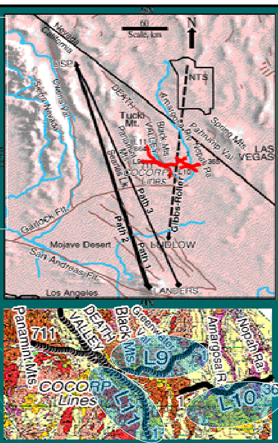
Figure 1.

Above:
map of eastern Calif.- southern Nevada. Solid lines indicate the general paths of their surface-wave analyses; the broken line represents the refraction profile of *Gibbs and Roller* [1966].



Below:
Below: the area of the COCORP Death Valley lines magnified and superimposed on *Jennings's* [1977] geologic map. Lighter areas represent Quaternary to Recent sediments; darker areas show pre-Cambrian to Tertiary metasediments, plutons, and volcanics.

Figure 2.
Velocity sections obtained by nonlinear optimization of first-arrival times picked from COCORP lines 9 (a), 10 (b), and 11 (c). Well-constrained parts of the sections are above the white lines. The arrows on (a) and (c) show where lines 9 and 11 intersect. Ticks across the surface profiles indicate where the lines cross from basin sediments to range basement rocks at the surface, and the locations of faults, based on *Jennings* (1977; Figure 1).

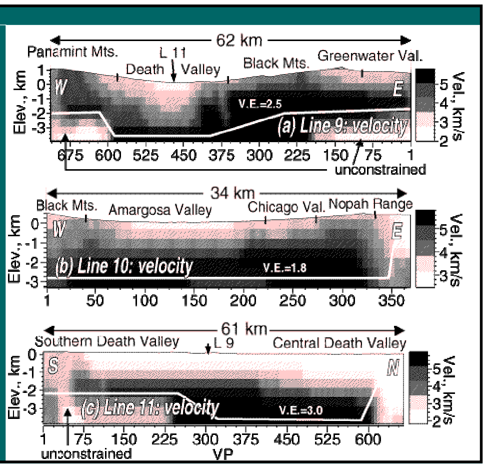
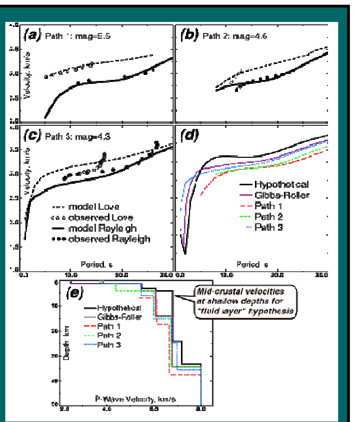


Figure 3.
Surface-wave dispersion analysis.
(a) group velocities of Path 1 surface waves recorded at DSP, and dispersion curves computed from the Path 1 velocity model in (e).

(b) and (c) observed and model dispersions for Paths 2 and 3.

(d) comparison of Rayleigh-wave dispersion curves for Paths 1, 2, and 3 with those computed from the results of *Gibbs and Roller* [1966].

(e) P-wave velocity models used to compute dispersion curves in (d) assuming a Poisson's ratio of 0.25, and the hypothetical model of uplifted ``fluid crust'' at only 5 km depth.



Velocity Models for the Highly Extended Crust of Death Valley, California

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GEOP 480: Special Topics
Done for Dr. Ali Oncel
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PURPOSE OF THE ARTICLE

- To compare the regional models for surrounding provinces with what the author did using :
  1. Nonlinear optimization to obtain shallow velocity structure from The Consortium for Continental Reflection Profiling COCORP seismic reflection profiles in the highly extended **Death Valley region, California**.
  2. Group-velocity analysis of regional earthquake surface waves that have traversed in and near the extended domain.

OUTLINE

- INTRODUCTION
- METHOD
- RESULTS
- DISCUSSION

INTRODUCTION

- The central Basin and Range province, including Death Valley, has been subject to Cenozoic crustal extension.
- Stewart [1971] proposed 20% extension across the province
- In the Death Valley area, Wright and Troxel [1973] propsed 50-100% extension.
- In contrast, *Wernicke* [1992] and *Jones et al.* [1992] suggest this region has undergone extension far in excess of 100%.

>>Cont.

INTRODUCTION

- Therefore, *Louie, satish, and Hojnas* test two competing end-member models for the degree of extension: *pure shear models* and *fluid layer models*.
- These models differ greatly in the extent of vertical motions. They use available seismic data to test for these vertical motions.
- The Consortium for Continental Reflection Profiling (COCORP) collected data across the Death Valley domain in 1982 (Figure 1).
- Using conventional seismic processing for upper- and mid-crustal reflectors.

>>Cont.

INTRODUCTION

- They extend their analyses using all the recorded data along lines 9, 10, and 11 (Figure 1) ,with a method that does not involve ray tracing and requires less *a priori* information.
- They also obtain a regional velocity model to the west of the highly extended domain (Figure 1) using surface-wave analysis, to constrain deeper velocities and complement *Gibbs and Roller's* [1966] velocity model from within the domain.
- They compare their results with regional models for the highly extended region as well as adjacent geologic provinces, and constrain the nature of extension beneath Death Valley.

