Deep Ocean Exploration Institute Final Project Report

A Seafloor Geodetic Experiment to Monitor Deformation on Slope of Kilauea Volcano, Hawaii (Mark D. Behn and Jeff McGuire)

What were the primary questions you were trying to address with this research?
Massive slope failure and debris avalanches on the flanks of oceanic volcanoes have been linked to tsunami generation in the Pacific and Atlantic Oceans. However the process by which the flanks of active volcanoes deform remains poorly understood. One of the best-studied active volcanic landslides is the Hilina slump on the southeast flank of Kilauea volcano, Hawaii. The goal of Project 'AHOLO* (**A** **H**awaiian **O**cean **L**andslide **O**bservatory) was to deploy a new acoustic extensometer system under development at WHOI to monitor deformation in Kilauea's submarine flank (Figure 1).

When and where was this investigation conducted?
The experiment was conducted on the southeast flank of Kilauea volcano, Hawaii. We deployed the extensometer system in October 2005 and recovered the instruments in June 2006. Because half of our instruments were knocked over by a submarine landslide in December 2005, a later cruise was conducted in October 2006, which successfully recovered the buried instruments using the *ROV Jason*.

What were the key tools or instruments you used to conduct this research?
Acoustic extensometers make very precise measurements of the two-way travel time of an acoustic wave between a transponder and a transceiver. Knowledge of water temperature and salinity is then used to convert the travel time to a distance measurement. By placing the transceiver and transponder on opposite sides of a fault or system of faults, the fault slip will be manifest as a change in distance between the instruments.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?
The most important result of this experiment was establishing the ability of WHOI's acoustic extensometer system to acquire centimeter-precision geodetic measurements over the time scale of several months (Figure 2). Although our experiment was unfortunately cut short by a submarine landslide, the first successful deployment of this system in deep water indicates that we are indeed capable of monitoring long-term seafloor deformation with similar precision to land-based instruments.

What is the significance of this research for society?
Geodetic measurements and field observations on land show that the Hilina slump on the southeast flank of Kilauea volcano breaks away along a system of seaward dipping normal faults that transport material to the southeast at rates of ~10 cm/yr (Figure 1). This extension may represent the upper-flank expression of a massive slump sliding coherently seaward. Alternatively, several recent studies have proposed that volcanic spreading associated with magma injection at the summit of Kilauea places the upper subaerial flanks in extension, while simultaneously generating compression and thrust faulting in the lower submarine flanks. If

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* '*Aholo* is the Hawaiian word for landslide.

correct, this model implies a more stable flank configuration, with less potential for massive landslides and tsunami-genesis.

What were the greatest challenges and difficulties?

The largest challenge we faced was the burial of half of our instruments during a submarine landslide 2 months into our experiment (Figure 3). Because the extensometers require constant line-of-sight communication to measure deformation, the landslide prevented us from collecting the desired 9-month time series of data. However, this event demonstrates the dynamic environment on the flanks of oceanic volcanoes and illustrates the necessity of future research into geologic hazards in these regions.

Is this research part of a larger project or program?

Seafloor geodesy represents an exciting new field in marine geophysics. Over the last several decades, the development of GPS and InSAR has provided the ability to make geodetic measurements with sub-centimeter accuracy on the continents. These techniques have led to unprecedented new discoveries in fault behavior and earthquake mechanics. In comparison, seafloor geodesy is in its infancy and to date only a few scattered geodetic measurements have been made in the ocean basins. One of our long-term goals is to establish a strong seafloor geodesy program at WHOI. To this end, McGuire will be using the WHOI extensometer system on an upcoming NSF-funded cruise to study fault behavior on oceanic transform faults on the East Pacific Rise. Furthermore, we are currently involved in the ORION program's cabled seafloor observatory initiative to place a continuously recording extensometer system on the Blanco transform.

Have you published findings or web pages related to this research? Please provide a citation, reprint, and web link (when available).

Our results have been submitted to the Springer Complexity Encyclopedia on Complexity in Earthquakes, Tsunamis, and Volcanoes, and Forecasting and Early Warning of their Hazards (http://refworks.springer.com/complexity).

