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Sidescan Sonar Imagery of the Escanaba Trough, Southern Gorda Ridge, Offshore Northern California

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Descriptive Notes

This map features sidescan imagery of the northern Escanaba (NESCA) site at the Escanaba Trough, southern Gorda Ridge, offshore northern California (fig. 1). The Escanaba Trough, a largely sediment-covered seafloor spreading center, contains at least six large massive sulfide deposits. It is a slow spreading center (2.5 cm/yr) with axial depths locally exceeding 3,300 m. Discrete igneous centers occur at 5- to 10-km intervals along this slow-spreading ridge (fig. 2; Morton and others, 1994). Basaltic magma intrudes the sediment fill of the axial valley, creating uplifted sediment hills, and, in some areas, erupts onto the sea floor.

Large massive sulfide deposits occur along the margins of the uplifted sediment hills (Zierenberg and others, 1993; Koski and others, 1994). The only active hydrothermal system is located on Central Hill where 220° C fluids construct anhydrite chimneys on pyrrhotite-rich massive sulfide mounds (Campbell and others, 1994). Central Hill is bounded by both ridge-parallel basement faults and a concentric set of faults that rim the top of the hill and may be associated with sill intrusion. Central Hill was one of the primary drill sites for Ocean Drilling Program (ODP) Leg 169 (Fouquet and others, 1998; Zierenberg and others, 2000).

The sidescan sonar data (mosaics A, B, C, D) were collected aboard the National Oceanic and Atmospheric Administration (NOAA) research vessel *Discoverer* in the summer of 1996 with a 60-kHz system towed 100 to 200 m above the sea floor. Major faults and contacts are interpreted from the sidescan mosaics and 4.5-kHz seismic profiles collected simultaneously, as well as from previously conducted camera transects and submersible dives. The seismic profiles (lines 9, 11, 13) provide high-resolution subbottom structure and stratigraphy to a depth of about 50 m.

In the sidescan images (mosaics A, B, C, D), bright areas denote high-energy returns from hard reflectors such as volcanic flows, sulfide deposits, or seafloor scarps. Dark areas denote low-energy returns and generally signify relatively undisturbed surface sediment. The grid lines mark one-minute intervals of latitude and longitude.

The large sidescan sonar image (mosaic A) is centered on the NESCA igneous center. The spreading axis is flanked on either side by uplifted, sediment-covered terraces that show relatively continuous and undisturbed turbiditic sediment (fig. 2; Morton and others, 1994; Zuffa and others, 2000; Normark and Serra, 2001). These terraces bound the 4- to 5-km-wide neotectonic zone that is characterized by more closely spaced, small offset (<20 m) faults, volcanic flows (brightest area of backscatter), and areas where the seismic layering of the turbidites has been partially to completely disrupted by the intrusion of basaltic sills.

The most prominent bathymetric features are the three uplifted sediment hills: Central Hill, Southwest Hill, and an unnamed uplifted hill to the north. These features are interpreted to be uplifted above large-volume basaltic intrusions emplaced near the basalt/sediment interface (Zierenberg and others, 1993; Denlinger and Holmes, 1994; Ross and Zierenberg, 1994; Zierenberg and Miller, 2000). Southwest Hill is adjacent to the zone of most recent faulting. This hill no longer retains the circular shape of the other hills due to slumps (lines 9, 11), which may have failed along faults related to the most recent spreading. Central Hill is interpreted to be the most recently uplifted sediment hill based on the morphology of the hill and the presence of an active hydrothermal system.

The generally continuous area of volcanic basalt flow east of Central Hill appears as a distinct, bright sonar reflector stretching for approximately 6 km along axis (red contact on mosaic A). This flow may be related to the intrusion that is presumed to have uplifted Central Hill. Submersible observations indicate that lava flowed around the sediment hills and ponded against the eastern up-faulted turbidite-covered sediment terrace. Previously collected, deep-penetration seismic data indicate that the lavas overlie about 450 m of sediment (Morton and Fox, 1994). Late-stage emplacement of magma in the shallow subsurface beneath the exposed lava flow is interpreted to have domed the lava flow, forming the east-west-trending volcanic ridge with a fissured top (mosaics A, B, C). North Hill at the southern Escanaba Trough (SESCA) volcanic center also shows evidence for eruption of basaltic flows from the base of the hill (mosaic D); eruption of the flows was contemporaneous with the uplift of the hill (Zierenberg and others, 1993, 1994).

