Technical Report on the SCEC funded proposal: **High-resolution seismic imaging of the Bishop Basin using a mixed-mode seismic array**

1. Proposal Overview and Objectives

Owens Valley represents an important geographic and tectonic divide in western North America. Bounding the eastern edge of the Sierra Nevada, the valley marks the westernmost edge of the Basin and Range, but also accommodates significant dextral plate boundary motion (e.g., Hammond and Thatcher, 2007; Faulds and Henry, 2008). Sitting at the nexus of these distinctive modes of deformation, the valley itself has been subdivided into a number of smaller basins and blocks (Stevens et al., 2013), the geometry of which has largely been constrained by gravity inversion. A structural arch separating the two largest basins of Owens Valley is located south of Big Pine, CA and is conterminous with several other notable features, including the Big Pine Volcanic Field, slow seismic wave speeds in the upper crust, and a more ambiguous and complex fault geometry relative to the southern half of the valley. While the region is included in SCEC Community Velocity Model CVM-S4.26 (Lee et al., 2014), the seismic station coverage for this area is limited. The main goal of the proposed project was to improve the community seismic velocity model of the upper crust beneath Bishop Basin, and the structural arch to the south, through the collection of new seismic data.

We proposed a mixed-mode array design (broadband and nodal sensors) that would allow us to maximize the area imaged, while keeping the station density high and total experiment duration short. Unfortunately, significant difficulties associated with station permitting (most of the land is publicly owned) meant that the seismometers could not be deployed within the duration of the funded project. Despite this setback work is still ongoing to secure permits, and numerous visits have been conducted up to the field area to (1) establish relationships with the relevant landowners, and (2) determine the appropriate locations for instruments given challenging road conditions throughout the valley. Our hope is that with continued effort and support we will be able to deploy instruments in 2026.

2. Background

One of the more distinctive features of the WL-ECSZ is Owens Valley, a narrow valley bounded by the Sierra Nevada to the west and the Inyo-White Mountains to the east. Owens Valley is an extensional basin, narrow (10-15 km) and long (115 km), internally riddled with a number of valley parallel dextral, normal and oblique-slip faults. Owens Valley can be subdivided into a number of smaller blocks and two basins, chief among them the Bishop Basin to the north and Owens Basin to the south (Stevens et al., 2013). Central to the focus of this proposal is the Bishop Basin, and the faults that are thought to bound the basin (approximate location shown in Figure 1). This includes the Owens Valley Fault (OVF), which ruptured during the 1872 Lone Pine earthquake (Mw 7.6) and bounds the western margin of the basin, and the White Mountain Fault (WMF), which bounds the eastern edge of the Bishop Basin adjacent to the White Mountains, and extends from roughly the latitude of Big Pine, CA northward to the northwestern terminus of the White Mountains (Stockli et al., 2003).

Estimated slip across the greater Southern Walker Lane region vary, with estimates of dextral slip ranging from 40 to 110 km, and GPS strain rates of 10 mm/yr or more (Faulds and Henry, 2008). While dextral slip in Southern Walker Lane is thought to have initially been accommodated on the northwest trending Fish Lake Valley-Furnace Creek- Death Valley fault system (FLV-FC-DVFZ) (Figure 1), the OVF and WMF have been active since 3 Ma (e.g., Rheis and Dixon, 1996; Stockli et al., 2003). Slip is thought to be transferred between the Owens Valley faults and FLV-FC-DVFZ along a series of northeast-striking normal faults, namely the Queen Valley fault and the Deep Springs fault, which bound the northern and southern ends of the White Mountains, respectively. An important nexus for these faults appears to be located south of Big Pine, CA, at the southern edge of the Bishop Basin. While the surface trace of the OVF can be well mapped for much of its southern extent (Beanland and Clark, 1994), it becomes obscured south of Big Pine in the vicinity of Poverty Hills, a 300-m-high mass of gently sloping plutonic and metasedimentary rocks.

Here, the singular fault strand appears to splay into a series of small, largely unnamed, subparallel faults (Figure 2). North of Poverty Hills the "Big Pine segment" of the Owens Valley Fault is thought to continue accommodating slip, before it is partitioned between the WMF and FLV-FC-DVFZ (Beanland and Clark, 1994).

A significant source of uncertainty in constraining an accurate kinematic model for the region is the large uncertainties in subsurface structure, particularly in the vicinity of Big Pine. The most comprehensive study of the subsurface structure of Owens Valley comes from a 1964 gravity survey (Pakiser et al., 1964). Subsequent work by Blakely and McKee (1985), and Hollett et al. (1989), refined this regional model, incorporating additional measurements and accounting for isostatic compensation. Their work further supported the model in which a structural arch is present beneath Poverty Hills, subdividing the valley into two distinct basins.