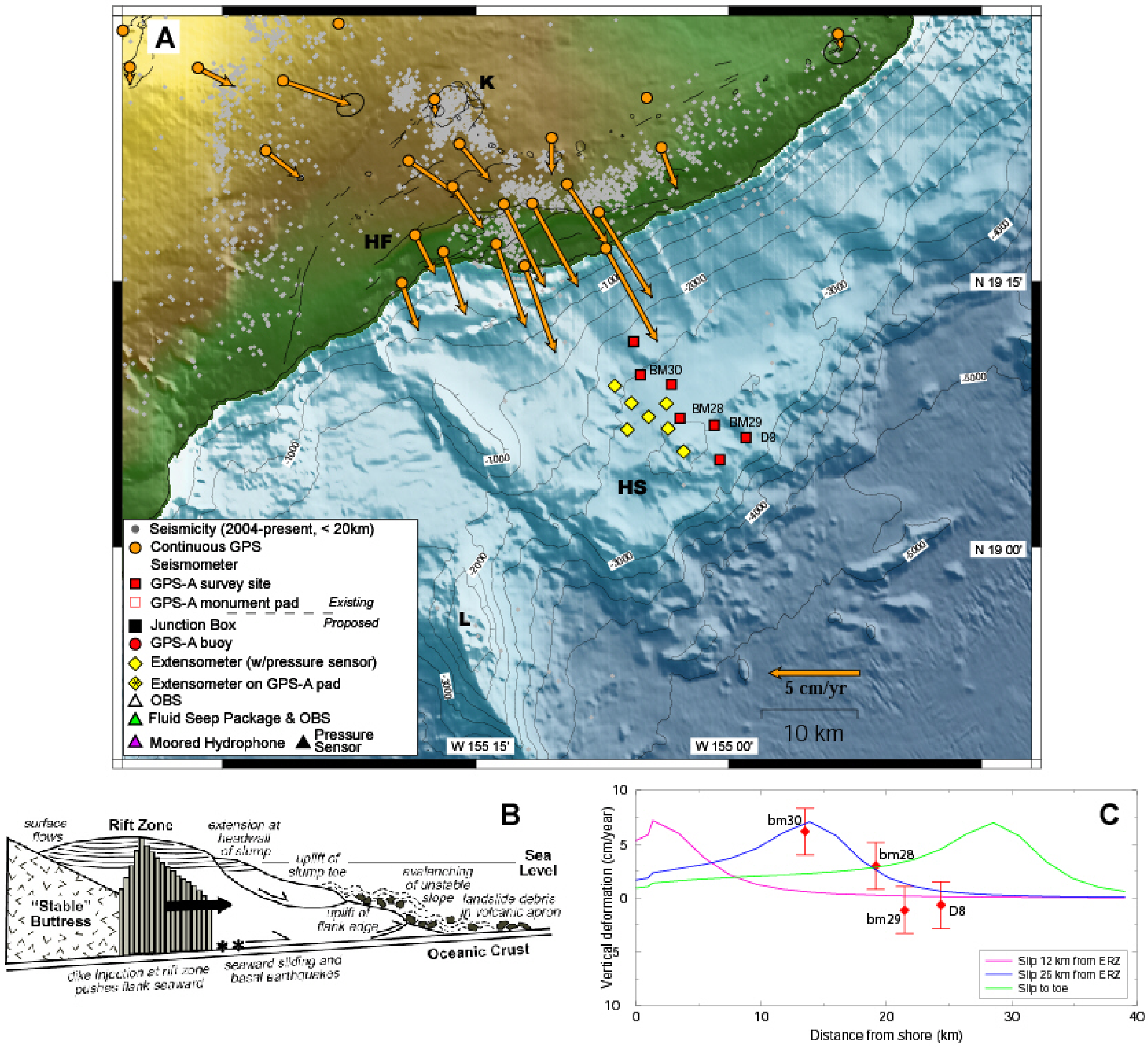

Figure 1. a) Location map showing position of extensometer network (yellow diamonds) deployed in October 2005. Earthquakes since 2004 shown by grey dots. Existing GPS-A infrastructure depicted by red diamonds. K, Kilauea caldera; HF, Hilina Faults; OW, Ocean Entry; HS Hilina Slump. **b)** Schematic cross-section (location indicated on a) of the Hilina slump from *Morgan et al.* [JGR, 2003]. **c)** Recent results of vertical displacements from GPS-A occupations from *Phillips et al.* [Eos. 2004]. Occupations were performed in November 2000, April 2002, and August 2004.

