

Proceedings of the International Ocean Discovery Program

Volume 390/393

South Atlantic Transect

Expedition 390C of the R/V *JOIDES Resolution*
from Kristiansand, Norway, to Cape Town, South Africa
Sites U1556–U1559
5 October–5 December 2020

Expedition 395E of the R/V *JOIDES Resolution*
from Cape Town, South Africa, to Reykjavik, Iceland
Sites U1556, U1557, U1560, and U1561
6 April–5 June 2021

Expedition 390 of the R/V *JOIDES Resolution*
from and to Cape Town, South Africa
Sites U1556, U1557, and U1559
7 April–7 June 2022

Expedition 393 of the R/V *JOIDES Resolution*
from and to Cape Town, South Africa
Sites U1558–U1560 and U1583
7 June–7 August 2022

Volume authorship

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Ministry of Earth Sciences (MoES), India

The JRSO is supported by the NSF. Any opinions, findings, and conclusions or recommendations expressed in this material do not necessarily reflect the views of the NSF, the participating agencies, TAMU, or Texas A&M Research Foundation.

The bulk of the shipboard-collected core data from this expedition is accessible at <https://zenodo.org/communities/iodp> (see list of [available data sets](#)). If you cannot access this site or need additional data, please contact Data Librarian, International Ocean Discovery Program *JOIDES Resolution* Science Operator, Texas A&M University (database@iodp.tamu.edu).

A complete set of the logging data collected during the expedition is available at http://mlp.ldeo.columbia.edu/logdb/scientific_ocean_drilling. If you have problems downloading the data, wish to receive additional logging data, or have questions regarding the data, please contact Database Administrator, Borehole Research Group, Lamont-Doherty Earth Observatory of Columbia University (logdb@ldeo.columbia.edu).

Supplemental data were provided by the authors and may not conform to IODP publication formats.

JRSO expedition photos are the property of IODP and are public access. Some core photographs have been tonally enhanced to better illustrate particular features of interest. High-resolution images are available upon request.

Cover photograph of ~61, 49, and 30 Ma uppermost basement along the South Atlantic Transect (SAT) highlights some interactions between igneous crust, sedimentation, and fluid flow—potential sites of biogeochemical exchange in aging crust. The multidisciplinary SAT experiment was designed to recover both sediment and basement cores along an age transect across the SAT. From left: sedimentary breccia of pillow lava fragments in hydrothermally altered (indurated) calcareous sediments (390C-U1556A-32X-1), pillow lavas with interflow indurated calcareous sediments (393-U1558D-6R-2), and breccia of broken basalt and altered glass clasts in indurated calcareous sediment matrix (393-U1583F-16R-2) (left: 360° images of core exteriors from Deutsche Montan Technologie [DMT] scanner generously loaned to IODP by International Continental Scientific Drilling Program [ICDP] for SAT expeditions; right: split-core surface linescan images). Photo credit: IODP JRSO. Site map shows SAT study region. Top: bathymetry of South Atlantic Ocean (<https://doi.org/10.1029/2008GC002332>). Inset: regional setting. Bottom: magnetic anomalies (<https://doi.org/10.7289/V5H70CVX>). Solid lines = Crustal Reflectivity Experiment Southern Transect (CREST) seismic reflection profiles (<https://doi.org/10.1594/IEDA/500255>). WOCE = World Ocean Circulation Experiment, MAR = Mid-Atlantic Ridge, RGR = Rio Grande Rise, ERGR = eastern Rio Grande Rise, TdC = Tristan de Cunha.

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Core descriptions

Visual core descriptions (VCDs) are presented in PDF files for each site. Thin sections and/or smear slides for each site or hole are presented in CSV or PDF format in the CORES directory and in Excel format in DESC_WKB in Supplementary material. The entire set of core images in PDF is available in the IMAGES directory.

