries, type, thickness, frequency, rhythms and cycles indicate facies differentiation and changes.

Physical properties can be identified by the brightness of the negatives, as well as by internal structures like layering (e.g. ash layers), lamination, bedding planes, cross bedding, current ripples or sorting. By using a magnifying glass while investigating the x-ray image, individual grains with a size of > 1 mm can be classified in terms of grain shape and composition. Support of a high-resolution sedimentology is given in the millimetre- to centimetre-scale, including large components like mud clasts or gravel grains, e.g. as ice rafted debris (Grobe, 1987; Principato 2004). Any gravel fraction reveals itself by the distinct appearance of each individual grain.

Extracted high-resolution grayscale curves were correlated with physical parameters (colour, gamma-ray density, magnetic susceptibility, grain size) (St-Onge et al. 2007). There is a clear relationship between grain size distribution and brightness/blackening of the film. Sandy to clayey sediments are composed of just a few minerals (quartz, feldspar, clay minerals, carbonates), with all of them having a similar specific grain density of 2.6 to 2.8 [g/cm^3]. Thus, differences in brightness result mostly from changes in grain size rather than from a heterogeneous distribution of minerals. Water content, density and porosity are the major factors controlling grey-scale values; porosity increases from coarse grained to fine grained sediments. The sediment density and thus the brightness of the image negative increases with core depth because the compaction results in reduced pore space and water content.

Minerals may result from diagenesis including authigenic pyrite, zeolite, or the rarely formed porcelanite (Gerland et al. 1997). Heavy minerals such as pyrite and other iron sulphide as well as iron oxide minerals can easily be identified by their high brightness/X-ray attenuation and their specific grain shapes and internal structures. On the other hand, dark grey features visible in negatives can be areas with an extremely high water content, plant fossils, wood or even small voids. In case the samples were stored for a longer period, new minerals may have formed through chemical processes in the sediment (e.g. see Fig 6 G).

Artefacts reflecting the post-depositional disturbance of the original sedimentary structure must be identified within the core. Those effects can have various reasons, which should always be kept in mind while investigating and interpreting the images (Skinner and McCave 2003). During the coring process and recovery, the mostly soft and often “soupy” sediments from near the seafloor surface (i.e. at the core top) may flow, resulting in a loss of the original structure. In some instances it is not even possible to prepare a sediment slab useful for X-radiography from the upper decimetres of the core. Coring disturbance caused by the piston or gravity coring process may result in pseudo ”tectonic” features” (e.g. faults, fractures, sediment mixing, “flow in”) which are predominantly observed at the bases of longer piston cores. Gravity coring can cause micro-faulting within the sediment as the result of an artificial shortening of the sediment column (Fig. 6 C). Especially in clayey sequences, even pseudo-hiatuses can occur when parts of a sediment section let the core barrel pass but are pressed out and thus are not recovered. Also the outer edges of a core segment may show an upward bending (gravity core) or downward bending (piston core) of layers in close proximity to the core liner, which results from the friction between the liner and the sediment when the core barrel penetrates the seabed.

Further effects visible in radiography might be: if the sediment slice is not properly sealed in lay flat tubing it may dry out and produce drying cracks, which can, however be clearly identified. If a sediment slice has a variable thickness, the brightness of the X-radiograph will vary throughout the sample. If the sediment contains larger particles, the marginal areas around the particle may be disturbed during the preparation. Regular stripes and patterns observed on an X-radiograph are usually the result of insufficient smoothening of the slab surface and reflect tracks from the cutting wire. Also the projection has to be taken into account during analysis: structural elements of a three dimensional slice are projected in two dimensions onto the film.

3 Archiving

The X-radiographs archived at GIK were taken from 1355 globally distributed sediment cores recovered on 93 cruises of the German research vessels “Wattenberg”, “Alkor”, “Littorina”, “Poseidon”, “Meteor” and “Sonne”, mostly on expeditions between 1964 and 2000 (Fig. 4). For the list of cores with metadata see doi:10.1594/PANGAEA.875415, linked as "Further details" to the parent set. RV “Sonne” cores collected on behalf of the Preussag manganese nodule project and BGR-led cruises to the Equatorial and South Pacific were also sampled and analysed. Most of the remaining material is available in the core storage of GIK and at the Lithothek of GEOMAR Helmholtz Centre for Ocean Research Kiel.