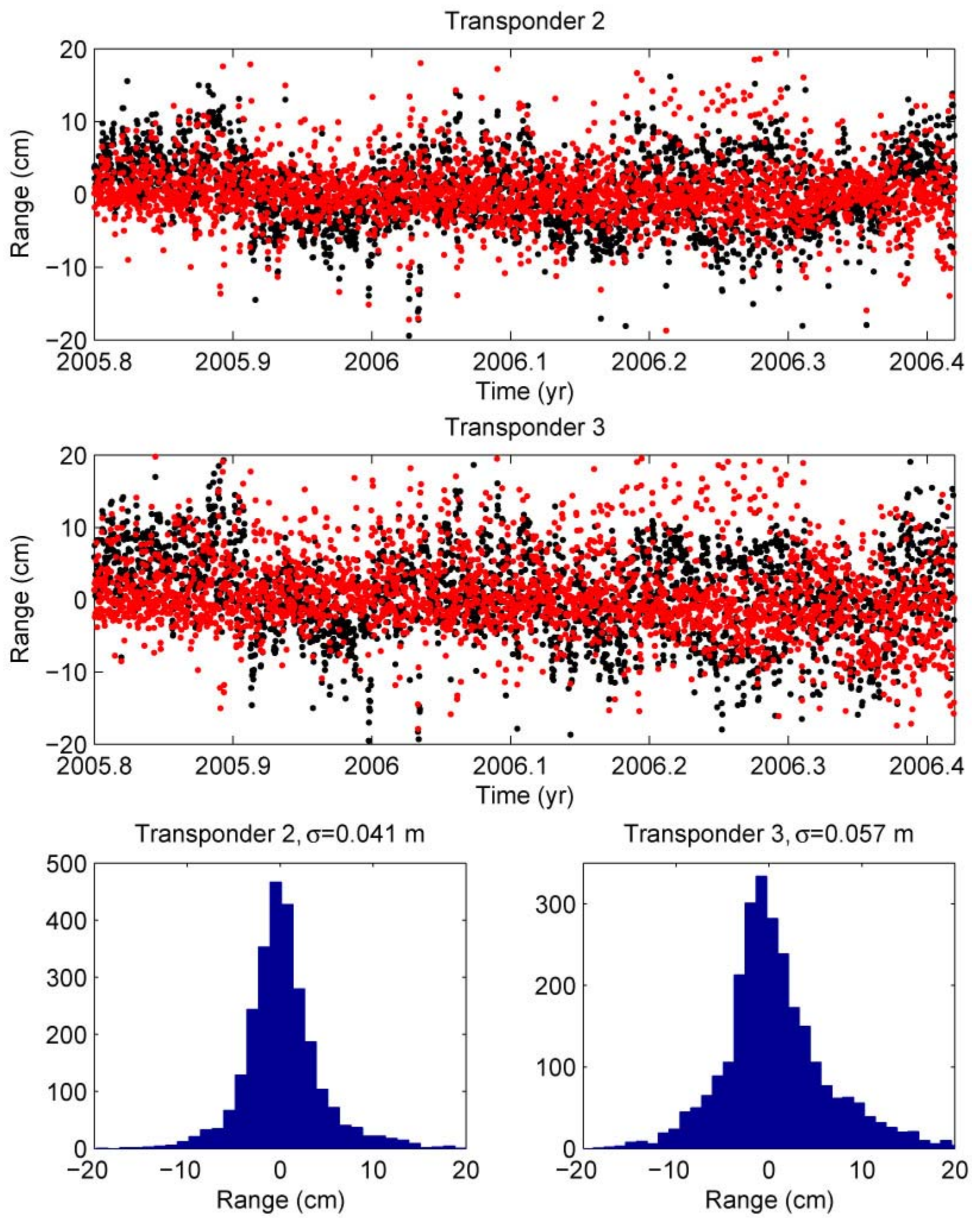

Figure 2. A,B) Baseline difference (position – median position) for transponder-transceiver pairs (T2-C1, T3-C1 in Figure 3) pairs from October 2005 – June 2006. Black dots, raw baseline difference uncorrected for temperature. Red dots, baseline differences corrected for temperature. C,D) Histogram of the corrected baseline residuals from A and B, respectively. The standard deviations are small enough to allow 1 cm errors on daily position values, more than sufficient for detecting major tectonic events such as dyke intrusions, eruptions, and large (M>5) earthquakes.

