RISC

HIGH RESOLUTION CRUSTAL IMAGES OF THE SOUTHERN BASIN AND RANGE

Submitted By

David Okaya

University of Southern California

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RISC High Resolution Crustal Images of the Southern Basin & Range - Salton Trough

David Okaya, University of Southern California and Alan Levander, Rice University

The deployment of a passive multichannel seismic array during a crustal seismic refraction experiment is an effective approach to collect high-quality vertical-to-intermediate offset crustal images. This technique has been applied with great success during the USGS-PACE 1985-1987-1989 and PASSCAL 1986 Basin and Range seismic experiments. These "piggyback" experiments (1) are cost-effective since the source energy is "free"; (2) use high density intermediate-aperture arrays to provide spatial resolutions far superior to the host seismic refraction experiments; (3) recently can provide three-component recording as opposed to the host experiment's vertical component data; (4) can address specific scientific questions not resolvable by the refraction data; and (5) offer close coordination and collaboration between refraction and piggyback investigators during all phases of data collection, analysis, and synthesis.

In collaboration with the USGS, Rice University and the University of Southern California (RISC) conducted a multichannel piggyback experiment during the USGS PACE 1992 refraction experiment in the Colorado River region of southeastern California - southwestern Arizona. This region represents the transition between the Southern Basin & Range and the Salton trough (Figure 1). The piggyback experiment was located in the center of the refraction experiment and involved three distinct sets of instrumentation: two industry-style multichannel recording systems and a full complement of PASSCAL instruments for 1332 recording channels.

Several milestones were reached during the RISC piggyback experiment: the first PASSCAL experiment to utilize all of the then available 3-channel instruments (48 at that time); the largest PASSCAL experiment up to that date in terms of total number of PASSCAL instruments deployed (88), and total number of recording channels (384); the first experiment for the new PASSCAL Instrument Center at Stanford/Menlo Park; the largest three-component piggyback study ever conducted (888 continguous stations at 50 m spacing); and the first to use three-component sensors at 100% of the recording stations (see table).

Scientific Objectives

Major tectonic problems of southeastern California to be addressed by both the host refraction experiment and the RISC piggyback included the structure of the crustal transition between the ~30 km-thick Southern Basin & Range and the <25 km-thick Salton Trough; the process of continental crustal growth as indicated by the emplacement of the late-Mesozoic oceanic supracrustal ("Orocopia") terrane; and the possible lateral continuation of regional extension related to mid-Tertiary metamorphic core complexes which are found

