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Hydroacoustic Monitoring of Oceanic Spreading Centers: Past, Present, and Future

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Abstract

Mid-ocean ridge volcanism and extensional faulting are the fundamental processes that lead to the creation and rifting of oceanic crust, yet these events go largely undetected in the deep ocean. Currently, the only means available to observe seafloor-spreading events in real time is via the remote detection of the seismicity generated during faulting or intrusion of magma into brittle oceanic crust. Hydrophones moored in the ocean provide an effective means for detecting these small-magnitude earthquakes, and the use of this technology during the last two decades has facilitated the real-time detection of mid-ocean ridge seafloor eruptions and confirmation of subseafloor microbial ecosystems. As technology evolves and mid-ocean ridge studies move into a new era, we anticipate an expanding network of seismo-acoustic sensors integrated into seafloor fiber-optic cabled observatories, satellite-telemetered surface buoys, and autonomous vehicle platforms.

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References

- Baker, E.T., G.J. Massoth, R.A. Feely, R.W. Embley, R.E. Thomson, and B.J. Burd. 1995. Hydrothermal event plumes from the CoAxial seafloor eruption site, Juan de Fuca Ridge. *Geophysical Research Letters* 22(2):147–150, <http://dx.doi.org/10.1029/94GL02403>.
- Bath, M., and M. Shahidi. 1971. T-phases from Atlantic earthquakes. *Pure and Applied Geophysics* 92:74–114, <http://dx.doi.org/10.1007/BF00874995>.
- Bath, M. 1954. Study of T-phases recorded at the Kiruna seismograph station. *Tellus* 6(1):63–72.
- Barnes, C., and V. Tunnicliffe. 2008. Building the world's first multi-node cabled ocean observatories (Neptune Canada and VENUS, Canada): Science, realities, challenges, and opportunities. Pp. 1–8 in *Oceans 2008: MTS/IEEE Kobe Techno-Ocean*. <http://dx.doi.org/10.1109/OCEANSKOB.2008.4531076>.
- Blackman, D.K., C.E. Nishimura, and J.A. Orcutt. 2000. Seismoacoustic recordings of a spreading episode on the Mohns Ridge. *Journal of Geophysical Research* 105(B5):10,961–10,973, <http://dx.doi.org/10.1029/2000JB900011>.
- Bohnenstiehl, D.R., R.P. Dziak, H. Matsumoto, A. Lau, M. Fowler, K.E. Cook, C.M. Scheip, K.W. Warren, J.A. Conder, and D.A. Wiens. 2010. Hydroacoustic monitoring of seismic and volcanic activity within the Lau Basin. *Eos, Transactions, American Geophysical Union* 90(52):Fall Meeting Abstract T11E-02.
- Bohnenstiehl, D.R., R.P. Dziak, M. Tolstoy, C. Fox, and M. Fowler. 2004. Temporal and spatial history of the 1999–2000 Endeavour Segment seismic series, Juan de Fuca Ridge. *Geochemistry Geophysics Geosystems* 5, Q09003,

Bohnenstiehl, D.R., and M. Tolstoy. 2003. Comparison of teleseismically and hydroacoustically derived earthquake locations along the north-central Mid-Atlantic Ridge and equatorial East-Pacific Rise. *Seismological Research Letters* 74:790–801, <http://dx.doi.org/10.1785/gssrl.74.6.791>.

Bohnenstiehl, D.R., M. Tolstoy, and E. Chapp. 2004. Breaking into the plate: A 7.6 Mw fracture-zone earthquake adjacent to the Central Indian Ridge. *Geophysical Research Letters* 31, <http://dx.doi.org/10.1029/2003GL018981>.

Bohnenstiehl, D.R., M. Tolstoy, R.P. Dziak, C.G. Fox and D.K. Smith. 2002. Aftershock sequences in the mid-ocean ridge environment: An analysis using hydroacoustic data. *Tectonophysics* 354:49–70, [http://dx.doi.org/10.1016/S0040-1951\(02\)00289-5](http://dx.doi.org/10.1016/S0040-1951(02)00289-5).