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Supplementary material

Supplementary material for the Volume 390/393 expedition reports includes mass accumulation rate data, piece logs, X-ray diffraction data, and DESClogik workbooks in Microsoft Excel format; Dick Kroon memorial service files and photographs in PDF, JPG format, and Microsoft Word format; and a portable X-ray fluorescence calibration workbook in Microsoft Excel format. A full list of directories can be found in SUPP_MAT in the volume zip folder or on the [Supplementary material for Volume 390/393 expedition reports](#) web page.

Expedition research results

Data reports

Titles are available in [HTML](#).

Drilling location maps

A site map showing the drilling locations for this expedition and maps showing the drilling locations of all International Ocean Discovery Program (IODP) expeditions, produced using QGIS (<http://www.qgis.org>), and all Integrated Ocean Drilling Program, Ocean Drilling Program (ODP), and Deep Sea Drilling Project (DSDP) expeditions, produced using Generic Mapping Tools (GMT) of Paul Wessel and Walter H.F. Smith (<https://www.generic-mapping-tools.org>), are available in PDF.

[iODP Expedition 390/393 site map](#)

[IODP map](#)

[Integrated Ocean Drilling Program map](#) (Expeditions 301–348)

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[DSDP map](#) (Legs 1–96)

Dedication

Professor Dirk “Dick” Kroon

24 December 1957–24 May 2022

Regius Professor of Geology

University of Edinburgh, United Kingdom

This volume is dedicated to Dick Kroon, who passed on 24 May 2022 during IODP Expedition 390. A memorial tribute to Dick Kroon was held aboard *JOIDES Resolution* on 6 July while establishing Site U1583 at 20°26.03'W, 30°42.62'S.

Dick Kroon was a charismatic leader of the scientific ocean drilling community. He was a world class, highly cited scientist who made fundamental observations about our planet’s climate, life, and oceans and their response to changes in the Earth system. Most of his research stemmed from sedimentary and paleoceanographic records preserved in cores from the oceans. Dick had a long and most productive engagement with scientific ocean drilling and *JOIDES Resolution* in particular, ever since he first sailed during Ocean Drilling Program (ODP) Leg 117 in 1987 in the early days of ODP. *JOIDES Resolution* was his temporary home for six voyages. Dick was Co-Chief Scientist twice aboard *JOIDES Resolution* for two of the most important and impactful paleoceanographic expeditions in the history of scientific ocean drilling that returned critical and influential records of major changes in the Earth system, including the Cretaceous/Tertiary (K/T) boundary and the Paleocene/Eocene Thermal Maximum (PETM), during ODP Legs 171B (Blake Nose) and 208 (Cenozoic Climate Extremes), respectively.

Dick was more than an excellent scientist. He was deeply involved in orchestrating and lubricating the many national and organizational parts of scientific ocean drilling in the Netherlands and the UK in Europe and internationally. He served as Chair of IODP-Netherlands (2002–2006), as Co-Chair of the IODP Science Evaluation Panel for 5 years (2012–2016), and finally as Chair of the IODP Forum (2019–2021), where he played an essential role ensuring that the whole is much greater than the sum of its parts. Through his guidance of the 2050 Science Framework, we have clear future goals and most importantly a willing and able next generation of international scientists to lead and take scientific ocean drilling forward.

Dick was a positive man, a natural optimist and enthusiast. He could see constructive ways forward in most things in life and science. This attitude is important and infectious. He promoted the idea that science and especially ocean drilling is fun. Science teams aboard *JOIDES Resolution* get to do things and go places in space and time that others do not. This is a privilege and luxury that we should embrace and not forget.

The multidisciplinary research of the South Atlantic Transect will be the first of many ways we uphold Dick’s legacy.

Photo credit: Catherine Nigrini.