Areas with relatively low backscatter, but where 4.5-kHz seismic reflection profiles show basaltic reflectors at shallow (<50 m) depth below the turbidite cover, are mapped as sediment-covered basalt (pink contacts, mosaic A). The area north of the large exposed basalt flow is interpreted from both submersible observations and seismic profiles to be sediment-covered basalt flows that are slightly older than the exposed basalt. The area of basalt just north of Central Hill may represent a buried basalt flow or a shallowly emplaced sill (Clague and others, 2001). The contacts of the buried basalts are shown as solid lines where they can be readily inferred from seismic profiles and sidescan reflections of the topographic expressions of their edges; dashed contacts are extrapolated using the sidescan reflectance where there are no crossing seismic lines.

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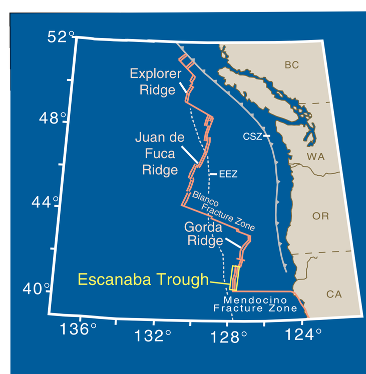
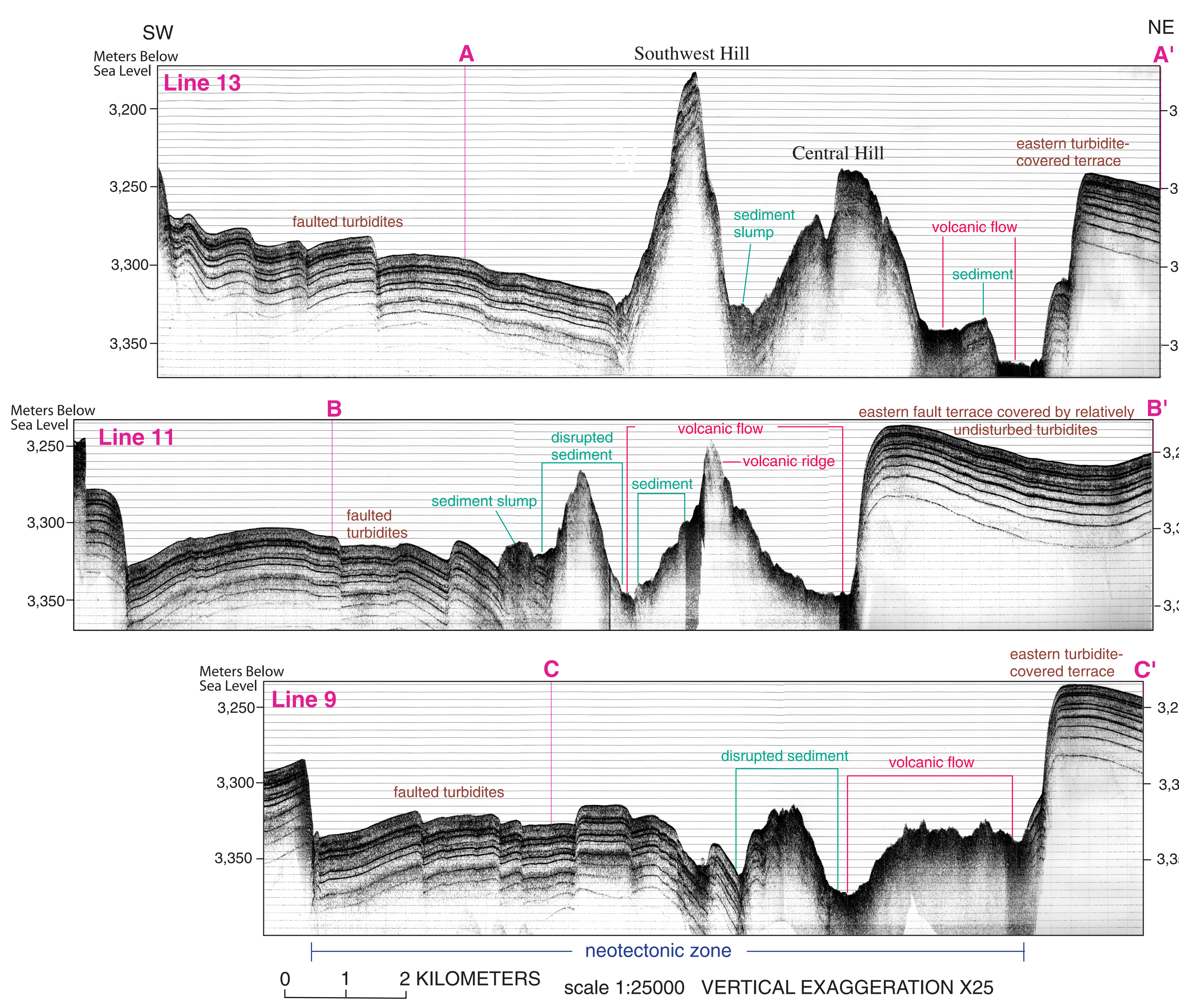