Brocher, T.M. 1983. T-phases from an earthquake swarm on the Mid-Atlantic Ridge at 31.6°N. *Marine Geophysical Researches* 6(1):39–49, <http://dx.doi.org/10.1007/BF00300397>.

Collins, M.P. 1936. *Bulletin Number 5*. Harvard University Seismograph Station, 23 pp.

Cooke, R.J.S. 1967. Observations of the seismic T-phase at Macquarie Island. *New Zealand Journal of Geology and Geophysics* 10:1,212–1,225.

Crane, K., L. Johnson, B. Appelgate, C. Nishimura, R. Buck, C. Jones, P. Vogt, and R. Kos'yan. 1997. Volcanic and seismic swarm events on the Reykjanes Ridge and their similarities to events on Iceland: Results of a rapid response mission. *Marine Geophysical Researches* 19(4):319–338, <http://dx.doi.org/10.1023/A:1004298425881>.

deMartin, B.J., R.A. Sohn, J.P. Canales, S.E. Humphris. 2007. Kinematics and geometry of active detachment faulting beneath the Trans-Atlantic Geotraverse (TAG) hydrothermal field on the Mid-Atlantic Ridge. *Geology* 35(8):711–714, <http://dx.doi.org/10.1130/G23718A.1>.

Dziak, R.P., D.R. Bohnenstiehl, J.P. Cowen, E.T. Baker, K.H. Rubin, J.H. Haxel, and M.J. Fowler. 2007. Rapid dike emplacement leads to eruptions and hydrothermal plume release during seafloor spreading events. *Geology* 35(7):579–582, <http://dx.doi.org/10.1130/G23476A.1>.

Dziak, R.P., D.R. Bohnenstiehl, H. Matsumoto, M.J. Fowler, J.H. Haxel, M. Tolstoy, and F. Waldhauser. 2009. The January 2006 seafloor spreading event at 9°50'N, East Pacific Rise: Ridge dike intrusion and transform fault interactions from regional hydroacoustic data. *Geochemistry Geophysics Geosystems* 10, Q06T06, <http://dx.doi.org/10.1029/2009GC002388>.

Dziak, R.P., D.R. Bohnenstiehl, H. Matsumoto, C.G. Fox, D.K. Smith, M. Tolstoy, T.-K. Lau, J.H. Haxel, and M.J. Fowler. 2004a. P- and T-wave detection thresholds, Pn velocity estimate, and detection of lower mantle and core P-waves on ocean sound channel hydrophones at the Mid-Atlantic Ridge. *Bulletin of the Seismological Society of America* 94:665–677, <http://dx.doi.org/10.1785/0120030156>.

Dziak, R.P., W.W. Chadwick, C.G. Fox, and R.W. Embley. 2003. Hydrothermal temperature changes at the southern Juan de Fuca Ridge associated with the Mw 6.2 Blanco Transform earthquake. *Geology* 31(2):119–122, [http://dx.doi.org/10.1130/0091-7613\(2003\)031<0119:HTCATS>2.0.CO;2](http://dx.doi.org/10.1130/0091-7613(2003)031<0119:HTCATS>2.0.CO;2).

Dziak, R.P., C.G. Fox, R.W. Embley, J.E. Lupton, G.C. Johnson, W.W. Chadwick, and R.A. Koski. 1996. Detection of and response to a probable volcanogenic T-wave event swarm on the western Blanco Transform Fault Zone. *Geophysical Research Letters* 23(8):873–876, <http://dx.doi.org/10.1029/96GL00240>.

Dziak, R.P., and C.G. Fox. 1999. The January 1998 earthquake swarm at Axial Volcano, Juan de Fuca Ridge: Hydroacoustic evidence of seafloor volcanic activity. *Geophysical Research Letters* 26(23):3,429–3,432, <http://dx.doi.org/10.1029/1999GL002332>.

Dziak, R.P., C.G. Fox, and A.E. Schreiner. 1995. The June-July seismo-acoustic event at CoAxial segment, Juan de Fuca Ridge: Evidence for lateral dike injection. *Geophysical Research Letters* 22(2):135–138, <http://dx.doi.org/10.1029/94GL01857>.

