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16. ABSTRACT

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The study shows an apparent correlation between seismic velocity and earthwork factor for the sedimentary rock types encountered on this project. A design earthwork factor based on this correlation agrees more closely with the field earthwork factor than the design earthwork factor actually used for this project.

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Design earthwork factor, field earthwork factor, earthwork factor, swell, shrinkage, seismic velocity, construction, relative compaction, correlation, sedimentary, strata

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November 2005, Division of Research and Innovation

HIGHWAY RESEARCH REPORT

CORRELATION OF SEISMIC VELOCITIES WITH EARTHWORK FACTORS

INTERIM REPORT NO. 3

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

CA-HWY-MR-632103 (3) 72-23

Prepared in Cooperation with the U.S. Department of Transportation, Federal Highway Administration August, 1972

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STATE OF CALIFORNIA—BUSINESS AND TRANSPORTATION AGENCY

RONALD REAGAN, Governor

DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

August 1972

Interim Report No. 3
M & R 632103

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is an interim research report titled:

CORRELATION OF SEISMIC VELOCITIES

WITH EARTHWORK FACTORS

INTERIM REPORT NO. 3

Travis Smith
Principal Investigator

Marvin McCauley
Ronald Mearns
Co-Investigators

Karl Baumeister
Analysis & Report

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

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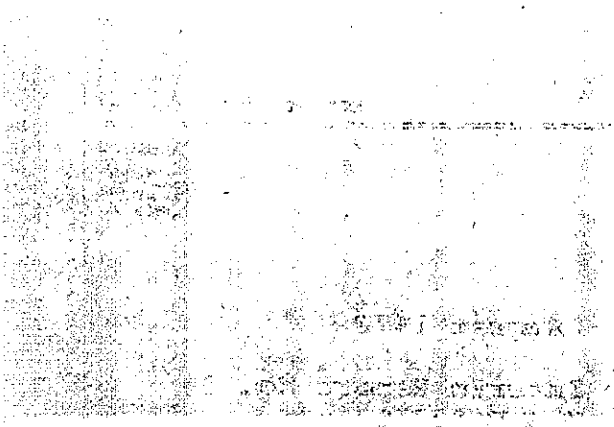

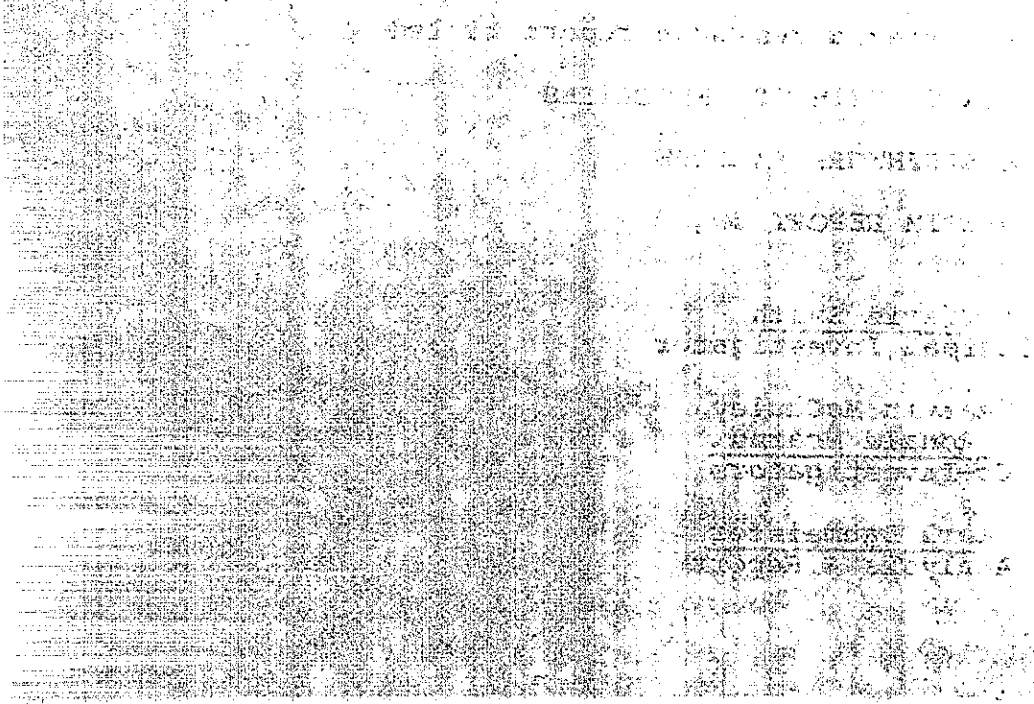

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REFERENCES: Smith, Travis; McCauley, Marvin; Mearns, Ronald; Baumeister, Karl. "Correlation of Seismic Velocities with Earthwork Factors, Interim Report No. 3, CA-HWY-MR632103(3)-72-23 May 1972.