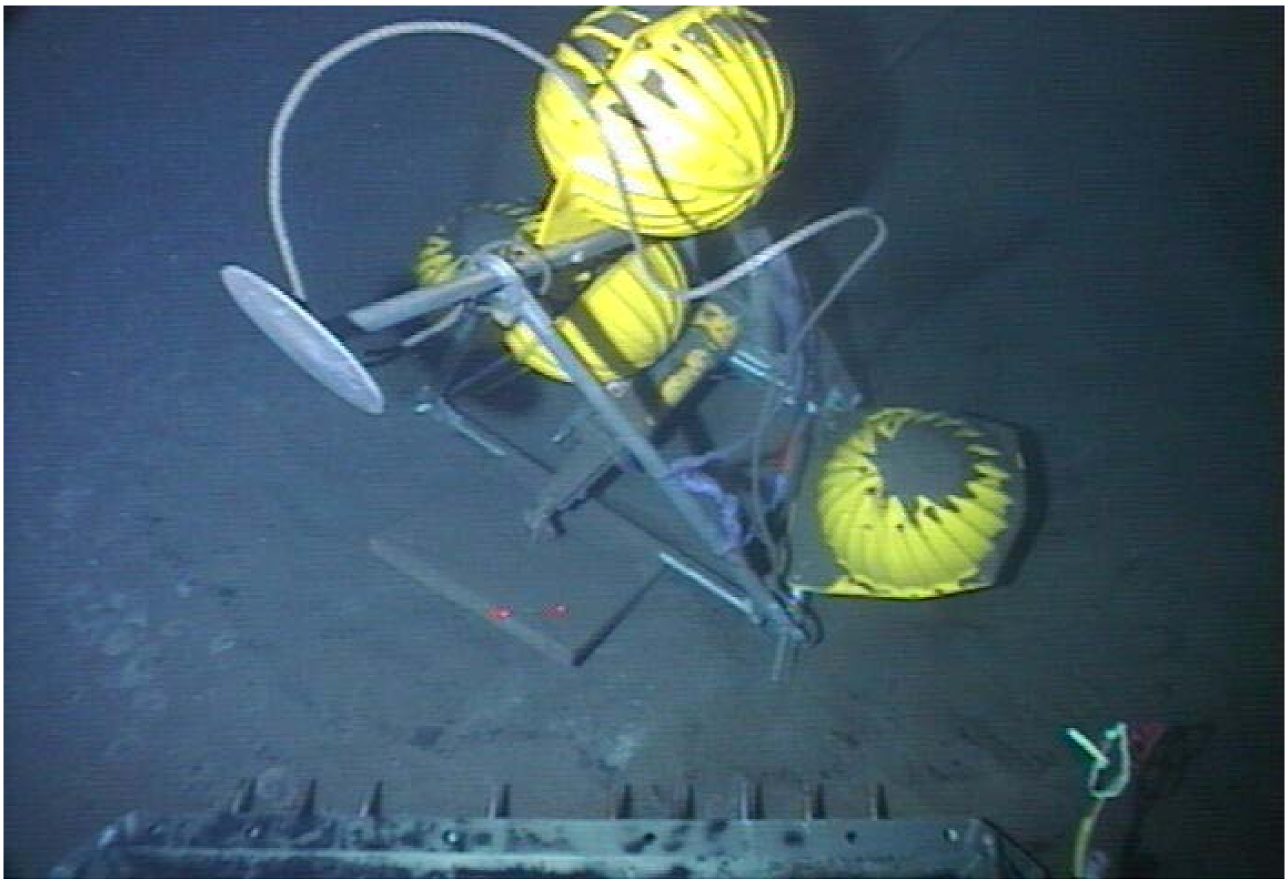

Figure 3. Photograph taken from the *ROV Jason* showing one of the extensometers after it had been buried and knocked over by the December 2005 submarine landslide.