Continued on page 2

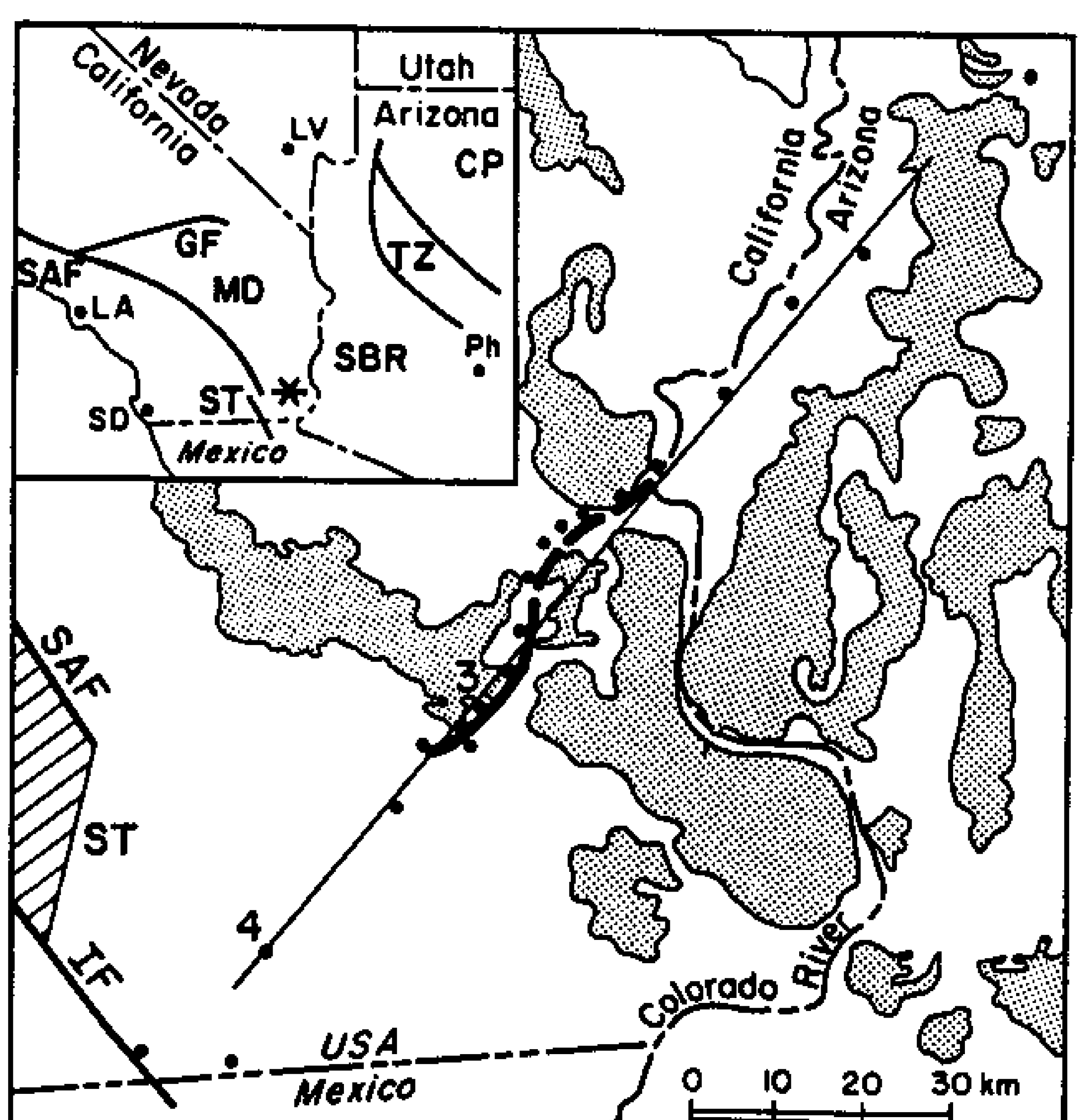

Figure 1. Location of RISC experiment. Left inset: Southwestern U.S. Regional features are Salton Trough (ST), Southern Basin & Range (SBR), Transition Zone (TZ), Colorado Plateau (CP), Mojave Desert (MD), Garlock fault (GF), and San Andreas fault (SAF). Right: Location of USGS and RISC experiments. Bold solid and dashed lines are RISC arrays, thin line is USGS PACE refraction transect. Dots are source points; "3" and "4" are shot point for Figures 2 and 3, respectively. Salton Trough is located to the southwest.

What's Inside

Seismogram Display

As part of an IRIS educational initiative, Tom Early and Paul Silver (Department of Terrestrial Magnetism, Carnegie Institution of Washington) are developing a seismograph display for a new Earth Science exhibit at the Smithsonian Institution's Museum of Natural History.

The display consists of three windows on a Sun workstation: three component seismograms; a world map showing the location of the event and station; and a cross section of the earth with ray paths of the major seismic phases. The expected arrival times for these phases are marked on the seismograms. Waveform and event data for recent events are automatically received from the GOPHER system at the IRIS DMC.

The display is based in form on a similar system developed by Terry Wallace at the University of Arizona. The programs SAC and MAP (see article on page 7) are used for plotting. In addition to its primary application in a museum environment, the display makes an excellent teaching tool for "record reading" in seismology.

The Smithsonian display will also include a display of global seismicity based on the SEISMIC program developed by Allan Jones of SUNY, Binghamton. SEISMIC currently runs on PC computers and can be obtained directly from Alan Jones, or through the Software Exchange Library (SEL) at the IRIS DMC.

A copy of the seismogram display program and related documentation also can be obtained through SEL — use the "p" (Program) option on the Bulletin Board at the IRIS DMC for directions on how to retrieve SEL software. SAC and MAP are required to run the program and IRIS members can also obtain copies through the DMC.

Try it - you'll like it! Comments or suggestions for improvement would be welcome. •

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near the Colorado Plateau to the north.

The objectives of the RISC piggyback were both geological and seismological. The primary geological focus was to obtain near-to-vertical incident, high-resolution, low-fold reflection profiles. From previous exploration industry seismic profiles, reflectors were known to exist at all crustal levels. Imaging targets for the RISC piggyback were thus: the (three-component) seismic signature of the upper-crustal Orocopia schist terrane; the identification of middle crustal strong-amplitude discrete reflections as observed in the industry data; the characterization of known lower crustal reflectivity; and a vertical incident image of the Moho.