Figure 1. Map of the northeast Pacific Ocean showing the Escanaba Trough (yellow box), offshore northern California, relative to oceanic spreading ridges and fracture zones, the U.S. Exclusive Economic Zone (EEZ), and the Cascadia Subduction Zone (CSZ).



Lines 9, 11, and 13. High-resolution seismic reflection profiles (4.5 kHz) collected at the same time as the sidescan sonar data show the upper 50 m of turbidite sediment, volcanic flows, and uplifted sediment hills (Central Hill, Southwest Hill) in cross section. All three lines have the same orientation. See mosaic B for locations of lines and letters (A, B, C) on lines.

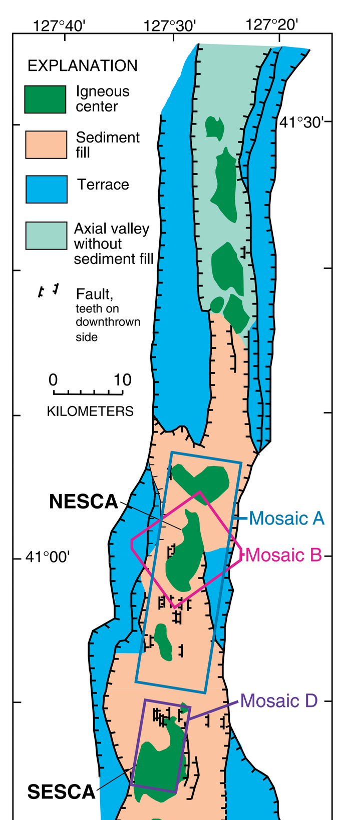
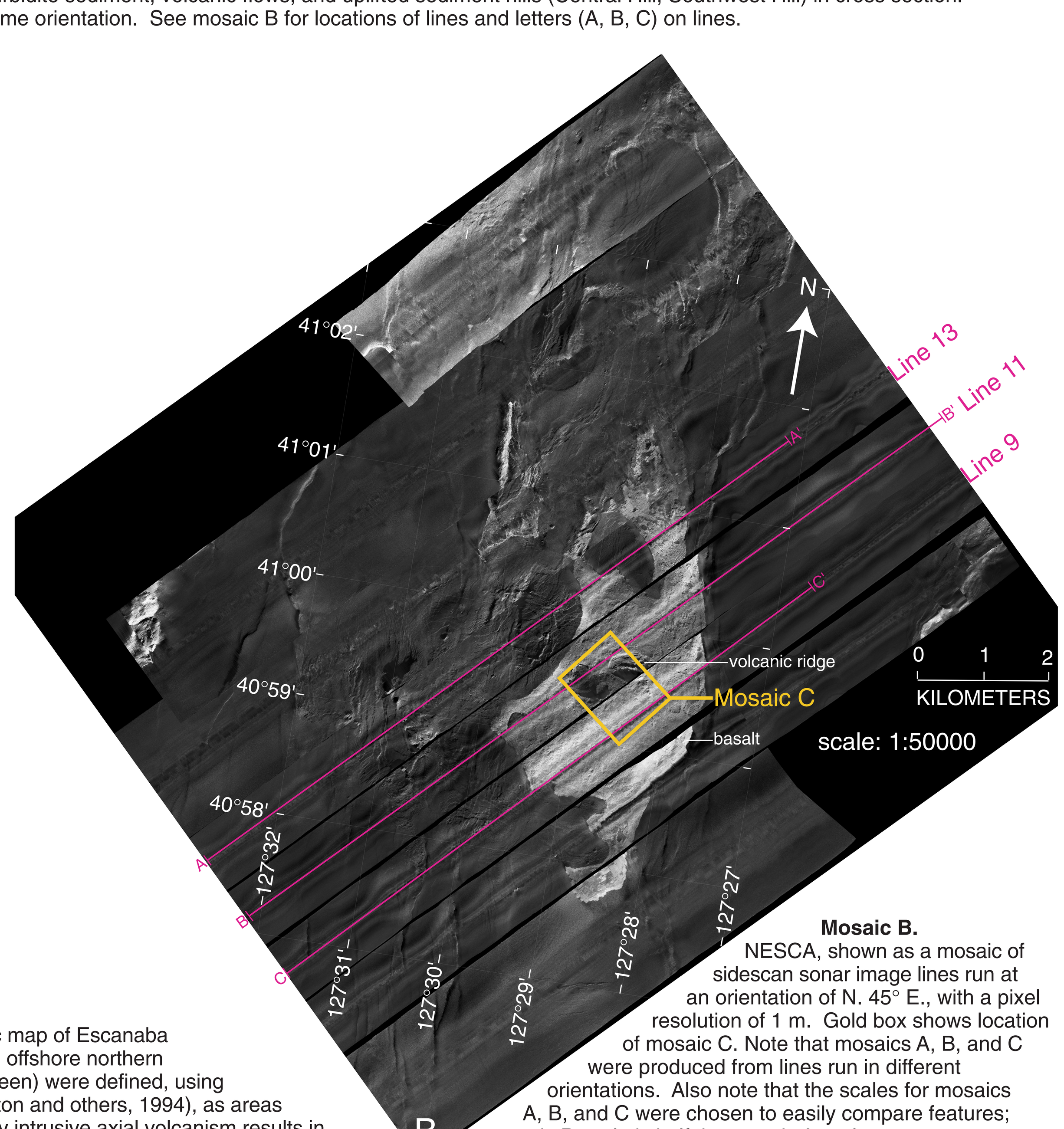
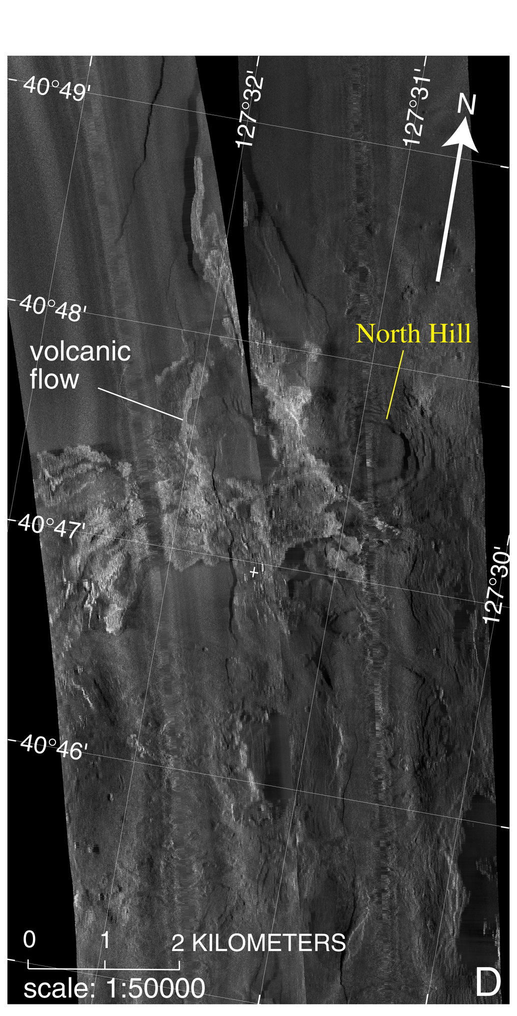


