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FAULT PATTERN AND ACTIVE DEFORMATION OF OUTER ARC RIDGE OF NORTHWEST OF SIMEULUE ISLAND, ACEH, INDONESIA

By:

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ABSTRACT

New bathymetric map of northwest Simeuleu Island area (3° 01'N-4°57'N and 93°16'E-94°08'E) has evidently illustrated fine morphological image of Outer Arc ridge and Aceh Fore Arc. The structural lineament pattern, inferred from the bathymetric map, could define in general elongated major NW-SE thrust fault complex, thrust fold, or bedding trace and N-S, NNE-SSW, WNW-ESE or ENE-WSW and E-W structural lineament trend.

High intensity deformation processes related to high degree obliquity subducted plate was represented by rough and sigmoidal morphological shape, landward and steep to very steep dip angle of bedding plan. Rough morphology, V to U shape valley, dissected ridge and circular shape of landslide trace are common morphology features of active deformation zone.

In the near future, high resolution marine seismic will be planned across this area to capture and confirm the subsurface structure configuration and fault movement.

Keyword: bathymetric map, Outer Arc ridge, thrust fault, thrust fold, bedding trace, sigmoidal morphological, V to U shape valley,and landslide.

SARI

Peta batimetri baru di sebelah barat laut Pulau Simelue (3° 01'LU - 4°57'LU and 93°16'BT-94°08'BT), memperlihatkan citra morfologi yang halus pada punggungan busur luar dan busur depan Aceh. Pola kelurusan struktur mengacu pada peta batimetri, dibagi dalam komplek sesar naik yang berarah umum baratlaut - tenggara, lipatan, atau jejak perlapisan dengan kecendrungan arah struktur utara-selatan, utara timur laut – selatan barat daya, barat - barat daya, timur tenggara atau timur laut - barat daya dan timur - barat.

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Proses deformasi intensitas tinggi berkaitan dengan derajat kemiringan penunjaman yang tinggi, diwakili oleh bentuk morfologi sigmoid dan kasar, ke arah darat dicirikan oleh kemiringan bidang lapisan terjal hingga sangat terjal. Bentuk morfologi kasar seperti bentuk lembah V hingga U, punggungan yang terpotong dan bentuk melingkar dari jejak longsoran merupakan gambaran morfologi umum dari zona deformasi aktif.

Dalam waktu dekat, seismik laut resolusi tinggi akan direncanakan memotong daerah ini untuk menggambarkan dan mengkonfirmasi konfigurasi struktur bawah permukaan dan pergerakan sesar.

Kata kunci : peta batimetri, punggungan busur luar, sesar naik, lipatan, jejak bidang perlapisan, morfologi sigmoid, bentuk lembah V hingga U,dan longsoran.

INTRODUCTION

The Sumatra fore arc has been recorded as an active and complex history of geological processes such as plate rift-drift, plate amalgamation, collision and subduction since Cretaceous and continuous nowadays. Sumatra arc formation synchronous with Southeast Asia Plate re-organization was forced by collision of Greater India with Eurasia Plate at 45 Ma or Middle Eocene (Hamilton, 1979; Hamilton, 1981; Metcalfe, 1993, Wakita and Metcalfe, 2005). This event was followed by subduction of Indian Plate beneath Eurasia Plate at Late Oligocene to Early Miocene (35Ma). Seafloor spreading rate of the Indian oceanic crust is 50 mm/year during Early Oligocene and optimum rate about 70 mm/year at Late Miocene (Laughton e*t al*., 1973). Sieh and Natawidjaja (2000) stated that the convergent rate was about 50 mm/ year since the Late Oligocene to the Early Miocene. Subduction of Indian oceanic crust beneath the western margin of Sumatra at Late Eocene – Early Oligocene (38-35Ma) was followed by Sunda Trench formation at Upper Oligocene or 29Ma (Laughton, *et.al*, 1973) and the formation of all Sumatra fore arc basins parallel to the Sunda Trench at Oligocene/ Early Miocene age (Karig *et al*., 1979; Karig *et al.*, 1980; Malod and Kemal, 1996; Schlüter *et al*., 2002; Susilohadi *et al*., 2005, Berglar *et al*, 2009). Up to 4 Km thick of Miocene to Recent sediment filled the basin. At the Neogene age, the Sumatra fore arc was dominated by accretional prism development which compose Middle Miocene to the Present sedimentary rocks and, in some parts, a slice of oceanic crust material (Hamilton, 1981). A formation and exposure to the sea surface of non-volcanic island arc, such as Simeulue, Nias, Siberut, Sipora, Pagai and Enggano islands as part of outer arc high of western offshore of Sumatra caused by tectonic uplifting at 4Ma to Recent (Sieh and Natawidjaja, 2000). A high degree oblique subduction about 20° -30° recently occurred at the study area (Baroux *et al.*, 1998). High obliquity caused increase degree of partitioning especially at the northern of Sumatra (Sieh and Natawidjaja, 2000).