The RISC piggyback was also designed to address seismological problems relating to the reflectivity of crustal rocks. Petrophysical measurements of a sample from the intensely foliated Orocopia schist indicate >20% P wave anisotropy. Three-component seismometers were deployed in order to identify the seismic response to this anisotropic behavior. The array was designed to measure the statistical properties of the propagating wavefields when scattered by reflectors; for example, the coherence of signal when scattered from presumably discontinuous reflectors as measured by source-receiver offset variance.

Field Operations

The basic RISC piggyback array was composed of 444 three-component stations (1332 recording channels) every 50 m for a total length of 22 km. For comparison, the host refraction array was 390 single component stations with an average 330 m spacing for an array length of 132 km. The PASSCAL instruments were deployed as a 6.4 km segment (128 three-component stations) with CHEVRON industry strings of 4 Hz three-component sensors. Recorded data were written to disk and downloaded at the base motel in Blythe, California.

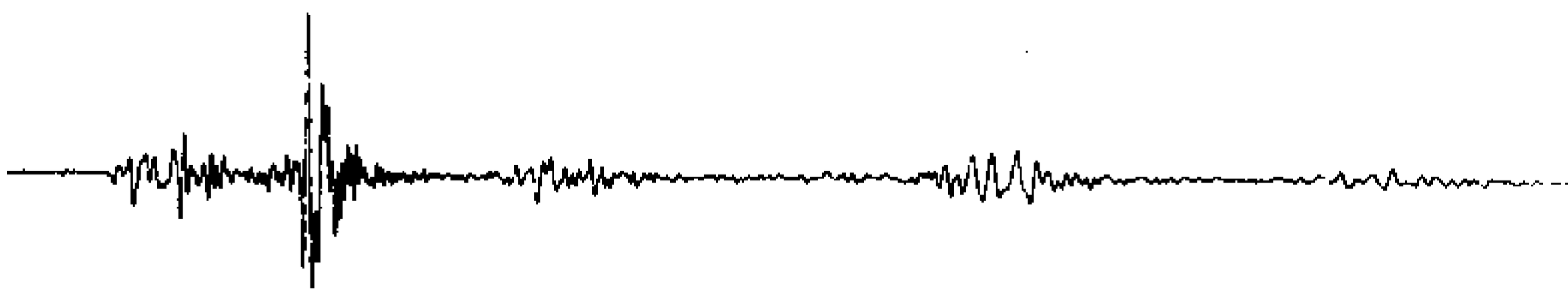
The ARCO GUS multichannel recording system composed the bulk of the array. Originally designed for 3-D seismic reflection acquisition, this system was stretched to its maximum 2-D capability in order to obtain 276 three-component stations (13.8 km). Seismic signals from the 10 Hz three-component strings were field demultiplexed (42 MB records) and written to magnetic tape. The CHEVRON DFS-V conventional cable recording system used 40 three-component stations to cover 2 km distance. Sensors were the same as those used on the PASSCAL instruments.

Recent Piggyback Studies in the Western United States

	Refraction Experiment				
	PACE85	PASSCAL86	PACE87	PACE89	PACE92
Piggyback Experiment:	UCSB	PASSCAL working grp	Stanford/ USC	Stanford/ U of Ariz	RISC
#Channels:	48	200-300	568	1700	1332
Vert stations:	48	200-300	448	650	—
3Comp stations:	—	—	40	350	444
Station spacing:	100 m	50-100 m	50 m	50 m	50 m
Total aperture:	4.8 km	20 km	24.4 km	45 km	44.4 km (2 x 22.2 km)
Array note:		array used 3 times		3 comp in 1-5 km arrays	array 2 times, end-to-end
Equipment*:	UCSB	CGG,UCSB, Wyo	Arco,Chev, UCSB	Arco,SGR, Wyo	Arco,Chev, Reftek Srs,Jrs

* Equipment Type:

UCSB = UCSB DFS-IV Chev = CHEVRON DFS-V
Arco = ARCO GUS 8000 CGG = CGG SERCEL 348
Wyo = Univ. Wyoming DFS-IV SGR = Stanford & Amoco SGRs



