Abstract

The convergent margin off central Japan is characterized by numerous deep-sea channels such as the Nankai and Zenisu channels which are closely related to the subduction process. The geomorphology, sedimentation processes and tectonic development of these deep-sea channels were studied using swath bathymetry, submersible observations, as well as sidescan and seismic data.

The Nankai deep-sea channel starts from Suruga Bay and apparently vanished from the trough floor in the middle Nankai Trough off the Kii Peninsula. The undulations of the trough floor that reflect the deformation of the trough-fill deposits become gentle in the middle and western Nankai Trough in concert with the disappearance of a marked channel morphology. The existence of this remarkable deep-sea channel is closely related to its geological and/or tectonic development. The primary cause for the formation of a deep-sea channel may be fluid flow at the seafloor and active tectonics. One possibility for such a fluid flow is bottom current. However, the average current velocity measured in the eastern Nankai Trough region is only 2 to 7 cm/sec and the bottom flow is not steady (Taira and Teramoto, 1985). More probable are turbiditic flows, according to which the Nankai deep-sea channel may be regarded as a passageway for terrigenous sediments into the Nankai Trough. Our high resolution bathymetric data, submersible observations and seismic profiles provide detailed information for a better understanding of deep-sea sedimentation processes and the tectonic evolution of subduction in the Nankai deep-sea channel. Turbidity currents have been observed at the base of the slopes of the Nankai Trough even during times when this trough was seismically quiescent. Small-scale turbidites were found at the base of the slope. Debrites dominate the western slope and are closely related to the distribution of seep communities which are controlled by sediment facies and active faulting.

The Zenisu deep-sea channel is situated south of Kozushima Island and Miyashima Island of the Izu-Ogasawara Arc. Its geomorphology and the associated sedimentation processes are constrained by tectonic activity as well as the supply of volcanic debris as revealed by SeaBeam bathymetry and observations from manned submersible dives (*Shinkai 6500* dives 371, 523, 555 and 556). Morphologically, the Zenisu deep-sea channel consists of three segments: the Zenisu Canyon, the E-W Channel and the Trough Axis Channel.

Several bottom sediment types were identified on the basis of observations from a submersible and acoustic imaging. Very thin, fine layers drape the slopes of the accretionary wedge and the Zenisu Ridge, while debris flow deposits and turbidites dominate the floor of the deep-sea channels. At the base of the slope of these channels, large slumps and rock outcrops with associated clam communities occur amid

abundant small-to-large scale debrites. Sampling of vesicomyid white clams seen during dive 523 of 1999 was successfully carried out in 2000. Two species were recovered, the hitherto unknown large form *Calyptogena sp*. (Wu et al., 2000) and a form common to the recently described species *Calyptogena (Archivesica) tsubasa* collected from the Tenryu Canyon area (Fujioka and Taira, 1989).

The occurrence of dense beds of *Calyptogena* bivalves, buccinid snails and white galatheid *Munidopsis sp*. provides unequivocal supporting evidence for nascent subduction and concomitant seepage at the base of the southern flank of the Zenisu Ridge.

In the Zenisu Trough, four seismic sequences with distinct external geometries and internal configurations were recognized. Sequences A and B are trough-fill turbidites. Age dating suggests that unit B is younger than Late Pliocene and uplift of the Zenisu Ridge probably occurred since the Late Pliocene or the Pleistocene (after 2.65 Ma). The discovery of dead clams and living deep-sea biological communities at the base of the slope point to active faulting and sediment dewatering.

To study the development of these deep-sea channels, a total of 454 km of G-gun seismic data were acquired during cruise KH96-02 of the R/V *Hakuho-mura*. Six structural zones were recognized in the study area according to their deformational style and sediment architecture. These are: forearc basin, accretionary prism, trough axis, Zenisu Ridge, Zenisu Trough and Izu-Ogasawara Arc. The Tokai Thrust which marks the southeastern boundary of the forearc basin is considered an important regional tectonic element that has decisively influenced the lithofacies distribution. The strata of the footwall of this fault consist of slope basin deposits and terrigenous components. A more active imbricated thrust system exists on the lower slope since the Late Pliocene. Backthrusts and extensive erosion occur at the Yukie Ridge on the lower accretionary slope. The southern segment of Zenisu Ridge is considered the site of a nascent subduction zone by many authors (Le Pichon et al., 1987; Lallemant et al., 1989), and is marked by several compressional fractures in its upper layers. During our dives 523 and 556, a similar thrust fault has been found along the middle segment of the Zenisu Ridge. Northward extensions of the thrust faults have been mapped using direct observations from a submersible and seismic reflection profiling on the southern slope of the Zenisu Ridge. These data show that shortening occurs at least in the middle segment of the Zenisu Ridge and has resulted in the formation of a nascent subduction zone.

The Nankai deep-sea channel exihibits an incised straight channel pattern with marked erosional features and is controlled by E-W, N-S and NNE-SSW-trending faults. The channel pattern, channel position, relief and other characteristics are dependent on the structural style of the trough-fill. The morphology of the Nankai deep-sea channel reflects the subduction of an oceanic plate. Its easternmost segment is related to the collision between the Honshu and Izu-Ogasawara island arcs which resulted in intense uplift of the Izu-Ogasawara Arc and a high erosional rate in the adjacent trough.

The growth of deep-sea channels at this convergent margin took place in several stages. The initial stage in the development of the Nankai deep-sea channel ended by the breakdown of subduction at about 5-3 Ma (Kobayashi et al., 1995). During this time, turbidity currents travelled down the continental shelf and slope, incised a deep canyon, and reached the deep basin because of the lack of a trench morphology. Assuming that there were no tectonic elements acting as obstacles in the deep basin, the channel must have had a freely meandering pattern such as the Amazon today (Damouth, 1988). During stage 2, subduction of the oceanic plate and hence the formation of a trench morphology took place 15–12 Ma (Kobayashi et al., 1995). At approximately the same time, the Nankai deep-sea channel changed its course along the trench axis. In stage 3, subduction temporarily ceased due to collision between the Japan Island Arc and the Izu-Ogasawara Arc in the east which resulted in intense uplift and erosion in central Honshu (Soh et al., 1998). Abundant clastic material was produced and transported by gravity flow into the trench, filling it up and forming the trench wedge. The deep-sea channel at this time had a freely meandering pattern. During stage 4, probably at 1 Ma when the deformation front and the NE-SW and E-W striking fault systems were formed in the course of subduction, the channel course became confined to these orientations. Thus, the deep-sea channel exhibited a straight channel patten. These stages constituted a major cycle that began with oceanic subduction and ended in the breakdown of the subducted slab.

Development of the Zenisu deep-sea channel is closely related to uplift of the Zenisu Ridge as a result of the extensive collision between the Japan Island Arc and the Izu- Ogasawara Arc. It is therefore tectonically controlled. Nascent thrust faults formed during the latest Pliocene or the Pleistocene, and the channel grew thereafter. The trough morphology formed at this time (at ca. 2.0 Ma). The sedimentary sequence in the deep-sea channel of the Zenisu Trough has a thickness of about 100 m in the south (sequence 1a of Tokuyama et al., 1998). Using an average sedimentation rate of 1 cm/yr (Takayama et al., 1998), this implies that the deep-sea channel started to form about 1 myr ago. During Recent times, the northern segment of the channel developed along a N-S trending transtensional fault, while the southern segment was under the control of a nascent thrust.