Dziak, R.P., M. Park, W.-S. Lee, H. Matsumoto, D.R. Bohnenstiehl, and J.H. Haxel. 2010. Tectonomagmatic activity and ice dynamics in the Bransfield Strait back-arc basin, Antarctica. *Journal of Geophysical Research* 115, B01102, <http://dx.doi.org/10.1029/2009JB006295>.

Dziak, R.P., D.K. Smith, D.R. Bohnenstiehl, C.G. Fox, D. Desbruyeres, H. Matsumoto, M. Tolstoy, and D.J. Fornari. 2004b. Evidence of a recent magma dike intrusion at the slow spreading Lucky Strike segment, Mid-Atlantic Ridge. *Journal of Geophysical Research* 109, B12102, <http://dx.doi.org/10.1029/2004JB003141>.

Edwards, M.H., G.J. Kurras, M. Tolstoy, D.R. Bohnenstiehl, B.J. Coakley, and J.R. Cochran. 2001. Evidence of recent volcanic activity on the ultraslow-spreading Gakkel Ridge. *Nature* 409:808–812: <http://dx.doi.org/10.1038/35057258>.

Embley, R.W., W.W. Chadwick Jr., I.R. Jonasson, D.A. Butterfield, and E.T. Baker. 1995. Initial results of a rapid response to the 1993 CoAxial event: Relationships between hydrothermal and volcanic processes. *Geophysical Research Letters* 22(2): 143–146, <http://dx.doi.org/10.1029/94GL02281>.