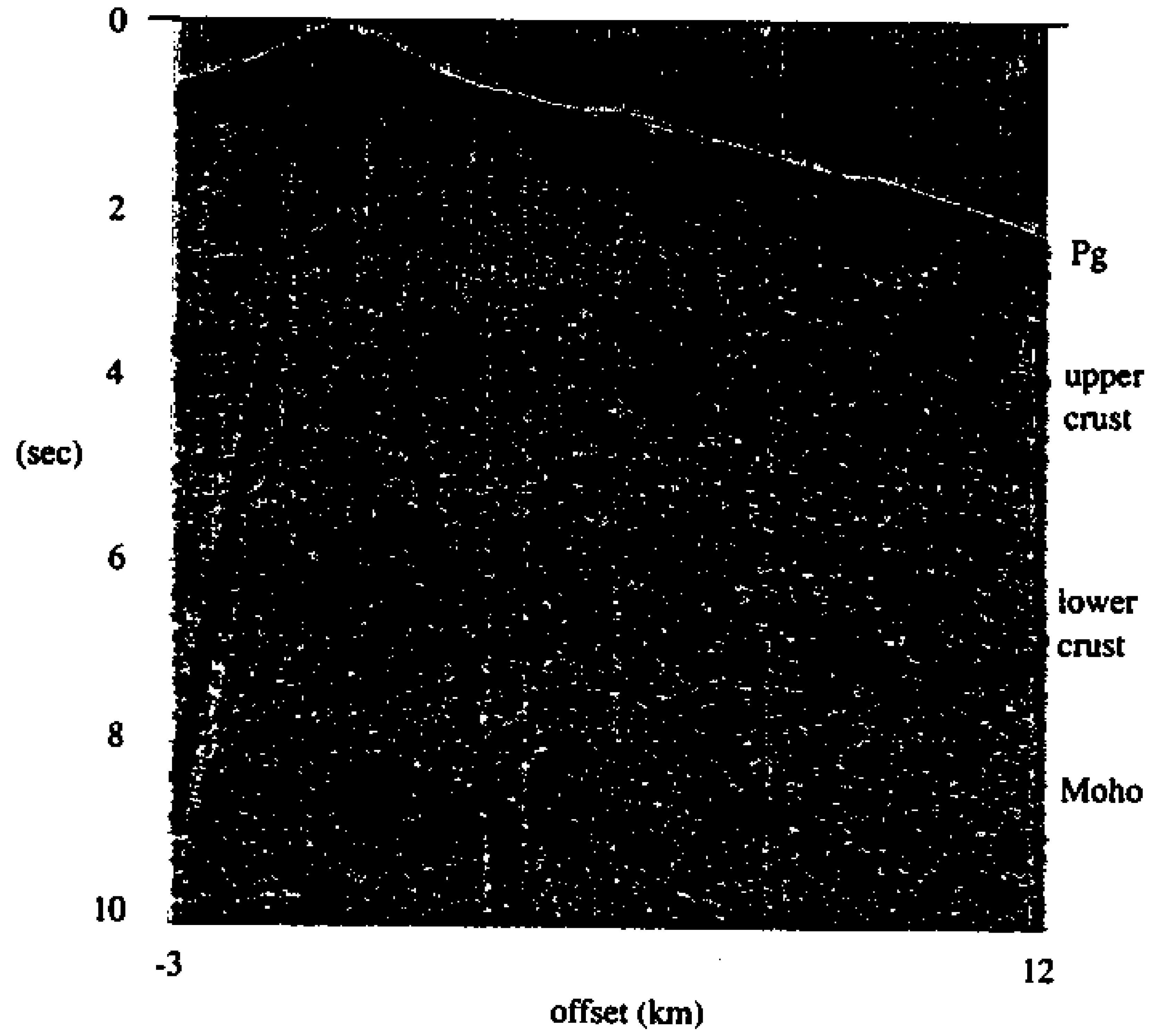


Figure 2. Portion of a 44-km wide shot gather. Offsets are -3 to +12 km. A 10-35 Hz filter is applied. Strong crustal reflectivity is present through much of the approximately 30 km crust.

Because the experiment sources were divided into two groups and collected on different nights, the RISC piggyback array was redeployed in order to make an effective 888 station, 44 km three-component array. The USGS sources ranged between 300-4000 lbs and created source-receiver offsets of 0-100 km. In order to provide full vertical incidence imaging, the RISC project contributed several additional shots. Of the 22 source locations, five were used for both deployments, in order to construct common shot gathers of significant aperture (33% of the host refraction array).