Acknowledgments

This volume presents the initial findings of the first phase of the South Atlantic Transect (SAT) campaign (IODP Expeditions 390, 393, 390C, and 395E) to drill a series of holes through sediment and basalts at increasing crustal ages across the western flank of the southern Mid-Atlantic Ridge. These activities are the culmination of ideas first discussed at the Multidisciplinary Transect Drilling During Transits workshop in College Station, Texas (USA), in 2013, supported by the U.S. Science Support Program and the Consortium for Ocean Leadership. Our operations and science in this region stand on the scientific shoulders of the ocean drilling giants of Deep Sea Drilling Project (DSDP) Leg 3—Arthur E. Maxwell, Richard von Herzen, and Kenneth J. Hsu—and the generations of colleagues who have built and nurtured this unique international collaboration to explore the oceans and the wider Earth system.

Since its inception, the multidisciplinary SAT campaign was strongly supported by the IODP Science Evaluation Panel, the *JOIDES Resolution* Facility Board, and the *JOIDES Resolution* Science Operator (JRSO). This support was further reflected in the enabling response to the Coronavirus Disease 2019 (COVID-19) pandemic that greatly enhanced our scientific achievements with engineering operations during Expeditions 390C and 395E that installed reentry cones and deep casing strings at the great majority of our primary target sites and recovered preliminary sediment sections to volcanic basement. These operations freed up time for great science during Expeditions 390 and 393, which returned to the South Atlantic with shipboard science teams.

We thank Captains Harm Nienhuis (Expedition 390C), Jake Robinson (Expeditions 395E and 390), and Tom Hartt (Expedition 393) and all of the mates, engineers, and crews of all four expeditions for keeping us safe, guiding us from site to site, keeping us in position, and bringing us safely back to port. Operations during the SAT expeditions were guided by TAMU Operations Superintendents Steve Midgley (Expeditions 390C and 390), Bill Rhinehart (Expedition 395E), and Kevin Grigar (Expedition 393). We greatly appreciate the efforts of the rig floor and aerial teams led by Offshore Installation Managers Wayne Lambert (Expeditions 390C and 393) and Mark Robinson (Expeditions 395E and 390) and tool pushers Craig Prosser and Glenn Barrett (Expeditions 390C and 393) and Joe “Bubba” Attryde and Phil Christie (Expeditions 395E and 390)—thank you for the great cores and for all your efforts keeping the holes open, keeping cones in the seafloor, and getting tools and bits back to the surface. We also thank the Schlumberger Logging Engineers Clayton Furman (Expeditions 390C, 395E, and 390), and Kirby Garrett (Expedition 393) for their expertise and unending energy during logging operations.

A huge shout out and thank you to the smiley and always welcoming Entier catering and stewarding teams who kept the ship spotless, our beds made, and all of us well fed and tidily folded in that eternal battle between our expanding waistlines and tightening clothes.

Great thanks to the IODP technical team, including Laboratory Officers Chieh Peng (Expeditions 390C and 390) and Eric Moortgat (Expedition 393) and Assistant Laboratory Officers Heather Barnes (Expeditions 390C and 393), Eric Moortgat (Expedition 390C), Aaron de Loach (Expedition 395E), Beth Novak (Expeditions 395E and 390), Daniel Marone (Expedition 390), and Doris Piñero Lajas (Expedition 393), who kept everything in the laboratories running and organized, backed up, and archived aboard the R/V *JOIDES Resolution*. Last but not least, we thank the JRSO publications team (Lorri Peters, Amy McWilliams, Jenni Hesse, Patrick Edwards, Julie Myers, Jean Wulfson, Doug Cummings [Expedition 393], Keith Dupuis, Rhonda Kappler, and Alyssa Stephens [Expedition 390]) for their support and professional organization of this huge report.

Site survey data for the SAT and IODP Proposal 853 was collected during the NSF-sponsored Crustal Reflectivity Experiment Southern Transect (CREST) aboard the R/V *Marcus G. Langseth* (MGL1601; January–February 2016; OCE-1537169 UT and OCE-1537108 TAMU to G.L. Christeson and R. Reece, respectively).