3.1 Image digitisation and archiving

More than 18500 exposures of X-radiographs were digitised using two A3-format scanners, model Microtek ScanMaker 9800XL, with a resolution of 600 dpi and stored in *.jpg-format with moderate compression to generate file sizes for convenient internet download times. Not all images were post-processed and thus some might still be underexposed. Brightness, lucidity and contrast can be corrected as required for investigation with any image processing software. The full information is in each image due to the high resolution scan of the finegrained film. Images were uploaded to PANGAEA and stored in a database archiving granularity of all images per core in one subset. Metadata and additional documentary files including core descriptions and photos were added if available. The metadata contain core ID, latitude and longitude, water depth, recovery, coring device and date/time when the core was taken. The label of the expedition linking to the cruise report (if available) is given. Each dataset starts with a „Citation:“ tagged line, consisting of the name of the principal investigator(s), a standard title ”Documentation of sediment core GIKxxxxx-x“, year of electronic storage and thus public availability, and the source institute (in this case always set to GIK). The DOI as persistent link to the dataset is the mandatory part of any modern citation. If the images were already used in publications, the corresponding references can be found under the „Related to:“ field. Selected examples of images from this collection are presented in Fig. 7.

3.2 Data availability

The GIK-Archive of radiography is available at doi:10.1594/PANGAEA.854841.

With the establishment of polar research through the foundation of the Alfred Wegener Institute for Polar Research (AWI) in 1980 in Bremerhaven, the methods of sediment core sampling and analysis, developed at GIK, were utilised and adopted by the department of marine geology at AWI (Grobe, 1987). All geological sample material taken aboard RV ”Polarstern” was archived in an institutional core repository, administered by a database. Between 1987 and 1997, this system was developed further and finally became an archiving and publishing system for data from earth system research, namely PANGAEA® - Data Publisher for Earth and Environmental Science (Diepenbroek et al. 2002). Technically PANGAEA is a relational database (RDB) with geo-reference in time and space for a consistent storage of analytical and observational data. A storage

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

system (tape robot) for files and binary objects, e.g. images assists the RDB. For single or collections of files, only the metadata are stored in the relational tables of the data model, including stable links to the image files on tape (Fig. 8).

PANGAEA provides its content not only for direct download from its web site (http://www.pangaea.de) but also for harvesting. Apart from standard search engines, the image datasets are distributed via web services through library catalogues, e.g. WorldCat and a number of portals (listed at http://wiki.pangaea.de/wiki/Portal). Most images of a core can be found easily via the PANGAEA query window or even via Google by using the (unique) core label as search phrase. The requested dataset mostly is listed under the first hits.

Metadata of PANGAEA are routinely mirrored in DataCite (reference http://data.datacite.org) which is the central entry portal for citable research datasets on the Internet. This information is also stored in the catalogue of the German National Library of Science and Technology (reference TIB), co-inventor of the data DOI and co-founder of DataCite. Since 2004, PANGAEA provides its content for OAI-PMH harvesting (Open Archives Initiative - Protocol for Metadata Harvesting). The recent opperator is OCLC (https://www.oclc.org) with its WorldCat (https://www.worldcat.org) which incorporates the content of repositories following the OAI standard and thus also includes the metadata of the Pangaea content.

3.3 Query examples

Three query examples are given on how using the PANGAEA search:

Show all data related to core GIK10117-2:
https://www.pangaea.de/?q=gik10117-2

Show the documentation images of alle cores at station GIK12520:
https://www.pangaea.de/?q=gik12520*+documentation

Show data and documentation images of all stations during METEOR cruise M40/1:
https://www.pangaea.de/?q=M40/1

4 Conclusion

With this publication, the complete digitised archive of more than 18500 radiographs from the world ocean has been made available to the scientific community. This dataset is publicly available under the CC-by 3.0 license (https://creativecommons.org/licenses/by/3.0/) with a persistent identifier (doi:10.1594/PANGAEA.854841) as supplement to this publication.

Although X-ray imaging is a well suited method to supplement documentation of sediment cores, this technology has increasingly lost attention in some parts of the scientific community because it is time consuming and new high resolution analytical sedimentology techniques (e.g. multi sensor core logging, and X-ray fluorescence and colour scanning) have been continuously introduced and gained priority over the last couple of decades. In addition, nowadays digital X-ray images of sediments can be taken very quickly both on-board and in the lab, e.g. with the ITRAX XRF scanner, Croudace et al. 2006). For the old FAXITRON models a digital X-ray scanner is now available to fit in (NTB 2005). The time of analog X-ray imaging of sediments is over and will now continue with digital X-ray devices and X-ray computed tomography (CT) systems (e.g. Freifeld et al. 2006).