Data Merging and Preliminary Observations

After transcription, demultiplexing and conversion to common format, the combined data produced twenty-seven 444-trace shot gathers for each component, representing a three-component data set of 2.88 Gbytes of seismic data. Co-location of stations of the three recording systems allowed for direct comparison of seismogram waveforms and the construction of transfer functions.

The crustal image in Figure 2 reveals reflective zones in the middle of the upper crust and in the lower crust, with a less-prominent Moho at 9 sec. Clarity (coherence) in the overall reflectivity increases with offset as predicted by scattering theory. The complexity in the lower crustal reflections suggests strong geologic dips or out-of-plane/scattering propagation behavior.

The character of Pg and PmP phases are exhibited in Figure 3 for offset distances of 53-80 km. The vertical component section possesses coherent arrivals for both phases at all offsets. Note the second-order lateral variability of each phase. The in-line horizontal component section has weak events which are identifiable due to the close station spacing (e.g., phase lateral continuity). Not shown is the transverse horizontal component which has little recognizable energy.

The RISC piggyback data set represents seismic imaging of transitional continental crust using vertical-incidence to wide angle (100+ km) source propagation. The availability of large numbers of recording channels allowed for the construction of a wide-aperture array which could record the full wavefield at high spatial resolution. These data can produce a low-fold vertical incidence profile at nominal experimental costs. This and earlier piggyback experiments have greatly benefited from the participation of industry groups whose seismic equipment in most cases provided the majority of the recording capacity. Current economic trends make future industry participation more difficult, increasing the importance of a large pool of portable PASSCAL instruments. •

