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Chemical diagenesis, porosity reduction, and rock strength, IODP Site U1480: Influences on great earthquakes at shallow depths

Insun Song (1), Kitty Milliken (2), Brandon Dugan (3), Sylvain Bourlange (4), Tobias Colson (5), Marina Frederik (6), Tamara Jeppson (7), Mebae Kuranaga (8), Nisha Nair (9), Timothy Henstock (10), and the IODP Expedition 362 Scientists Team

(1) Korea Institute of Geosciences and Mineral Resources, Daejeon, Korea, Republic Of (isong@kigam.re.kr), (2) Bureau of Economic Geology, Austin TX, USA (kitty.milliken@beg.utexas.edu), (3) Department of Geophysics, Colorado School of Mines, Golden CO, USA (dugan@mines.edu), (4) CNRS-Université de Lorraine-CREGU, Ecole Nationale Supérieure de Géologie, Vandoeuvre-lès-Nancy, France (sylvain.bourlange@univ-lorraine.fr), (5) School of Earth Sciences, University of Western Australia, Crawley, Australia (tobias.colson@research.uwa.edu.au), (6) Center for Regional Resources, Agency for the Assessment and Application of Technology, South Tangerang, Indonesia (marina.frederik@bppt.go.id), (7) Department of Geology and Geophysics, University of Wisconsin, Madison WI, USA (tnjeppson@wisc.edu), (8) Graduate School of Science and Engineering, Yamaguchi University, Yamaguchi City, Japan (may.hazime@gmail.com), (9) CLCS/Marine Geophysical Division, National Centre for Antarctic and Ocean Research, Goa, India (nishanair@ncaor.gov.in), (10) National Oceanography Centre, University of Southampton, Southampton, UK.(then@noc.soton.ac.uk)

International Ocean Discovery Program (IODP) Expedition 362 drilled two sites, U1480 and U1481, on the Indian oceanic plate ~250 km west of the Sunda subduction zone to a maximum depth of 1500 meters below seafloor (mbsf). One of the primary objectives was to understand the mechanism of great earthquakes such as the 2004 Sumatra earthquake (Mw 9.0) which showed unexpectedly shallow megathrust slip by establishing the initial and evolving properties of the North Sumatran incoming sedimentary section. Core sampling and logging from the complete sedimentary section at U1480 indicates a distinct change in sedimentation rate from a slowly deposited pelagic system to a rapidly deposited submarine fan system at late Miocene. Following burial, sediments of the Nicobar Fan underwent compaction leading to porosity reduction from 66±9% near seafloor to ~30% at the base of the sampled Nicobar Fan section (~1250 mbsf), representing a normal consolidation behavior. Rock strength gradually increases with depth as the sediments are mechanically compacted. Below the fan (1250-1415 mbsf), the pelagic sediments are composed of tuffaceous, calcareous, and siliceous sediments/rocks and their porosity is dependent upon lithology more than upon depth. Tuffaceous materials exhibit high porosity ranging from ~30-60%, even higher than that of overlying layers. However, porosity of most calcareous samples is lower than 20% at the same depth. The large variation in porosity depends on the degree of cementation, which in turn is controlled by grain assemblage composition and environmental conditions such as slow sedimentation rates and locally high temperatures related to igneous activity as documented by local igneous intrusives and extrusives. The minor cementation in tuffaceous sandy sediments has retained high porosity, but strengthened their skeleton so as to bear the overburden. The low porosity in calcareous rocks is considered to come from extensive cementation rather than mechanical compaction. The rock strengthening by mechanical compaction is dependent on effective stress, and does not facilitate storage of a large amount of elastic energy at shallow depth. However, chemical diagenesis (cementation) can lead to high strength that does not necessarily arise directly from burial. This chemical diagenesis potentially influences sediment strengthening that localizes great earthquakes at shallow depths.