Acknowledgements. With this publication the work of Wilma Rehder and Ursula Faber, technicians at GIK, is greatly acknowledged. Both ensured the continuous very high quality of both the sediment slices for X-radiography and of the X-radiographs themselves during many sampling parties on research vessels and at the institute. During nearly four decades they demonstrated hundreds of students how to prepare proper samples, guided them through the x-ray exposure and dark room procedures and archived the images. We are thankful to Michael Seebeck who reliabel and patient digitized those thousands of exposures in a long lasting workflow. For the improvement of the manuscript the authors are grateful to ....

*This article with its supplementary image collection is dedicated to co-author **Dr. Friedrich Werner**, head of the sediment core sampling laboratory and core curator at GIK for more than 40 years who passed away in 2012.*

References

Bouma, A. H.: Methods for the study of sedimentary structures. 458 pp., Wiley, New York, doi:10.1002/iroh.19710560422, 1969.

Bromley, R.G.: Spurenfossilien: Biologie, Taphonomie und Anwendungen. Springer, Berlin/Heidelberg. 347p, doi:10.1007/978-3-642-59832-6, 1999.

Croudace, I.W., Rindby, A., and Rothwell, R.G.: ITRAX: description and evaluation of a new multi-function X-ray core scanner. In: Rothwell, R.G. (Ed.), New techniques in sediment core analysis. Geological Society, London, Special Publications, 267, 51–63, doi:10.1144/GSL.SP.2006.267.01.04, 2006.

Diepenbroek, M., Grobe, H., Reinke, H., Schindler, U., Schlitzer, R., Sieger, R., Wefer, G.: PANGAEA—an information system for environmental sciences, Computers & Geosciences, 28(10), 1201-1210, doi:10.1016/S0098-3004(02)00039-0, 2002.

Exon, N.: Sedimentation in the outer Flensburg Fjord area (Baltic Sea) since the last glaciation. Meyniana 22:5-62, doi:10.2312/meyniana.1972.22.5, 1972.

Farris, R. A. and Crezée, M.: An improved Reineck Box for sampling coarse sand. Internationale Review of Hydrobiology, 61(5), 703-705, doi:10.1002/iroh.3510610515, 1976.

Faxitron X-Ray Corporation, Rohde & Schwarz GmbH: Technical Manual, Bedienungsanleitung, 3 documents, hdl:10013/epic.50709, 1975-1996.

Faxitron: Web site "About us", http://www.faxitron.com/life-sciences-ndt/about, access 2017-04.

Freifeld, B. M., Kneafsey, T. J., and Rack, F. R.: On-site geological core analysis using a portable X-ray computed tomographic system. Geological Society, London, Special Publications, 267, 165-178, doi:10.1144/GSL.SP.2006.267.01.12, 2006.

Gerland, S., Kuhn, G., and Bohrmann, G.: Physical properties of a porcellanite layer (Southwest Indian Ridge) constrained by geophysical logging. Marine Geology, 140(3-4), 415-426, doi:10.1016/S0025-3227(97)00046-7, 1997.

Grobe, H.: Spätpleistozäne Sedimentationsprozesse am antarktischen Kontinentalhang vor Kapp Norvegia, östliche Weddell See, Berichte zur Polarforschung, 27, 1-121, doi:10.2312/BzP_0027_1986, 1986.

Grobe, H.: Determination of IRD in sediment cores. Polarforschung 57(3), 123-345, doi:10.2312/polarforschung.57.3.123, 1987.

Hinz, K., Kögler, F.-C., Richter, I., & Seibold, E.: Reflexionsseismische Untersuchungen mit einer pneumatischen Schallquelle und einem Sedimentecholot in der westlichen Ostsee. Teil II: Untersuchungsergebnisse und geologische Deutung. Meyniana, 21, 17-34, doi:10.2312/meyniana.1971.21.17, 1971.

Holyer R. J., Young, D. K., Sandidge, J. C., and Briggs K. B.: Sediment density structure derived from textural analysis of cross-sectional X-radiographs. Geo-Marine Letters, 16(3), 204-211, doi:10.1007/BF01204510, 1996.