- Escartin, J., D.K. Smith, J. Cann, H. Schouten, C.H. Langmuir, and S. Escrig. 2008. Central role of detachment faults in accretion of slow-spreading lithosphere. *Nature* 455:790–794, <http://dx.doi.org/10.1038/nature07333>.
- Ewing, W.M., G.P. Woollard, V.C. Vine, and J.L. Worzel. 1946. Recent results in submarine geophysics. *Geology Society of America* 40:53–58, [http://dx.doi.org/10.1130/0016-7606\(1946\)57\[909:RRISG\]2.0.CO;2](http://dx.doi.org/10.1130/0016-7606(1946)57[909:RRISG]2.0.CO;2).
- Ewing, W.M., and J.L. Worzel. 1948. *Long-Range Sound Transmission*. Geological Society of America Memoir 27(3), 39 pp.
- Fox, C.G., and R.P. Dziak. 1998. Hydroacoustic detection of volcanic activity on the Gorda Ridge, February–March 1996. *Deep Sea Research Part II* 45(12):2,513–2,530, [http://dx.doi.org/10.1016/S0967-0645\(98\)00081-2](http://dx.doi.org/10.1016/S0967-0645(98)00081-2).
- Fox, C.G., R.P. Dziak, H. Matsumoto, and A.E. Schreiner. 1994. Potential for monitoring low-level seismicity on the Juan de Fuca Ridge using military hydrophone arrays. *Marine Technology Society Journal* 27(4):22–30.
- Fox, C.G., and S.R. Hammond. 1994. The VENTS Program T-phase project and NOAA's role in ocean environmental research. *Marine Technology Society Journal* 27(4):70–74.
- Fox, C.G., H. Matsumoto, and T.-K. Lau. 2001. Monitoring Pacific Ocean seismicity from an autonomous hydrophone array. *Journal of Geophysical Research* 106:4,183–4,206, <http://dx.doi.org/10.1029/2000JB900404>.
- Fox, C.G., W.E. Radford, R.P. Dziak, T.-K. Lau, H. Matsumoto, and A.E. Schreiner. 1995. Acoustic detection of a seafloor spreading episode on the Juan de Fuca Ridge using military hydrophone arrays. *Geophysical Research Letters* 22(2):131–134, <http://dx.doi.org/10.1029/94GL02059>.
- Goslin, J., N. Lourenzo, R.P. Dziak, D.R. Bohnenstiehl, J. Haxel, and J. Luis. 2005. Long-term seismicity of the Reykjanes Rift (North Atlantic) recorded by a regional hydrophone array. *Geophysical Journal International* 162(2):516–524, <http://dx.doi.org/10.1111/j.1365-246X.2005.02678.x>.
- Hammond, S.R., and D.A. Walker. 1991. Ridge event detection: T-phase signals from the Juan de Fuca spreading center. *Marine Geophysical Researches* 13:331–348, <http://dx.doi.org/10.1007/BF00366282>.
- Hanson, J.A., and J.R. Bowman. 2005. Indian Ocean Ridge seismicity observed with a permanent hydroacoustic network. *Geophysical Research Letters* 32, L06301, <http://dx.doi.org/10.1029/2004GL021931>.
- Haxel, J.H., R.P. Dziak, H. Matsumoto, M.J. Fowler, and W.W. Chadwick Jr. 2011. A time history of micro-seismicity leading to volcanic eruption at Axial Volcano, Juan de Fuca Ridge. *Eos, Transactions, American Geophysical Union*, Fall Meeting Abstract V14C-06.
- Holden, J.F., M. Summit, and J.A. Baross. 1998. Thermophilic and hyperthermophilic microorganisms in 3–30°C hydrothermal fluids following a deep-sea volcanic eruption. *FEMS Microbiology Ecology* 25:33–41, <http://dx.doi.org/10.1111/j.1574-6941.1998.tb00458.x>.
- Hooft, E.E.E., H. Patel, W. Wilcock, K. Becker, D. Butterfield, E. Davis, R. Dziak, K. Inderbitzen, M. Lilley, P. McGill, and others. 2010. A seismic swarm and regional hydrothermal and hydrologic perturbations: The northern Endeavour Segment, February 2005. *Geochemistry Geophysics Geosystems* 11, Q12015, <http://dx.doi.org/10.1029/2010GC003264>.
- Jagger, T.A. 1930. How the seismograph works. *The Volcano Letter* 268:1–4.
- Johnson, R.H., R.A. Norris, and F.K. Duennebieer. 1968. Abyssally generated T-phases. Pp. 70–78 in *The Crust and Upper Mantle of the Pacific Area*. L. Knopoff, C.L. Drake, and P.J. Hart, eds, American Geophysical Union Monograph Series Volume 12, Washington, DC, <http://dx.doi.org/10.1029/GM012p0070>.
- Johnson, R.H., J. Northrop, and R. Epply. 1963. Sources of Pacific T-phases. *Journal of Geophysical Research* 68:4,251–4,261.
- Keenan, R.E., and I. Dyer. 1984. Noise from Arctic Ocean earthquakes. *Journal of the Acoustical Society of America* 75(3):819–825, <http://dx.doi.org/10.1121/1.390591>.
- Keenan, R.E., and L.R.L. Merriam. 1991. Arctic abyssal T phases: Coupling seismic energy to the ocean sound channel via under-ice scattering. *Journal of the Acoustical Society of America* 89(3):1,128–1,133, <http://dx.doi.org/10.1121/1.400648>.
- Kristoffersen, Y., E.S. Husebye, H. Bungum, and S. Gregersen. 1982. Seismic investigations of the Nansen Ridge during the FRAM I experiment. *Tectonophysics* 82(1):57–68, [http://dx.doi.org/10.1016/0040-1951\(82\)90088-9](http://dx.doi.org/10.1016/0040-1951(82)90088-9).
- Kong, L.S.L., S.C. Solomon, and G.M. Purdy. 1992. Microearthquake characteristics of a mid-ocean ridge along-axis high. *Journal of Geophysical Research* 97(B2):1,659–1,685, <http://dx.doi.org/10.1029/91JB02566>.
- Linehan, J. 1940. Earthquakes in the West Indian region. *Eos, Transactions, American Geophysical Union* 21:229–232.
- Macdonald, K.C., and J.D. Mudie. 1974. Microearthquakes on the Galapagos spreading centre and the seismicity of fast-spreading ridges. *Geophysical Journal International* 36(2):245–257, <http://dx.doi.org/10.1111/j.1365->