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KEYWORDS: Design earthwork factor, field earthwork factor, earthwork factor, swell, shrinkage, seismic velocity, construction, relative compaction, correlation, sedimentary, strata.

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ACKNOWLEDGEMENTS

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Special thanks are extended to Mr. Dale Neumen, the Resident Engineer on this project, for his time, comments and for furnishing the construction information used in this report.

This investigation was made in cooperation with the U. S. Department of Transportation, Federal Highway Administration (Federal Program No. HPR-1(9) F-07-92).

The opinions, findings and conclusions expressed in this publication are those of the authors and not necessarily those of the Federal Highway Administration.

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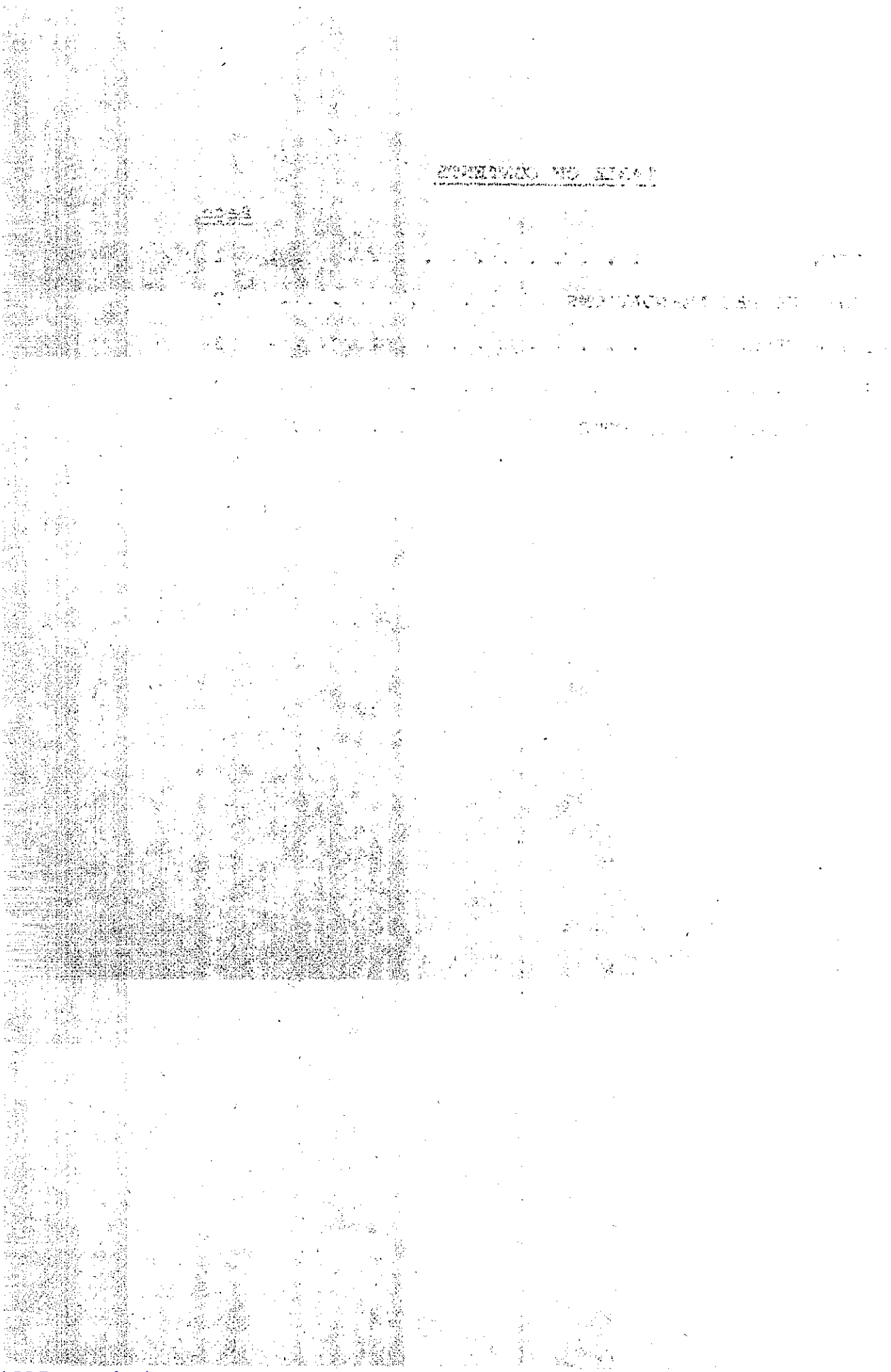

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8 Looking back across Coal Canyon and top of contoured area east of Coal Canyon.