St-Onge, G., Mulder, T., Francus, P., and Long, B.: Continuous physical properties of cored marine sediments. Developments in Marine Geology, 1, 63-98, doi:10.1016/S1572-5480(07)01007-X, 2007.

Kögler, F.-C.: Das Kastenlot. Meyniana, 13, 1-7, doi:10.2312/meyniana.1963.13.1, 1963.

Kowalczk, A.: The application of digital x-radiograph imaging for the determination of bulk density. NSF Research Experience for Undergraduates Project Report (REU Final Report, P. Dickhut and C. Friedrichs advisors), Virginia Institute of Marine Science, Gloucester Point, VA., CHSD-2005-04, 8 pp, (pdf 1.6 MB), hdl:10013/epic.50706.d001, 2005.

Löwemark, L.: Biogenic traces as paleoceanographic indicators in Late Quaternary sediments from the SW Iberian margin. Berichte-Reports, Institut für Geowissenschaften, Universität Kiel, 14, 138 p, doi:10.2312/reports-ifg.2001.14, 2001.

NTB elektronische Geraete GmbH: Digital x-ray scanners of the EZ series, Dickel, Germany, hdl:10013/epic.42410, 2005; http://www.ntbxray.com/products/digital_x_ray_scanner.html(access 2017-04).

Kullenberg, B.: The piston core sampler. Svenska Hydrografisk-biologiska Kommissionen Skrifter, Tredge serien hydrografi, 1(2), 1-46, (pdf 3.5 MB), hdl:10013/epic.50738.d001, 1947.

Principato, S. M.: X-ray radiographs of sediment cores: a guide to analyzing diamicton. In: Francus, P. (ed), Image analysis, sediments and paleoenvironments, Kluwer Academic Publishers, Dordrecht, The Netherlands, 165-178, doi:10.1007/1-4020-2122-4_9, 2004.

Reineck, A.: Bergung von Proben aus dem Meeresboden. Natur und Museum, 93(8), 331-336, (pdf 1 MB), hdl:10013/epic.50704.d001, 1963.

Seibold, E.: Ein Stoß-Kolbenlot für Flachwasser. Geol. Rundschau, 47(1), 28-36, doi:10.1007/BF01802314, 1958.

Seilacher, A.: Trace Fossils Analysis. Springer-Verlag, Berlin/Heidelberg. 226 pp, doi:10.1007/978-3-540-47226-1, 2007.

Skinner, L. C. and McCave, I. N.: Analysis and modelling of gravity- and piston coring based on soil mechanics. Marine Geology, 199(1-2), 181-204, doi:10.1016/S0025-3227(03)00127-0, 2003.

Thiel, H.: Forschungsschiff "Meteor" Reise Nr. 60, SUBTROPEX '82 Expeditionsprogramm. Deutsche Forschungsgemeinschaft, 23 pp, (pdf 6 MB), hdl:10013/epic.45025.d001, 1982.

Werner, F.: Gefügeanalyse feingeschichteter Schlicksedimente der Eckernförder Bucht (westliche Ostsee). Meyniana, 18, 79-105, doi:10.2312/meyniana.1968.18.79, 1968.

Werner, F.: Radiographien von Lockersedimenten - Herstellung von Radiographien an Sedimentkernen nach der im GIK üblichen Methode. Unpublished report, Geologisch-Paläonotologisches Institut und Museum der Christian-Albrechts-Universität, Kiel (GIK), 9 pp, (pdf 4.4 MB), hdl:10013/epic.50708.d001, 1975.

Werner, F.: 40 Jahre marin-geowissenschaftliche Forschung am Geologisch-Paläontologisches Institut der Universität Kiel. Meyniana, 50, 7-12, doi:10.2312/meyniana.1998.50.7, 1998.

Werner, F.: Bioturbation structures in marine Holocene sediments of the Kiel Bay (Western Baltic). Meyniana, 54, 41-72, doi:10.2312/meyniana.2002.54.41, 2002.

Wetzel, A.: Bioturbation in Spätquartären Tiefwasser Sedimentation vor NW-Afrika, Diss., Math.-Nat. Fak. der Christian-Albrechts-Universität zu Kiel, 111 pp, (pdf 49 MB), hdl:10013/epic.50707.d001, 1979.