The SCEC community (seismic) velocity model, CVM-S4.26 (Lee et al., 2014), samples Owens Valley and provides constraints on the upper, middle and lower crusts of southern California. At 1 and 2 kms depth, the slowest wave speeds in and around the Bishop Basin appear to be coincident with the Big Pine Volcanic Field (BPVF) (Figure 3). Slow velocities also appear along the northwestern edge of the basin. At a depth of 5 km, the band of slow wave speeds near the BPVF is still apparent, but now appear as a saddle, with the slowest wave speeds located east and west of the Owens Valley Fault. In general, the observed seismic velocities do not appear to correlate with the gravity constrained Bishop Basin, where slower wave speeds might be expected. As noted in Lee et al. (2014), "*CVM-S4.26 shows excellent correlation with surface geology*", including other basin-type features in the area, such as Owens Lake (Owens Basin), Indian Wells Valley and Searles Lake. Most interestingly, the authors remark on the presence of the slow seismic wave speeds being coincident with the BPVF, suggesting that the correlation is not coincidental.

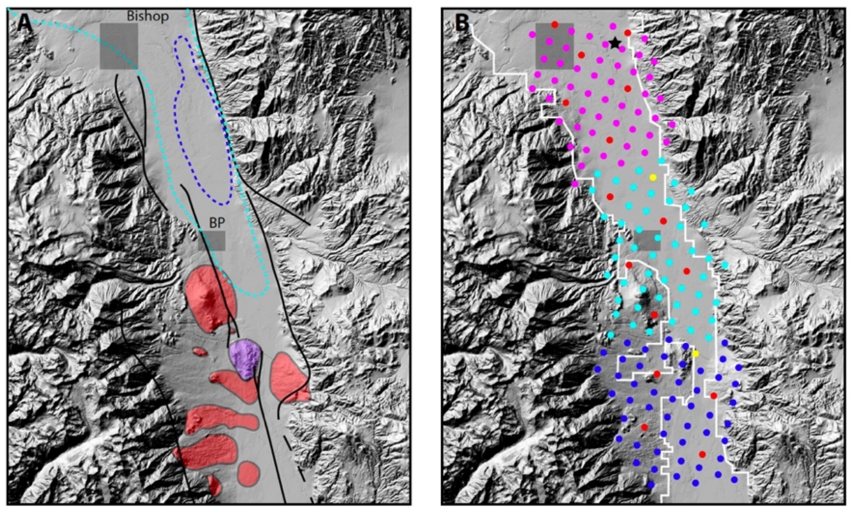

Figure 1. *(**A**) Shaded relief map of the Bishop Basin. Red polygons mark the locations of volcanic features of the Big Pine Volcanic Field. Poverty Hills is shown as a purple polygon. Black lines mark location of faults simplified from Stevens et al. (2013) and Stockli et al. (2003). Bishop Basin Cenozoic sediment thickness contours (dashed lines) for ~1 km (cyan) and ~3 km (blue) are included (from Stevens et al., 2013). Grey boxes mark the locations of Bishop, CA and Big Pine, CA. (**B**) Proposed deployment of broadband and nodal seismometers. Yellow circles represent location of the two permanent stations in the region. Red circles represent proposed locations of broadband seismometers. Nodal seismometers would be deployed in a rolling array with the magenta, cyan and blue circles each representing a deployment lasting for ~35 days. Exact location of deployed instruments will depend on site conditions. White lines mark the approximate limits of land owned by the LA Department of Water and Power. The black star marks the location of the Owens Valley Research Station.*

3. Proposed Research Plan

The primary objective of the funded work was to **collect new seismic data within (and around) the Bishop Basin in Owens Valley** (Figure 1) to generate a high-resolution ambient noise tomography model of the upper crust, Ps receiver function analysis, and calculating the horizontal to vertical spectral ratio (HVSR) to determine fundamental site frequency. With the data we hope to improve constraints on the seismic velocities, basin structure and associated fault structure for the study area, although the aforementioned analyses were not within the scope of the funded work, which was solely focused on data collection.