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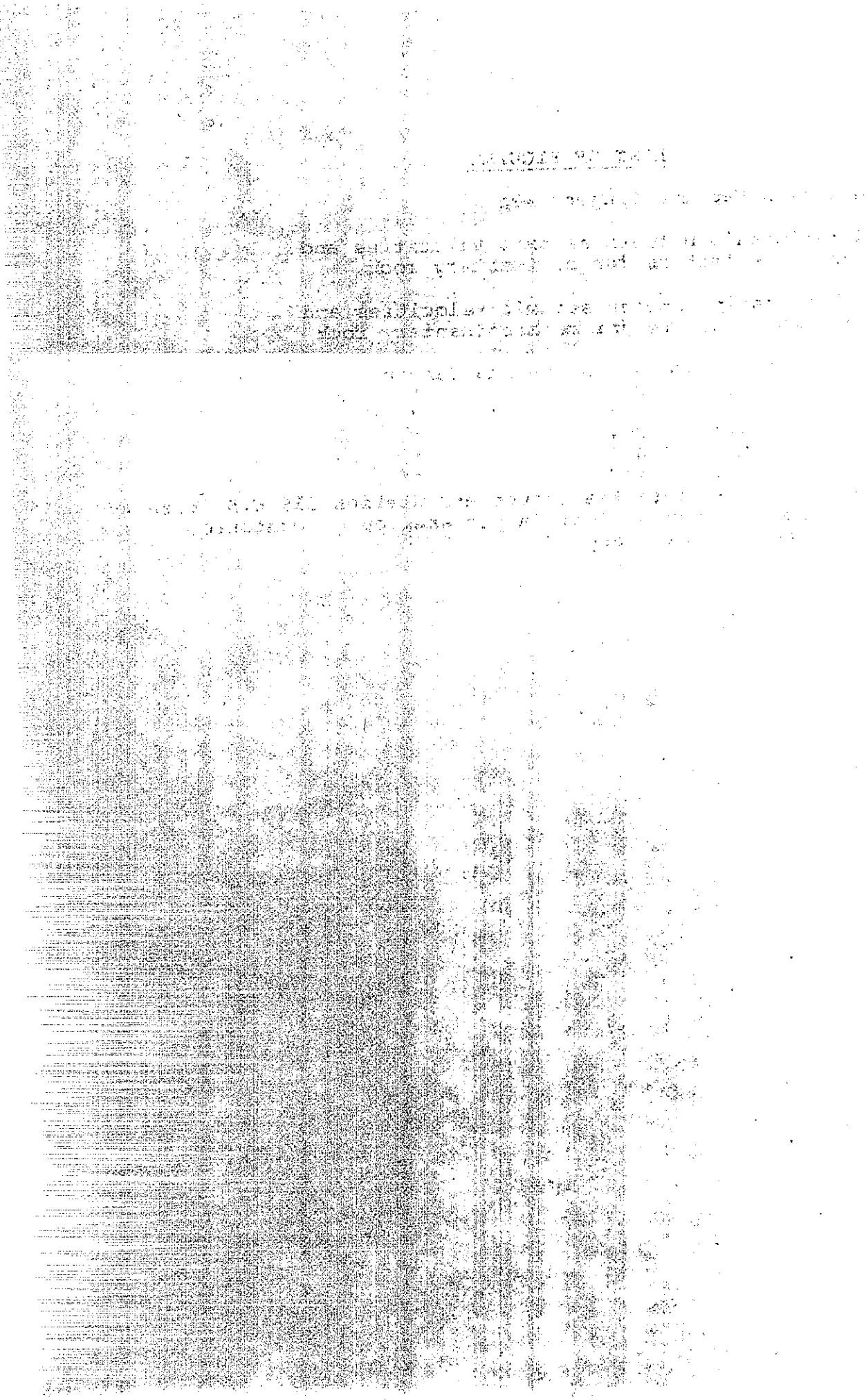

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INTRODUCTION

A report dated June 1971, titled "Correlation of Seismic Velocities with Earthwork Factors, Interim Report" described the study of a construction project in San Diego County and correlated seismic velocities to field earthwork factors for a granitic type rock.

Another report dated January 1972, titled "Correlation of Seismic Velocities with Earthwork Factors, Interim Report No. 2," described a study of a construction project in Tuolumne County. This study correlated seismic velocities and field earthwork factors for metasedimentary rock, metaigneous rock, and serpentine.

The study described in this report was made in Orange County on Route 91 between 1.7 miles east of Anaheim and the Riverside County line. The project map is shown on Figure 1.

The quantities of excavation used in this study were based on aerial topographic data and fully checked. The computed embankment quantities were based on the as designed fill sections superimposed on the original ground as determined from aerial topographic data. The constructed embankment sections were observed to be substantially the same as the design embankment sections and therefore these computed quantities were used. The field earthwork factor was determined by dividing the embankment quantity by the amount of roadway excavation that went into roadway embankment (roadway excavation minus estimated quantity of excavation that was used as aggregate base).