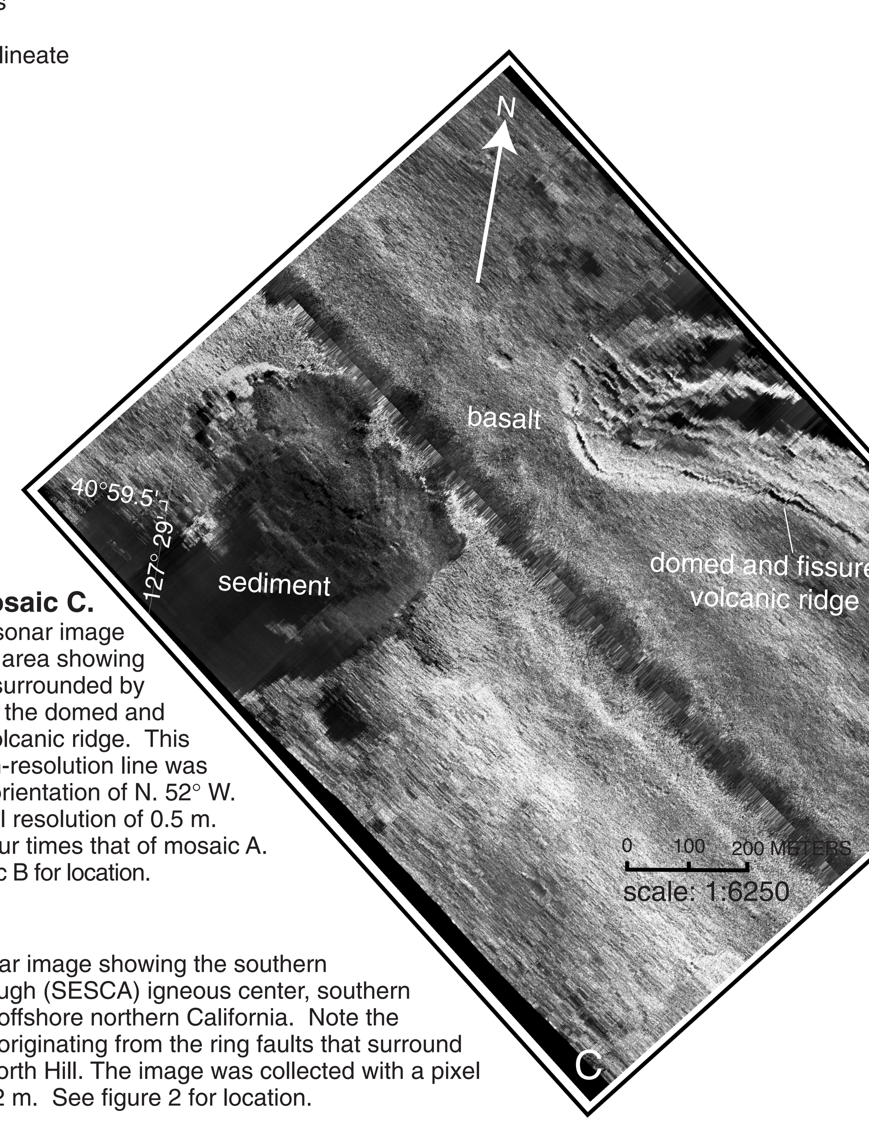
Figure 2. Generalized geologic map of Escanaba Trough, southern Gorda Ridge, offshore northern California. Igneous centers (green) were defined, using seismic-reflection profiles (Morton and others, 1994), as areas where increased, predominantly intrusive axial volcanism results in a shallowing of igneous basement. Up-faulted terraces (blue) are covered by relatively undeformed turbidit sediment. Sediment layering along the spreading axis is locally disrupted by shallow faults and basaltic intrusions. Thickness of sediment cover decreases northward, from >1 km near the Mendocino Fracture Zone and averages about 450 m between igneous centers. The boxes delineate the areas shown in Mosaics A, B, and D.