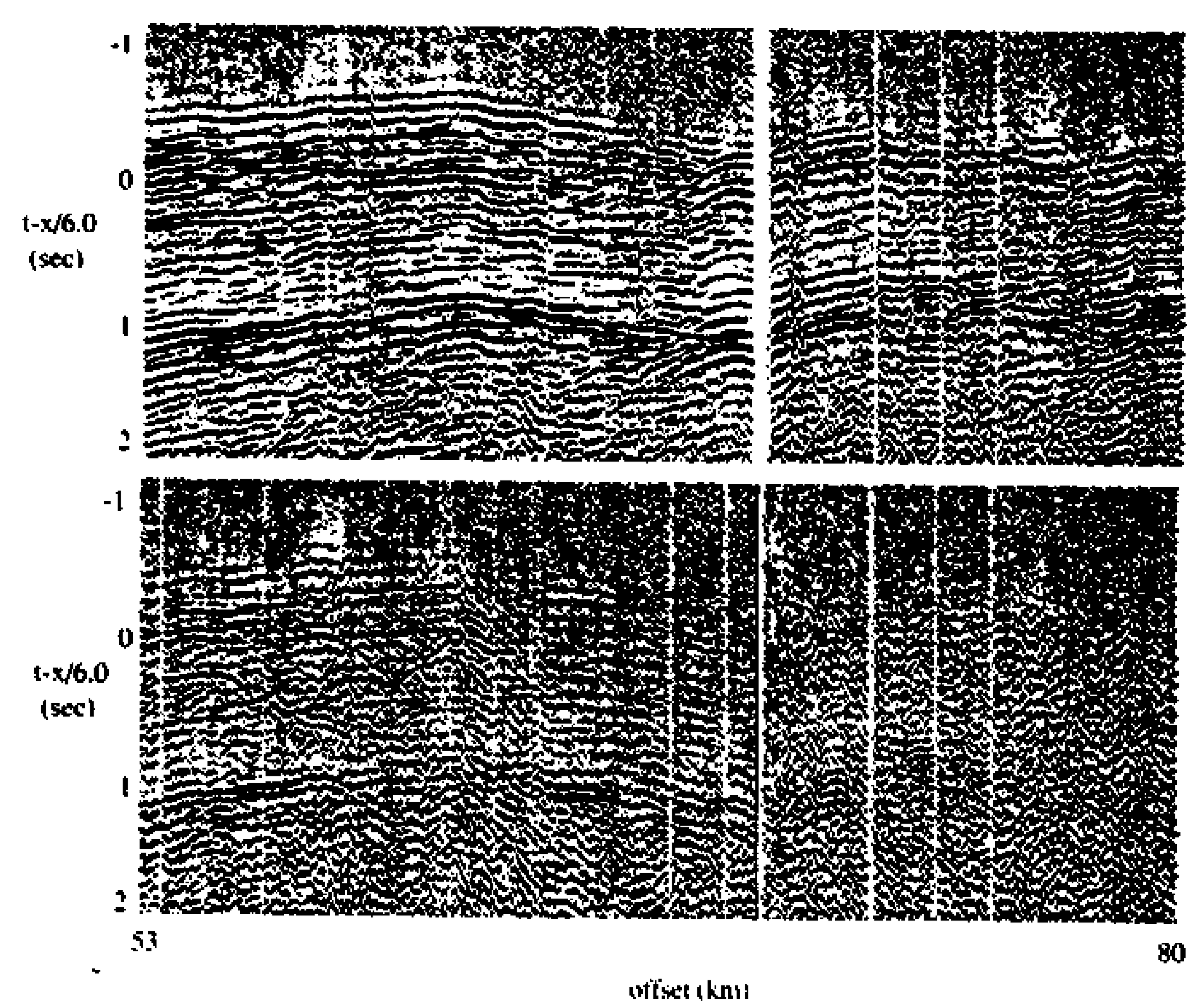


Figure 3. Vertical (top) and in-line horizontal (bottom) components for 53-80 km offset (Pg and PmP phases). Time scale is reduced travel time using a velocity of 6.0 km/s. The presence of PmP at low far-offsets suggests thin transitional crust between the Salton Trough and Basin & Range. Lateral variation within each phase is observable due to the high spatial resolution.

This Issue's Bannergram: The seismogram on the cover is the radial, very long-period component from IRIS/IDA station Lovozero, Russia (LVZ) for the M=7.5 Indonesian earthquake of December 12, 1992. As well as being rich in body wave phases, this record shows long-period surface waves that have encircled the Earth multiple times: R1 is the direct Rayleigh wave along the forward direction; R2 traveled along the reverse arc; R3 traveled the foward direction with an additional trip around the Earth. X phases denote surface wave overtone packets which travel with group velocities between Love and Rayleigh waves.

Data Tapes

There are four data tapes for this experiment.

Tape 1: SEGY format of VERTICAL component data.

SEGY tape has 27 shots containing 444 seismograms each.

Record	bytes	Content
1	3200	Standard SEGY EBCDIC header
2	400	Standard SEGY binary header
3	80244	data trace of SHOTSEQ 1 trace 1
.		
.		
11990	80244	data trace of SHOTSEQ 27 trace 444

The data records are 80 seconds long sampled at 4 msec.

Tape 2: SEGY format of HORIZ-INLINE component data.

SEGY tape has 27 shots containing 444 seismograms each.

Record	bytes	Content
1	3200	Standard SEGY EBCDIC header
2	400	Standard SEGY binary header
3	80244	data trace of SHOTSEQ 1 trace 1
.		
.		
11990	80244	data trace of SHOTSEQ 27 trace 444

The data records are 80 seconds long sampled at 4 msec.

Tape 3: SEGY format of HORIZ-TRANSVERSE component data.

SEGY tape has 27 shots containing 444 seismograms each.

Record	bytes	Content
1	3200	Standard SEGY EBCDIC header
2	400	Standard SEGY binary header
3	80244	data trace of SHOTSEQ 1 trace 1
.		
.		
11990	80244	data trace of SHOTSEQ 27 trace 444

The data records are 80 seconds long sampled at 4 msec.

Tape 4: UNIX tar format support files

This tape contains the following files:

GEOM27SHOTS_Z.DAT	SierraSEIS-compatible geometry file for vertical component.
GEOM27USGS.DAT	SierraSeis-compatible geometry file for USGS experiment.
RARCO0.f	IRIS-SEIS subroutine to extract ARCO data from archive
RARCOX.f	SEGY tapes. Stored 2 msec data -> 4 msec data.
README	This file.
SEGYHEAD.DAT	IRIS-SEIS job to print SEGY headers describing RISC.
SP.description	Description of USGS shots used in RISC experiment.
SP.latlong	Coordinates of shot points.
SP.stackchart	Description of shot points relative to RISC arrays.
XY.USGS_utm	Coordinates of USGS array in UTM.
XY.USGSarray	Coordinates of USGS array in lat-long.
colocated.stations	Table of RISC colocated stations (instrumentation).
data_size	Description of data format and size.
full_array	Table of entire RISC array. Stations, boxes, deployments.
instrument_set	Type of instruments in the RISC array.
segy_exabyte	RISC definition of SEGY headers on exabyte data tapes.
segy_headers	Full description of RISC use of SEGY headers.
segy_tapeformat	Description of data format on SEGY exabyte data tapes.