Whitaker, M.J., Werner, F.: Pockmarks: Submarine vents of natural gas or freshwater seeps? Geomarine Letters, 1, 193-199, doi:10.1007/BF02462433, 1981.

Winn, K.: Present and postglacial Sedimentation in the Great Belt Channel (Western Baltic). Meyniana 26, 63- 101, doi:10.2312/meyniana.1974.26.63, 1974.

Winn, K.: Bioturbation structures in marine Holocene sediments of the Great Belt (Western Baltic). Meyniana, 58, 157-178, doi:10.2312/meyniana.2006.58.157, 2006.

Winn, K., Averdieck, F.-R.: Postboreal development of the Western Baltic: comparison of two local sediment basins. Meyniana, 36, 35-50, doi:10.2312/meyniana.1984.36.35, 1984.

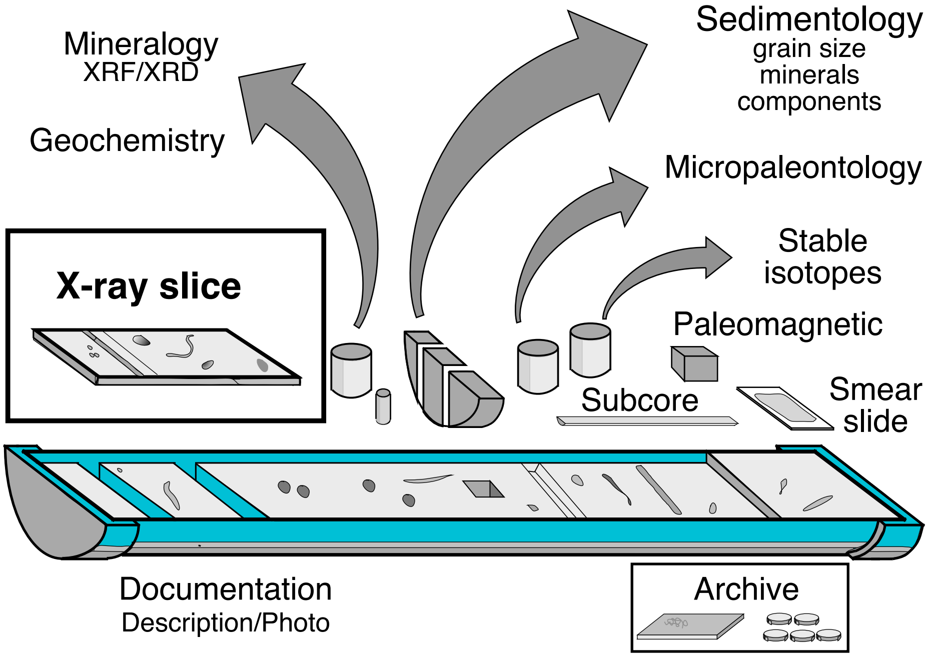

Figure 1: Standard sampling workflow for the investigation of sediment cores as developed at GIK. The first step during the sampling sequence was the preparation of sediment slabs for X-ray imaging along the core profile.

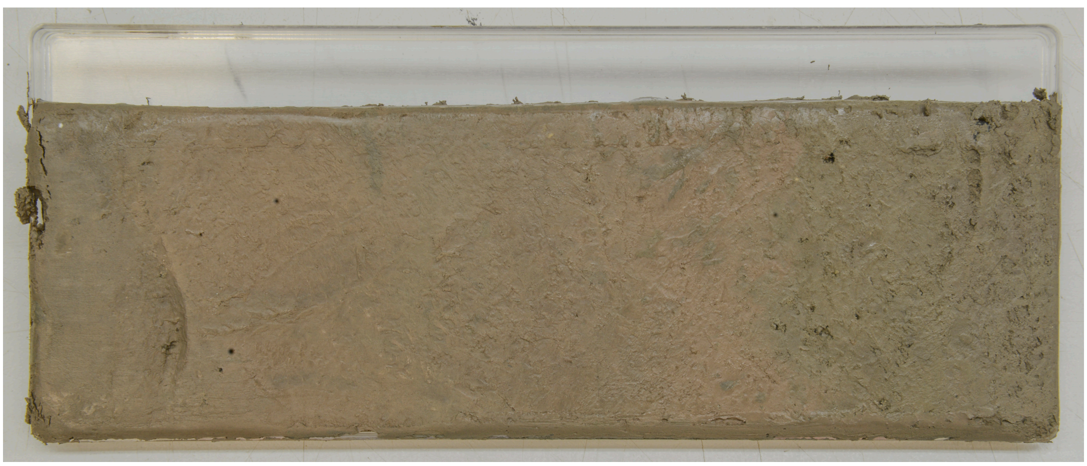

Figure 2: Sediment slab (25 x 10 cm) stabilized in plexiglas lid ready for X-raying.