METHODS

A small piece of northern Sumatra Fore Arc or Aceh Fore arc locates at 3° 01'N-4°57'N and 93°16'E-94°08'E has been a target for bathymetry mapping (Figure 1). The objective of this activity is mapped and recognized structural pattern and a fault or fault types occurred in the area. The bathymetric data were collected in study area using a SeaBeam 2100 multi-narrow beam echo-sounder system equipped with R/V

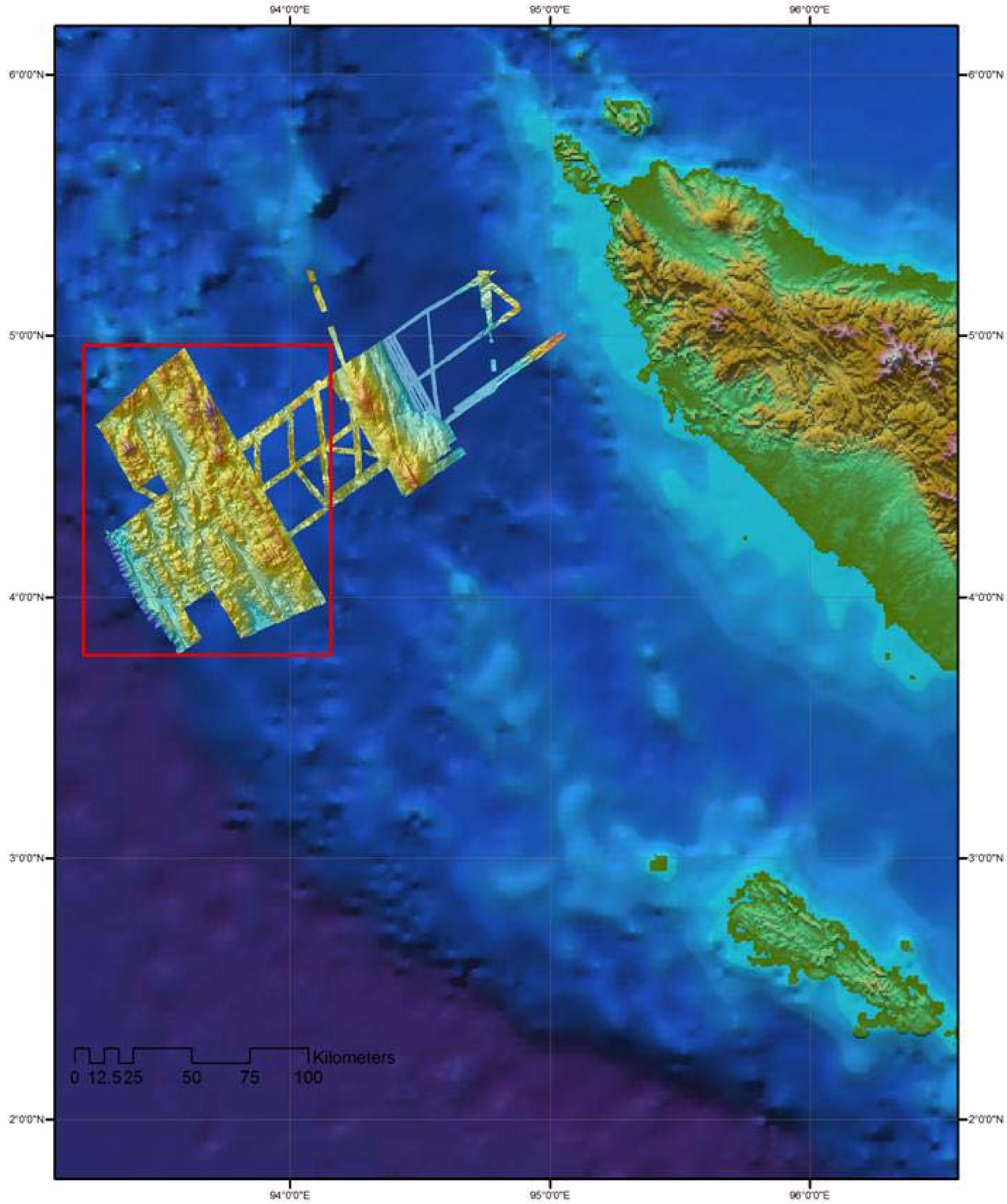

Figure 1. Bathymetry survey of study area

KAIYO. The machine runs at 12 kHz, 2º x 2º beam widths, 81 beams, and a swath width of 80º. The 10 knots ship speed during survey with ping interval of a few seconds yielded a detailed bathymetric map with a horizontal resolution of approximately 30 meters at 1000 meters water depth. Total 3500 km^2 approximately area coverage was obtained during the survey (Hirata and Permana, 2009; Hirata *et al*., 2010). The data then combined with previously obtained by NT-05 (2005) cruise. The new bathymetric map result shown in Figure 2.

In this preliminary study, lineament or structural pattern interprets based on only bathymetry features and no subsurface data like seismic data added. The lineament pattern has interpreted even speculative and less constraint. We use topographical features to define fault movement whereas a conventional cross-cutting law uses to define relative age of fault that a younger structural lineament cuts off an older one. Fault dipping trend or direction is also interpreted.

RESULTS

Morphology feature