METHOD

The 1ST Stage

1. Optimizing the first-arrival time picks for upper crustal velocities out of from shot gathers collected on COCORP Death Valley lines 9, 10 and 11 (Figure 1).
2. Inversing the first-arrival times because of the bending of seismic rays due to seismic wave velocities having strong lateral variations such as in alluvial basins.
3. Employing a generalized simulated-annealing method of optimization to account for ray bending.
4. Projecting the source locations to straight lines while maintaining the true offsets of the source-receiver pairs in order to overcome the effect of bends in the profile.
5. An advantage of the simulated-annealing optimization is that can fit the data equally well.

>>Cont.

METHOD

The 2nd Stage

1. The second part of their study uses surface-wave dispersion analysis of regional earthquake phases to constrain crustal velocities from 3 km to the Moho.
2. Constructing Rayleigh and Love wave group-velocity dispersion curves using the single-station ``peak and trough'' method
3. Using an interactive modeling program they developed using the method of Takeuchi and Saito fits an observed dispersion curve to calculated curves by trial and error.
4. Their method gives average velocity variations, but the depths of layers are not unique.
5. In general, the fundamental-mode Rayleigh waves are more sensitive to the S-wave velocity variations at shallow depths, while the Love waves are affected more by velocities in the deeper horizons.

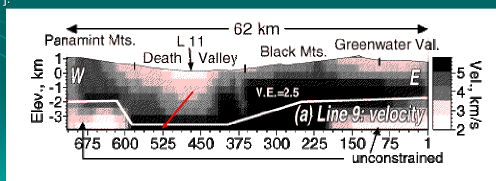
RESULT *of The 1st Stage*

Line # 9

- The prominent 2.4 to 2.8 km/s low-velocity region in the optimization result @ the Death Valley basin.
- Beneath the basin, velocity increases from 4.5 - 5.5 km/s at 3 ~4 km depth.
- The highest velocity they encounter in the section is 5.8 km/s at a depth of 4 km (below VP 525).
- Velocity error rises to 0.5 km/s to 2 km below the mountains, but remains good down to 4 km beneath Death Valley.

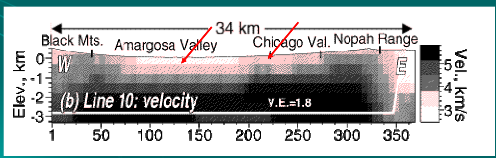
⇒ The Result:

Basin velocities in the line 9 section are within 10% of those obtained by *Geist and Brocher* [1987].



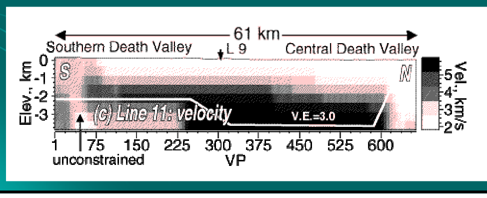
RESULT
Line # 10

- near-surface 2.5 km/s low-velocity zones in the optimization result.
- Gradually increaing 4 – 5.8 km\s at 3.4km beneath the Black Mountains and Nopah Range.
- Ray tracing finds that resolution is good everywhere except under the Nopah Range.



RESULT
Line # 11

- Line 11 is an axial profile from southern Death Valley to central Death Valley in the north, entirely within the basin region.
- It indicates thickening of the 2 km/s low-velocity sediments toward the central Death Valley basin.
- Velocities stay below 5.8 km/s until they reach depths of 3 to 4 km.



RESULT *of The 2nd Stage*
The Group Velocity Analysis

- They compute group velocity curves from a refraction velocity model [*Gibbs and Roller,* 1966].
- Then, they compare all the models against a hypothetical model having high mid-crustal velocities of 6.8 km/s at shallow depths of 5 km.
- Their deeper surface-wave study does not suggest the presence of any abnormally high-velocity zones in the shallow crust.

DISCUSSION

- Their seismic refraction analyses in the Death Valley region give similar results for the *Benz et al.* [1990] uppermost crust. They have seen a maximum velocity of 5.8 km/s at 4 km depth.
- Their surface wave analyses to the west of Death Valley do not show any anomalous crustal velocities, and are in agreement with *Gibbs and Roller's* [1966] refraction results from the highly extended area east of Death Valley, as well as with other regional velocity models [*Benz et al.*, 1990].
- Their data provide a test of extensional hypotheses involving large vertical movements or velocity alterations of the shallow crust.
- Major uplift of the middle crust, or radical thinning of the upper crust may not be consistent with the agreement between their observations and velocities in much less-extended regions.

DISCUSSION

- Their results constrain the conditions under which *fluid layer* based extension might operate in this region
- ***fluid layer hypothesis:***

  The normal velocities they observe in any of these areas would require the compensating medium to be very close in density to the upper crust. This density constraint would imply that this ``layer'' is rich in quartz. They would, however, expect a "fluid layer" derived from the middle crust during the Cenozoic to have a significantly higher velocity than similarly quartz-rich upper crust, as it would contain a significant fraction of very high-velocity metamorphic minerals at Greenschist grade or higher.

DISCUSSION

- Figure 2 shows that such high-velocity materials cannot be within 4 km of the surface near Death Valley, and the mismatch of the ``Hypothetical'' velocity model to the data in Figure 3 shows that any ``fluid layer'' having mid-crustal velocities is likely to be at least 12 km deep, whether inside or near *Wernicke's* [1992] zone of extreme extension. With these constraints on the minimum thickness of the upper crust, the ``fluid layer'' hypothesis may be incapable of explaining extreme amounts of extension.

Thank you