- Matsumoto, H., J. H. Haxel., R.P. Dziak, D.R. Bohnenstiehl, and R.W. Embley. 2011. Mapping the sound field of an erupting submarine volcano using an acoustic glider. *Journal of the Acoustical Society of America* 129(3):94–99, <http://dx.doi.org/10.1121/1.3547720>.
- Merle, S.M., R.P. Dziak, R.W. Embley, W.W. Chadwick Jr., J.E. Lupton, D.R. Bohnenstiehl, J. Braunmiller, R. Greene, and M. Fowler. 2008. Preliminary analysis of multibeam, subbottom, and water column data collected from the Juan de Fuca and Gorda Ridge earthquake swarm sites, March-April 2008. *Eos, Transactions, American Geophysical Union* 88: Fall Meeting Abstract T23B-2025.
- Nishimura, C.E., and D. Conlon. 1994. IUSS dual use: Monitoring whales and earthquakes using SOSUS. *Marine Technology Society Journal* 27(4):13–21.
- Nooner, S.L., and W.W. Chadwick Jr. 2009. Volcanic inflation measured in the caldera of Axial Seamount: Implications for magma supply and future eruptions. *Geochemistry Geophysics Geosystems* 10, Q02002, <http://dx.doi.org/10.1029/2008GC002315>.
- Northrop, J. 1970. Accuracy of earthquake epicenters on the Gorda ridge. *Bulletin of the Seismological Society of America* 60(1):265–267.
- Northrop, J., H.W. Menard, and F.K. Duennebieer. 1968. Seismic and bathymetric evidence of a fracture zone on the Gorda Ridge. *Science* 161:688–690, <http://dx.doi.org/10.1126/science.161.3842.688>.
- Okal, E.A. 2008. The generation of T waves by earthquakes. *Advances in Geophysics* 49:1–65, [http://dx.doi.org/10.1016/S0065-2687\(07\)49001-X](http://dx.doi.org/10.1016/S0065-2687(07)49001-X).
- Pan, J., and A.M. Dziewonski. 2005. Comparison of mid-oceanic earthquake epicentral differences of travel time, centroid locations, and those determined by autonomous underwater hydrophone arrays. *Journal of Geophysical Research* 110, B07302, <http://dx.doi.org/10.1029/2003JB002785>.
- Reid, I., and K. Macdonald. 1973. Microearthquake study of the Mid-Atlantic Ridge near 37°N using sonobuoys. *Nature* 246:88–90, <http://dx.doi.org/10.1038/246088a0>.
- Reid, I., M. Reichle, J. Brune, and H. Bradner. 1973. Microearthquake studies using sonobuoys: Preliminary results from the Gulf of California. *Geophysical Journal International* 34(3):365–379, <http://dx.doi.org/10.1111/j.1365-246X.1973.tb02401.x>.
- Royer, J-Y, R.P. Dziak, M. Delatre, C. Brachet, J.H. Haxel, H. Matsumoto, J. Goslin, V. Brandon, D.R. Bohnenstiehl, C. Guinet, and F. Samaran. 2008. Preliminary results from an hydroacoustic experiment in the Indian Ocean. *Eos, Transactions, American Geophysical Union* 88:Fall Meeting Supplement Abstract T51B-1883.
- Schlindwein, V., C. Muller, and W. Jokat. 2005. Seismoacoustic evidence for volcanic activity on the ultra-slow spreading Gakkel Ridge, Arctic Ocean. *Geophysical Research Letters* 32, L18306, <http://dx.doi.org/10.1029/2005GL023767>.
- Schreiner, A.E., C.G. Fox, and R.P. Dziak. 1995. Spectra and magnitudes of T-waves from the 1993 earthquake swarm on the Juan de Fuca Ridge. *Geophysical Research Letters* 22(2):139–142, <http://dx.doi.org/10.1029/94GL01912>.
- Simao, J., J. Escartín, J. Goslin, M. Haxel, M. Cannat, and R. Dziak. 2010. Regional seismicity of the Mid-Atlantic Ridge: Observations from an autonomous hydrophone array. *Geophysics Journal International* 183(3):1,559–1,578, <http://dx.doi.org/10.1111/j.1365-246X.2010.04815.x>.
- Simons, F.J., G. Nolet, P. Georgief, J.M. Babcock, L.A. Regier, and R.E. Davis. 2009. On the potential of recording earthquakes for global seismic tomography by low-cost autonomous instruments in the oceans. *Journal of Geophysical Research* 114, B05307, <http://dx.doi.org/10.1029/2008JB006088>.
- Slack, P.D., C.G. Fox, and R.P. Dziak. 1999. P-wave detection thresholds, Pn velocity estimates, and T wave location uncertainty from oceanic hydrophones. *Journal of Geophysical Research* 104:13,061–13,072, <http://dx.doi.org/10.1029/1999JB900112>.
- Sohn, R.A., W.C. Crawford, and S.C. Webb. 1999. Local seismicity following the 1998 eruption of Axial Volcano. *Geophysical Research Letters* 26(23):3,433–3,436, <http://dx.doi.org/10.1029/1999GL900505>.
- Sohn, R.A., and J.A. Hildebrand. 2001. Hydroacoustic earthquake detection in the Arctic Basin with the Spinnaker Array. *Bulletin of the Seismological Society of America* 91(3):572–579, <http://dx.doi.org/10.1785/0120000099>.
- Smith, D.K., J. Escartín, M. Cannat, M. Tolstoy, C.G. Fox, D.R. Bohnenstiehl, and S. Bazin. 2003. Spatial and temporal distribution of seismicity along the northern Mid-Atlantic Ridge (15°–35°N). *Journal of Geophysical Research* 108(B3), 2167, <http://dx.doi.org/10.1029/2002JB001964>.
- Smith, D.K., M. Tolstoy, C.G. Fox, D.R. Bohnenstiehl, H. Matsumoto, and M.J. Fowler. 2002. Hydroacoustic monitoring of seismicity at the slow-spreading Mid-Atlantic Ridge. *Geophysical Research Letters* 29(11), 1518, <http://dx.doi.org/10.1029/2001GL013912>.