The high-resolution bathymetric map acquired during the KY-0909 cruise allowed in identification different feature morphology of Outer Arc Ridge. The general water depth of the area is 500-1000 meters, shallowest depth of 290-400 meters occurs at the northern part of area, whereas the deepest water depth found in the southwestern area, with depth of approximately 3200 meters. Several depressions or valley shapes, mostly wider size to the SE side with various depths, 1800-2300 meters with the deepest valley is 2450 meters.

A major morphology characteristics is a series of ridges, and depressions or valley, NW-SE in the direction. The SE sides of ridge slopes are generally steeping ocean ward, contrary NE sides of ridge slopes are mostly gently dipping landwards. The ridge spacing (distance between ridge axis) is tightening to northeastward (landward), and wider towards southwestward (trench side). The bathymetric map at SW part of study area demonstrates NW-SE trending ridges in which are mostly narrow and stretched. The ridge surface shows very rough morphology indicated by dissected and narrow V-shape valleys or surface erosion. The sigmoidal shape morphology is unusual feature present in this area. Other feature is narrow and V to U shape valley or basin. Landslide traces can be clearly observed at almost all the SW facing steep scarps of the western side of ridges indicated by irregular shape and direction of an open circular feature. A wide and long valley is parallel to the ridge occupying the southwestern part of the area. The valley surface is mostly flat, smooth and bordered by steep scarp on both sides, but several valleys show an irregular shape with undulating surface of valley covered by small and irregular shape block possibly recently deposited.