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

Figure 3: Sediment core taken with a Kastenlot (30 x 30 cm) prepared with Plexiglas lids to remove the samples for X-raying.

Figure 4: Equipment used for the preparation of sediment slabs for X-ray imaging comprise fishing line, destilled water, cheese knife, spatule and special Plexiglas lids for support of the sediment slab. Lids used for preparation have a size of 25 x 10 x 1 cm (Bensberger Kunststoffwerk Lappe GmbH).

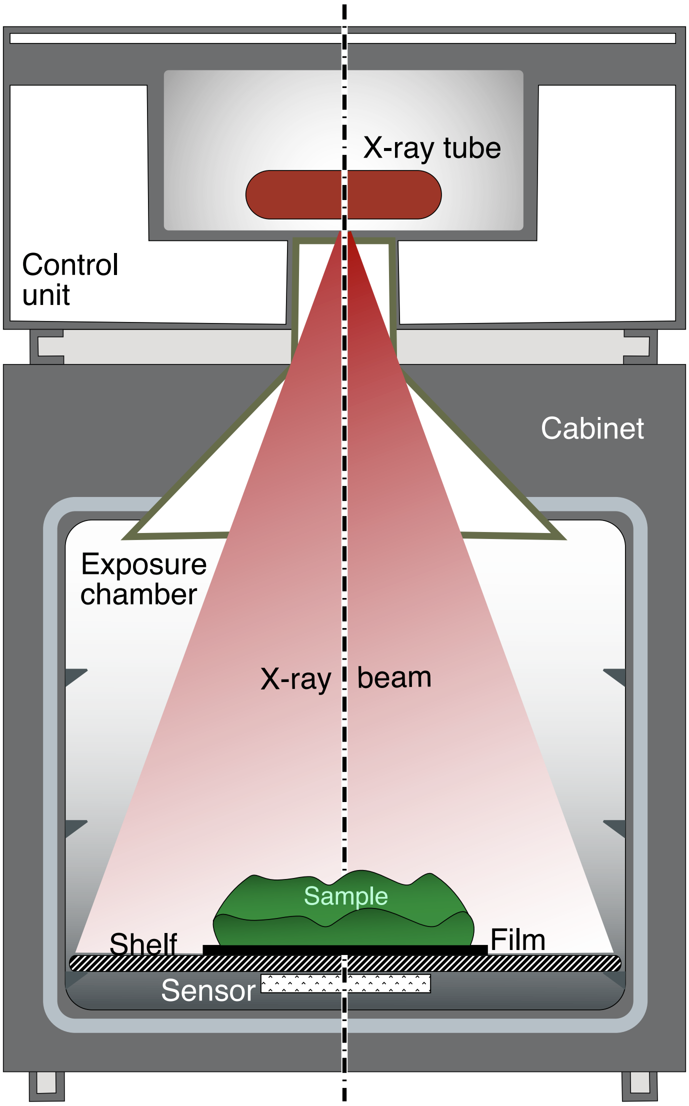

Figure 5: Schematic drawing of an X-ray device of the FAXITRON series (Hewlett Packard), which has an upper chamber for the X-ray tube with a control unit and an exposure chamber below. Both are fully lead shielded allowing for operation under normal laboratory conditions without special protection of registration. The sensor below the sample shelf can be used to set automatic exposure times. In modern digital operation mode, shelf, film and sensor are replaced by a scanner, sensitive to X-ray beams.