Central to our research plan was a mixed mode (broadband and nodal seismometers), passive source, seismic imaging experiment of the Bishop Basin and its southern margin (the aforementioned structural arch). Utilizing 50 nodal seismometers and 14 broadband seismometers, we intended to image a region approximately 15 km in width and roughly 50 km in length (Figure 2). 14 broadbands were to be deployed in a quasi-uniform array across the entire study area and would serve as the "backbone" for the duration of the experiment. Nodal seismometers would be initially placed in the northern third of the study area (magenta circles in Figure 2b) with 2 km station spacing, for 35 days. After retrieval for data harvesting and charging, they were to be redeployed in the central third (cyan circles) and subsequently in the southern end (blue circles), with each redeployment maintaining the 2 km station spacing. The harvesting and charging were to be completed in the field at the UC-owned Owens Valley Station in Bishop, CA to minimize turn-around time. The proposal funding was for fieldwork and summer support for one UCR graduate student responsible for assisting in fieldwork, managing instrumentation, metadata and data resulting from the experiment.

4. Outcomes

The proposal was funded in May 2024, and immediate efforts were underway to secure permits from the U.S. Forest Service (Inyo National Forest), Bureau of Land Management (BLM) (Bishop Field Office), and the Los Angeles Department of Water and Power (LADWP) (Eastern Sierra Office). Prior to the start of the project, we estimated that 65% of the deployed stations would need to be installed on land owned by LADWP (Figure 1), with most of the remainder (25-30%) being deployed on BLM land. This estimate proved to be accurate and emphasizes the importance of securing permits. Early communication with LADWP suggested that permitting would not be an issue and an application was submitted in May. However, the application was quickly rejected and numerous follow up conversations in the subsequent months, through to November 2024 were unsuccessful. Similar issues were not had with BLM. Despite this, work to secure permits has continued. PI Ford and her graduate student have made a collective five trips to the Bishop area for (1) siting, (2) to meet with LADWP geologists and (3) to develop a framework for deploying the nodes on LADWP property, which would include deployment on an unofficial network of "jeep roads". We hope to complete the deployment in 2026.

In addition to forward progress on permitting, the project has provided ample opportunity to learn and employ new tools useful for siting and deployment, the experiences we hope to describe in a peer reviewed article (Ford, in prep) and were presented at the 2024 AGU Annual Meeting (Ford, 2024). Specifically, we refer to two different mapping apps – CalTopo and ArcGIS. CalTopo (https://caltopo.com) is a web-based, digital mapping platform developed for, and used by, search and rescue teams, as well as recreational users interested in backcountry travel. It allows for collaborative mapping without the need to share or email files (e.g., kml) repeatedly. Importantly, the maps generated in CalTopo can easily be shared with a link and is free to use (limited features). While CalTopo was originally designed for backcountry travel, the available tools make it ideal for the initial siting of seismic experiments. Data layers, such as satellite imagery, public land boundaries, private land owner information, topography, amount of sun exposure (important for solar charged equipment), cell phone coverage, geology and more can easily be turned on/off. CalTopo is in many ways like Google Earth – kml files can be imported and exported, and data can be downloaded to phones for GPS navigation in the field (i.e., gpx files). In addition to general siting, CalTopo can provide insight into forecasted weather conditions, i.e. high and low temperatures (bottom left image) and wind speeds. In short, CalTopo is a useful tool for plotting proposed station locations and sharing this information quickly and easily.

The other tool that we have used extensively for siting is the Field Maps App. ArcGIS Field Maps App is a mapping app for cell phones (iOS and Android) that allows for customized data collection. The app is integrated with ArcGIS web-based mapping. The owner of the map can customize the fields for a specific project, and users can collectively record data and notes into one map, which can be reviewed on web browsers when back in the office. Owner of the Field Maps web map can enable data collection/markup, which is useful for metadata collection in the field by team members. The number and type of fields can be modified to meet the needs of any individual experiment. The overview map provides instant updates for other locations so that teams can track progress. The Field Maps App has proved to be a critical tool in our siting efforts. The maze of public land ownership and presence of sensitive infrastructure (i.e., aqueducts) in Owens Valley, means that significant navigation and knowledge of obstacles (rugged roads, locked gates) is required to make a future deployment successful. In each siting trip, we have relied on Field Maps to log information on every potentially relevant feature. Notes are made and a photo taken. Each object in Figure 2 corresponds to a road feature recorded as a Field Maps entry. Figure 2 also shows a screen shot (iphone) of data collected Field Maps during a December siting trip.