Morphology feature of the middle area illustrate a moderate to rough ridge, dissected by V- to U-shaped valley, relative wider and undulated surface ridge with elevated hill. A NW-SE trending ridges sliced by NE-SW scarps is commonly present consistent with important wider, longer and deep valley than previous area. A steep wall ridge at NE side and gently wall ridge at SW side limits a valley. The N-S trending ridges and V valley are observed and it sliced mostly NW-SE lineament. The small and irregular block covered the depression close to the N-S lineament indicates recently deposited. Other

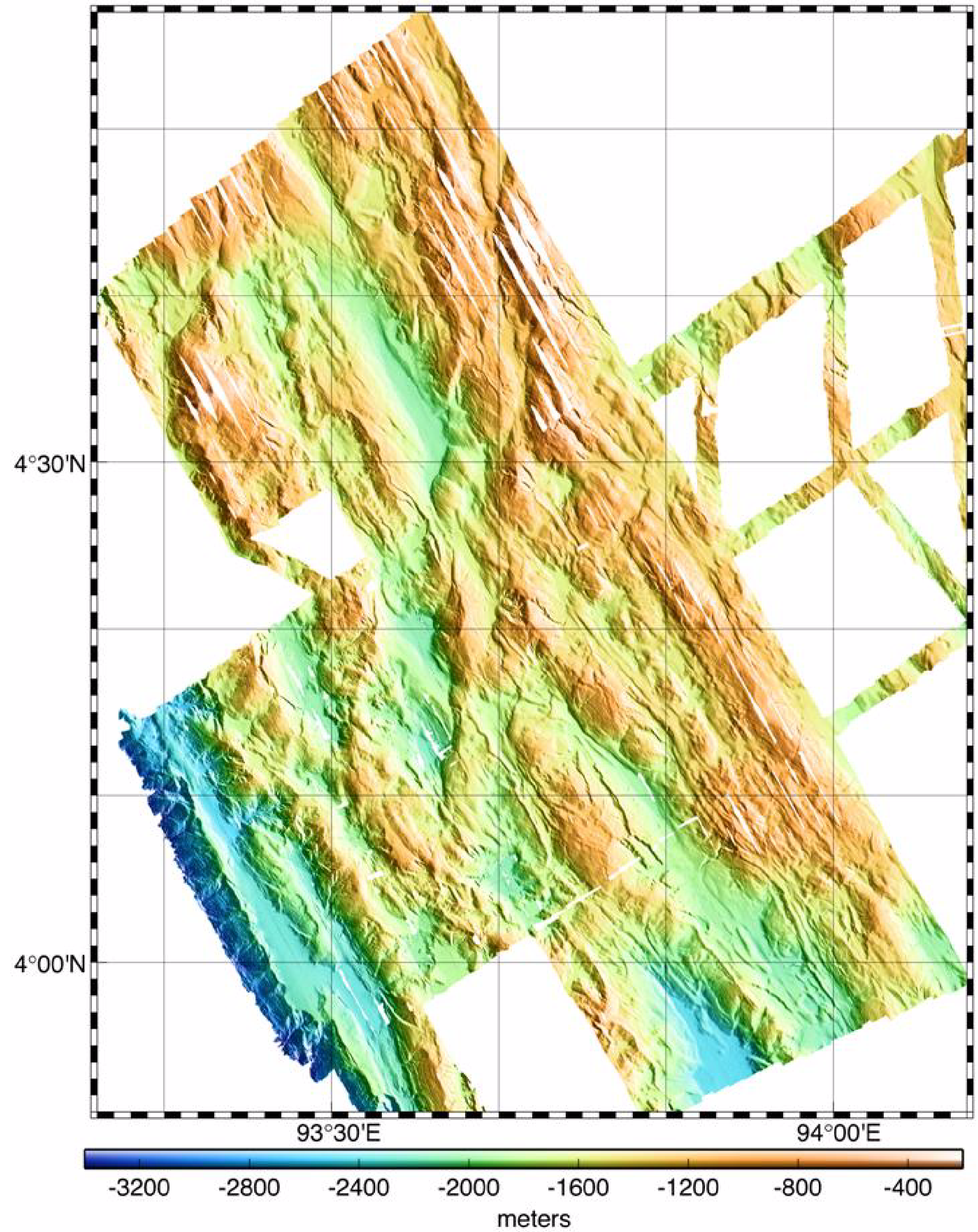

Figure 2. Bathymetry map result

Figure 3. Structural pattern inferred from the bathymetric map of Kaiyo cruise (KY0909).

feature in the area is an isolated hill or depression bounded by steep scarps. In this area, a steep wall bounded a valley with depth varies 1800 m - 2200 m and up to 2400 m. The surface of valleys generally has flat and very smooth.

