Age and migration of pore waters in the eastern Nankai Trough, Japan: Determination of source formations using I-129 analyses

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Decomposition of marine organic materials in anoxic deep sediments leads to enrichment of pore waters in reduced iodide, which commonly exceed seawater level by two orders of magnitude or more, because of the close association of molecular iodine and iodate with organic materials in oxic seawater and shallow sediments. Fluids found in gas hydrate fields as well as conventional fossil fuel fields are thus commonly enriched in iodine derived from the source materials which are principally responsible for the accompanying hydrocarbons in the aqueous phase. Iodine has a long-lived radio isotope, ^{129}I (half-life of 15.7 Myr), which is produced by cosmic ray spallation of Xe isotopes in the atmosphere and by spontaneous fission of ^{238}U in the subsurface. The ratio between the radioactive ^{129}I and the stable ^{127}I (^{129}I/I) of these fluids can be used to establish age and origin of organic source materials. We report here ^{129}I/I ratios determined in pore waters collected from the METI Tokai-oki to Kumano-nada gas hydrate research wells in the eastern Nankai Trough. These data were integrated with previous results of halogen concentrations and ^{129}I/I ratios in this area to examine the spatial age variability of dissolved iodine in association with methane and to provide three-dimensional models of mass transport for the gas hydrate system in the accreted belt.

While Cl concentrations are generally close to seawater value, I and, to a lesser degree, Br are enriched in pore waters a few meters below the seafloor. Relative to these values, all halogens (Cl, Br, and I) are diluted in the gas hydrate-bearing sediments due to the decomposition of hydrate structure and the following release of fresh water during core retrieval. Cl, the most incompatible element of the three halogens, most directly reflects the degree of gas hydrate accumulation, particularly close to the BSRs. Based on the Cl systematics, gas hydrate saturation reaches 80% of sediment pore volume in sands. Contrarily, the brine released from gas hydrate formation increases all halogen concentrations at the intervals above the gas hydrate-accumulated zones on the outer ridge. Deep fluids rising into the gas hydrate stability zone (GHSZ) in this area are substantially enriched in Br and I, probably derived along with dissolved methane from deep organic rich layers. The situation is somewhat different in the outer ridge sites, where lateral fluxes apparently provide I and methane to the GHSZ. ^{129}I/I results indicate that the fluids with ages of 40 Ma dominate in the forearc basin site, but that those on the outer ridge are 10 Ma younger, reflecting the age difference of underlying sediments between forearc basin and accretionary prism. These relatively young fluids are also present just below the BSRs, demonstrating that sources for the underlying free gas are substantially younger than those for overlying gas hydrates. Throughout the study area, fluids enriched in I in association with methane in the GHSZ are considerably older than the host sediments, and that these old fluids deliver the dominant portion of methane for the formation of gas hydrates. The well-developed fault system up-dipping to the ridge associated with the accretion is a potential conduit for allochthonous young fluids. Detailed geological settings and subsurface structures in the accreted sediments define the source and migration of these fluids in the eastern Nankai Trough gas hydrate field; old and low I fluids dominate in the relatively passive forearc basin while young and high I fluids are predominantly delivered in the relatively active outer ridge. The results demonstrate that gas delivery from old sequences is the principal process for enhanced gas hydrate accumulation in the eastern Nankai Trough area.