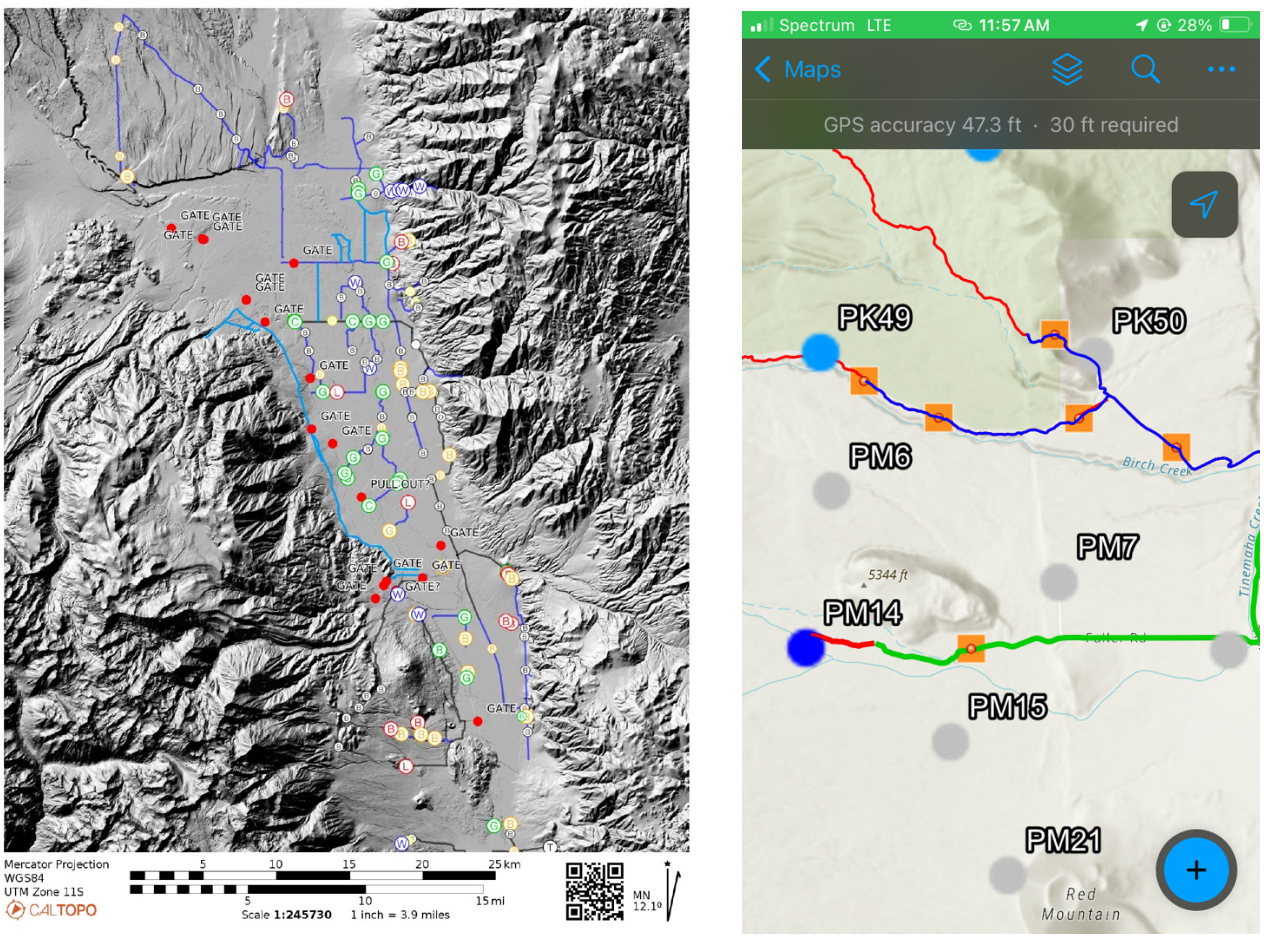

__Figure 2.__ (__left__) Shaded relief map taken from CalTopo. Circled letters mark the locations of recorded Field Maps entries, taken in the field during siting. The locations correspond to potential challenges in deployment, including gates, water crossings, rough terrain, etc. (__B__) Screen shot of similar data, shown in the Field Maps app. Each orange square indicates a location where information was recorded related to road conditions. Colored and grey circles correspond to proposed station locations.

5. Looking Forward

While forward progress on the experiment has been slower than expected, we are optimistic that the work will ultimately be completed. The data collected will be archived at the IRIS/EarthScope Data Management Center (DMC) and become publicly available two years after the last instrument is removed, in accordance with NSF standards. The ambient noise tomography model that is eventually generated will be publicly archived, and if desired, the PIs will work with the SCEC CVM group to ensure its integration into the UCVM framework. We also intend to publish an article outlining the utility of CalTopo and Field Maps. Finally, in addition to forming the basis of a graduate student's dissertation, we anticipate the opportunity to engage many undergraduate and graduate students as volunteers as part of the field work efforts and potentially as authors and co-authors on additional research endeavors.

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