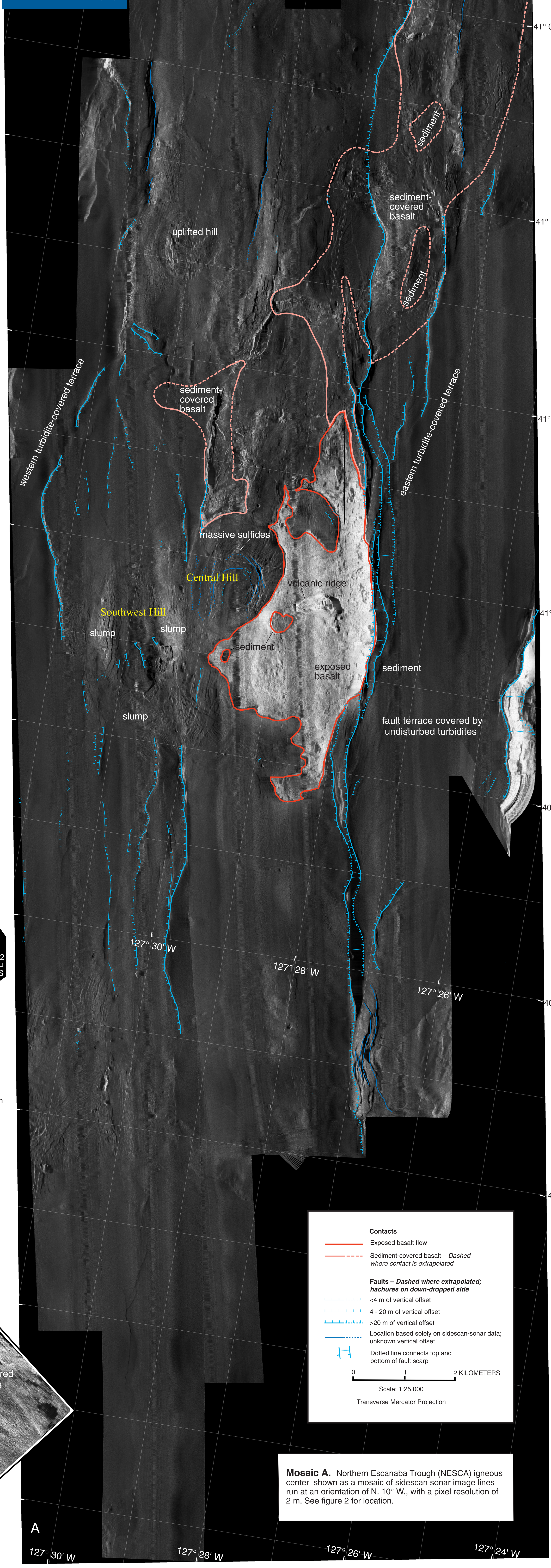
Mosaic B. NESCA, shown as a mosaic of sidescan sonar image lines run at an orientation of N. 45° E., with a pixel resolution of 1 m. Gold box shows location of mosaic C. Note that mosaics A, B, and C were produced from lines run in different orientations. Also note that the scales for mosaics A, B, and C were chosen to easily compare features; mosaic B scale is half the mosaic A scale. See figure 2 for location.



Mosaic D. Sidescan sonar image showing the southern EscanabaTrough (SESCA) igneous center, southern Gorda Ridge,offshore northern California. Note the volcanic flow originating from the ring faults that surround the uplifted North Hill. The image was collected with a pixel resolution of 2 m. See figure 2 for location.



Mosaic C. Sidescan sonar image of NESCA area showing sediment surrounded by basalt and the domed and fissured volcanic ridge. This single high-resolution line was run at an orientation of N. 52° W. with a pixel resolution of 0.5 m. Scale is four times that of mosaic A. See Mosaic B for location.



Mosaic A. Northern Escanaba Trough (NESCA) igneous center shown as a mosaic of sidescan sonar image lines run at an orientation of N. 10° W., with a pixel resolution of 2 m. See figure 2 for location.