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

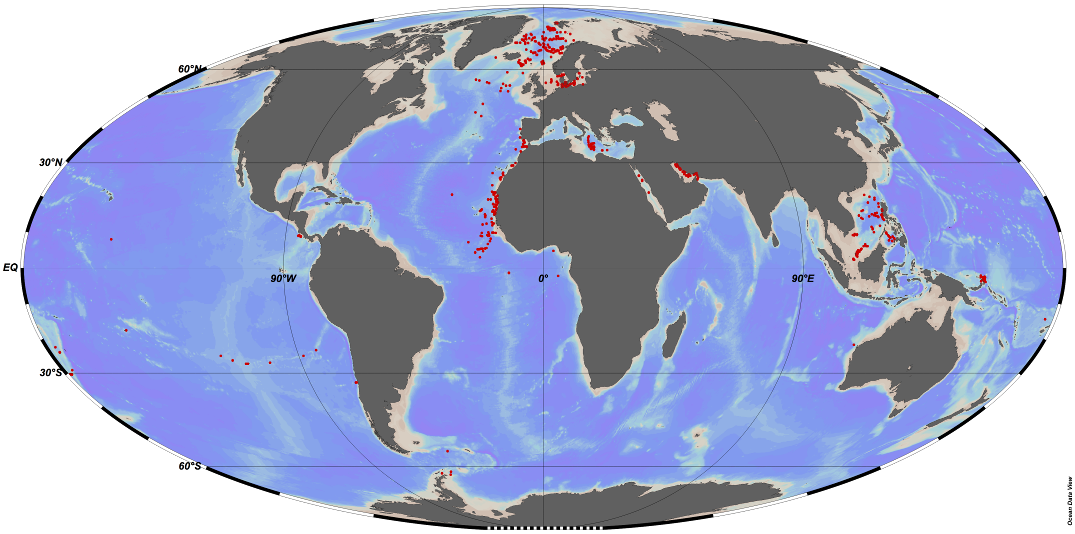

Figure 6: Map showing the locations of marine sediment cores, from which X-radiographs were obtained as part of the GIK-Archive. The cores were collected between 1965 and 2000 on 93 expeditions in total. The cores are listed in table doi:10.1594/PANGAEA.875415