Spindel, R.C., S.B. Davis, K.C. Macdonald, R.P. Porter, and J.D. Phillips. 1974. Microearthquake survey of the median valley of the Mid-Atlantic Ridge at 36°30'N. *Nature* 248:577–579, <http://dx.doi.org/10.1038/248577a0>.

Tolstoy, I., and M. Ewing. 1950. The T-phase of shallow-focus earthquakes. *Bulletin of the Seismological Society of America* 40:25–51.

Tolstoy, M., J.P. Cowen, E.T. Baker, D.J. Fornari, K.H. Rubin, T.M. Shank, F. Walderhauser, D.R. Bohnenstiehl, D.W. Forsyth, and R.C. Holmes. 2006. A sea-floor spreading event captured by seismometers. *Science* 314(587):1,920–1,922, <http://dx.doi.org/10.1126/science.1133950>.

Toomey, D., S.C. Solomon, G.M. Purdy, and M.H. Murray. 1985. Microearthquakes beneath the median valley of the mid-Atlantic Ridge near 23°N: Hypocenters and focal mechanisms. *Journal of Geophysical Research* 90(B7):5,443–5,458, <http://dx.doi.org/10.1029/JB090iB07p05443>.

Walker, D.A., and S.R. Hammond. 1998. Historical Gorda Ridge T-phase swarms: Relationships to ridge structure and the tectonic and volcanic state of the ridge during 1964–1966. *Deep Sea Research Part II* 45:2,531–2,545, [http://dx.doi.org/10.1016/S0967-0645\(98\)00082-4](http://dx.doi.org/10.1016/S0967-0645(98)00082-4).

Yun, S., S. Ni, M. Park, and W.S. Lee. 2009. Southeast Indian Ocean-Ridge earthquake sequences from cross-correlation analysis of hydroacoustic data. *Geophysical Journal International* 179:401–407, <http://dx.doi.org/10.1111/j.1365-246X.2009.04292.x>.

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