Both a narrow valley and isolated depression that bounded by scarps are commonly present at NE area. The wider, continuous and smooth surface of ridge is dominant feature within elevated hill and V or narrow shape of valley or basin. The shallower part reach up 290 meters water depth and deeper part is 1650 meters water depth. An isolated hill bordered by steep scarp, mostly in NE-SW direction is commonly present in the area within isolated and irregular depression in between at 1700-1600 meters water depth while the N-S trending ridge and scarp are commonly observed in the middle of the area.

DISCUSSION

The lineament interpreted through the bathymetry could be represented structural features as fracture or bedding plan or bedding strike, fold or fault and depression or valley. The relative gently NE dipping direction of NW-SE bedding plane lineament has mostly parallel to general morphology feature. A steep to very steep SW dipping bedding trend observes frequently at the SW side of ridge or scarp. We interpreted most of ridge represents a deformed folded ridge or an asymmetry folded ridge, or in general represents thrust fold belt, NW-SE in direction. These thrust folds are steeping at the SW side and gently towards NE side. Several fault types could be recognized from bathymetry. These are NW-SE lineament was interpreted as a thrust fault, N-S and NE-SW lineaments were interpreted as dextral or sinistral strike slip fault, the WNW-ESE sinistral strike slip fault and ENE-WSW or E-W normal fault.

The NW-SE longer and continuous lineament as a major lineament occurs along steeping wall of asymmetric U shape valley. These landward dipping thrust fault dominant in the area, except at NE part of the area whereas the large valley disappear. It is supposed that the thrust fault system at NE side area no more longer active, while a still active NW-SE thrust fault observed mostly at SW and middle area, close to the trench. These were indicating very rough and disturbed topographical and asymmetrical wide and longer valley. The relative en-echelon N-S dextral strike slip fault lineament, as the second major lineaments, significant presents in the middle of area. This fault cut across most of lineaments. Both the N-S fault and NW-SE thrust across cut and supposes that both fault lineaments were re-activated in different time. A discontinuous NE-SW sinistral strike slip fault lineament founds at the middle and NE side of study area and supposed inactive. The NWW-SEE sinistral strike slip fault occurs very limited, almost of the middle of western part the area. This type of fault forms sigmoidal ridge shape and merged with NW-SE thrust fault. The ENE-WSW or E-W lineaments are mostly appearing as short lineaments but they are distributed very densely in the entire study area. This lineament interprets as a normal fault commonly disrupted the ridge or thrust fault along the V or U valley or fault scarp. The valley or depression (piggy back basin?) mostly asymmetry shape valley, wider to the SE develops parallel or juxtapose to NW–SE lineament. The larger valley at the middle and SW study area was disturbed by relative N-S fault lineaments.

CONCLUSIONS

The NW-SE lineaments can be classified as the major landward dipping thrust fault in accretional prism of fore arc due to plate subduction compression. These faults were growth or shifted progressively towards the SW side or the trench or the relative active thrust towards the SW area during fore arc development. But it is very difficult to determine whether the N-S faults, that occur at certain limited area, was formed earlier (or later) than the NE-SW thrust faults. We suppose that the NE-SW thrust faults have occurred before the N-S lineament appears. But, sometime, undefined, re-activity of NW-SE fault line is possible to cut for examples the N-S fault line or other direction structural lineament. The WNW-ESE that forms a sigmoidal morphology occurs immediate or merged with NW-SE lineament. This fault formation is believed to be influenced by changing or increasing degree of obliquity of subduction plate. Similar hypothesis has done to describe the origin of the N-S fault lineament. The ENE-WSW or E-W lineament which is interpreted as normal fault possibly occur during plate subduction deceleration or change of degree obliquity whereas extension possibly intense. In the next future, high resolution marine seismic will be planned across this area to capture and confirm the subsurface structure configuration and fault movement.

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