The DMT 360° core scanner was generously loaned by the International Continental Scientific Drilling Program (ICDP) with support for the transfer to *JOIDES Resolution* and safe return to GFZ-Potsdam (Germany) via a Natural Environment Research Council (NERC) UK-IODP award to the University of Southampton (United Kingdom). Patricia Gibbs (Peters and May, United Kingdom) and Tim Bronk (JRSO) are thanked for the successful logistic arrangements.

The completion of the four IODP Expeditions 390, 393, 390C, and 395E and the publication of our initial results in these proceedings are not the end to this SAT campaign. We look forward to the wealth of multidisciplinary and collaborative postexpedition science that this campaign will generate and hope to return to the SAT sooner or later to address still outstanding science questions during future endeavors.

Foreword

The International Ocean Discovery Program (IODP) represents the latest incarnation of almost five decades of scientific ocean drilling excellence and is generally accepted as the most successful international collaboration in the history of the Earth sciences. IODP builds seamlessly on the accomplishments of previous phases: the Deep Sea Drilling Project, Ocean Drilling Program, and Integrated Ocean Drilling Program. The 2013–2023 IODP Science Plan (*Illuminating Earth's Past, Present, and Future*) defines four themes and thirteen challenges for this decade of scientific ocean drilling that are both of fundamental importance in understanding how the Earth works and of significant relevance to society as the Earth changes, at least in part in response to anthropogenic forcing. This phase of IODP represents an intense level of international collaboration in bringing diverse drilling platforms and strategies to increasing our understanding of climate and ocean change, the deep biosphere and evolution of ecosystems, connections between Earth's deep processes and surface manifestations, and geologically induced hazards on human timeframes.

The *Proceedings of the International Ocean Discovery Program* presents the scientific and engineering results of IODP drilling projects, expedition by expedition. As in the preceding Integrated Ocean Drilling Program, expeditions in the current IODP phase are conducted by three implementing organizations, each providing a different drilling capability. These are the US Implementing Organization (USIO; through September 2014) and the *JOIDES Resolution* Science Operator (JRSO; as of October 2014), providing the leased commercial vessel *JOIDES Resolution* for riserless drilling operations; JAMSTEC's Institute for Marine-Earth Exploration and Engineering (MarE3), providing the drillship *Chikyu* for riser and occasional riserless operations; and the European Consortium for Ocean Research Drilling (ECORD) Science Operator (ESO), providing "mission-specific" platforms (MSPs) for expeditions that extend the IODP operational range where neither drillship is suitable, for example, in polar environments and in shallow waters. Scheduling decisions for each capability are made by three independent Facility Boards, each of which includes scientists, operators, and platform funding partners: the *JOIDES Resolution* Facility Board (JRFB), *Chikyu* IODP Board (CIB), and ECORD Facility Board (EFB). At the beginning of the current IODP, the three Facility Boards agreed to utilize Publication Services at the USIO and now the JRSO for production of all expedition *Proceedings* volumes and reports.

The current IODP differs from prior scientific ocean drilling programs in that it has neither a central management organization nor commingled funding for program-wide activities. Yet this phase of IODP retains a fundamental integrative structural element: a "bottom-up" evaluation of all proposals for drilling expeditions by a single advisory structure composed of scientists representing all international program partners. International scientists may submit drilling proposals to the Science Support Office; all submitted proposals are then evaluated by a Science Evaluation Panel in the context of the Science Plan.

The current IODP also has an international integrative level for high-level discussion and global consensus-building: the IODP Forum. The Forum is not only charged with assessing program-wide progress toward achieving the current Science Plan, but also with overseeing approaches toward a new bright future of scientific ocean drilling post 2023. At present, IODP involves 22 international funding agencies, including those from the United States, Japan, an Australia/New Zealand consortium (ANZIC), China, India, South Korea, and the 15 members of ECORD (Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom). The IODP membership represents an unparalleled level of international scientific collaboration; one of the greatest and ongoing strengths of scientific ocean drilling.

Henk Brinkhuis
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