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

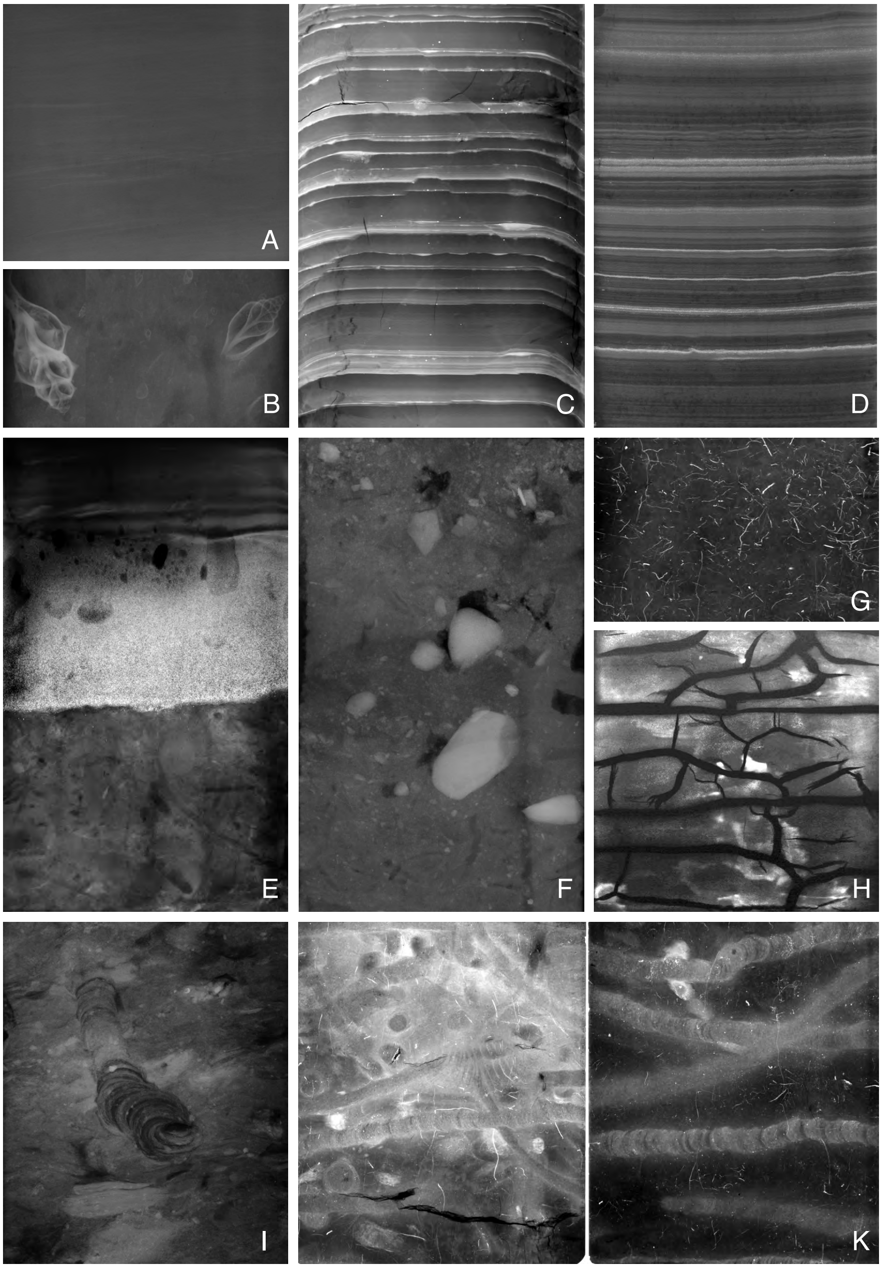

Figure 7: Examples of various X-radiographs from the GIK-Archive. (A) Homogeneous clayey sediment, Mediterranean Sea, doi:10.1594/PANGAEA.720925; (B) fossile molluscs, Persian Gulf, doi:10.1594/PANGAEA.720253; (C) interbedded strata with artificial downbending of layers and fault lines as a result of gravity coring, Baltic Sea, doi:10.1594/PANGAEA.690661; (D) laminated sediment, Red Sea, doi:10.1594/PANGAEA.720616; (E) turbidite with gradded bedding, South China Sea, doi:10.1594/PANGAEA.720737; (F) gravel as ice rafted debris, Norwegian Sea, doi:10.1594/PANGAEA.720368; (G) pyritized lebensspuren, West Atlantic - off Senegal, doi:10.1594/PANGAEA.705737; (H) artificial cracks from drying out of an unprotected sediment slab, doi:10.1594/PANGAEA.705491; (I, K) Examples of bioturbation, Baltic Sea off Flensburger Förde, doi:10.1594/PANGAEA.705626 and African continental slope, doi:10.1594/PANGAEA.705737.

Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2017-69
Manuscript under review for journal Earth Syst. Sci. Data
Discussion started: 19 July 2017

Open Access Earth System Science Data Discussions

Sediment core images

Citation:	**Werner, Friedrich; Winn, Kyaw (2009):** Documentation of sediment core GIK01154. *Institut für Geowissenschaften, Christian-Albrechts-Universität, Kiel*, doi:10.1594/PANGAEA.720263, *In:* Winn, K; Werner, F (2015): The Kiel archive of sediment radiographs. *Geologisch-Paläontologisches Institut, Christian-Albrechts-Universität, Kiel*, doi:10.1594/PANGAEA.854841
Coverage:	*Latitude:* 29.505000 * *Longitude:* 49.710000 *Date/Time Start:* 1965-04-09T00:00:00 * *Date/Time End:* 1965-04-09T00:00:00 *Minimum Elevation:* -31.0 m * *Maximum Elevation:* -31.0 m
Event(s):	**GIK01154** (M1_340 01154-B) * *Latitude:* 29.505000 * *Longitude:* 49.710000 * *Date/Time:* 1965-04-09T00:00:00 * *Elevation:* -31.0 m * *Recovery:* 1.78 m * *Location:* Persian Gulf * *Campaign:* M1 (IIOE - International Indian Ocean Expedition) * *Basis:* Meteor (1964) * *Device:* Kasten corer (KAL)
License:	Creative Commons Attribution 3.0 Unported
Size:	unknown

6 files found

Back to dataset

GIK01154_000-030d_x-ray.jpg

GIK01154_030-150d_x-ray.jpg

Figure 8: Example of the standard metadata header provided by PANGAEA from dataset doi:10.1594/PANGAEA.720263. Starting with the citation, comprising author(s), year, title, source and DOI. Citation is followed by the georeference in space and time and links to further references or reports. For this collection images of each core location have their own "child" dataset. The total of 1355 "child" datasets of this paper are grouped together in one "parent" dataset (doi:10.1594/PANGAEA.854841). At the end of the metadata header, each image is shown as thumbnail and can be downloaded either individually or as part of a compilation of all images in a single zip-archive.