The design earthwork factor was estimated on the basis of borings taken at the jobsite.

The seismic velocities were determined by use of an Electro-Tech 12-channel seismic instrument. The wave energy was provided by explosives.

The principal objectives of this research study are to:

1) Compare field earthwork factors and design earthwork factors.

2) Determine which construction procedures influenced field earthwork factors.

3) Determine whether earthwork factors can be correlated to seismic velocities.

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CONCLUSIONS AND RECOMMENDATIONS

The average design earthwork factor for the entire project was 0.91, while the corresponding field earthwork factor was 1.00 resulting in a difference of 9%.

The construction procedures which influence the field earthwork factor are those that affect the overall in-place density of the embankments. On this project, most of the excavation was done by scrapers. This results in the harder material being broken into smaller sizes than would be the case if most of the excavation were by shovel and the hauling done by trucks. Smaller maximum size of excavated material will result in less dense embankments (relatively higher field earthwork factors) where grading of material size is uniform.

The degree of relative compaction obtained in a fill is a factor which can be qualitatively evaluated by comparing the average relative compaction on the job (94% in this case) to the specified relative compaction (90%). If the average relative compaction had been 90% the field earthwork factor would have been 1.044. 4.4% of the fill on this project would be equivalent to 292,000 cu. yds.

The study indicates there is little or no appreciable difference in the relationship between seismic velocity and field earthwork factor when metasedimentary rock and sedimentary rock are compared to one another - at least in the velocity ranges (1,000 fps to 4,000 fps) encountered on this project. Figure 2 shows the relationship between seismic velocity and approximate field earthwork factor developed from this study.

Because of the variables involved, it is improbable that a precise method can be developed for estimating the design earthwork factor. However, use of seismic data for this purpose appears to show considerable promise in providing more reliable earthwork factor information, especially when compared to previous methods.

It is recommended that the graph in Figure 2 be used on a trial basis, where applicable, to determine its usefulness in obtaining design earthwork factors.

The curve was developed for sandstone and shale and therefore would probably be of limited use for conglomerate.

Prerequisites for a successful check on the method are (a) accurate load counts as to where identified material is placed, (b) accurate figures for cut and embankment volumes, (c) a fairly uniform material in the areas to be excavated (d) knowledge as to the geologic structure of the material to be excavated, and (e) sufficient seismic data.

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CONSTRUCTION METHODS

The project was nearly completed when the field investigation for this study began. Construction methods and details were obtained from the Resident Engineer and the inspectors on the project.

The major portion of the excavation was loosely cemented sandstone which was generally easily rippable. Shale was present in substantial quantities and sandy conglomerate was found at various locations. These also were rippable but the shale at the lower depths on either side of Coal Canyon was quite difficult to excavate by ripping.

Excavation was mostly by scrapers although considerable earth was moved by truck trailers and dozers. The compaction was achieved by hauling equipment and by 2-axle pneumatic and steel-tired compactors (Caterpillar 834). The average relative compaction was 94% by test.

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PROCEDURE

The volumes of roadway excavation and embankment were computed by aerial topographic data taken before and after construction. The type of rock encountered in the excavation was largely sandstone with some shale and minor amounts of clay and conglomerate. Since the material was roughly 85% sandstone, no adjustment was made for seismic velocities that may have been affected by materials other than sandstone.

The total quantity for roadway excavation was 6,843,815 cu.yds. Of this quantity, it is estimated from load counts that 186,000 cu. yds. was used for aggregate base material and therefore the excavated volume used in embankment was 6,658,000 cu. yds. The volume of embankment was approximately 6,633,360 cu. yds. The overall field earthwork factor from these figures is 1.00 compared to the design earthwork factor of 0.91.

The cross-sections of the cut areas were plotted from aerial topographic data. Interfaces of the various strata were plotted on these sections as per interpretation of seismic data and were identified by seismic velocities. The volumes of excavation per stratum were computed for all the cuts. The proportion of excavated material that fell within a certain range of seismic velocities could thus be ascertained for any particular cut.

While load counts are useful in a quantitative evaluation of a project, their use is limited in deriving a direct relationship between seismic velocity and earthwork factor. This is because excavation in any location will generally be carried through several layers of varying density as defined by seismic data. Thus, there is no way of using load counts to determine what the field earthwork factor was for each of these layers because their location in the fill and their compacted volume are indeterminate from load count data.

Weathered sedimentary and metasedimentary rocks have similar grain structure, especially when they are derived from the same type of sediments. It was therefore assumed that the weathered metasedimentary rock that was encountered in Tuolumne County (Interim Report No. 2) had the same seismic characteristics as the weathered sedimentary rock in this study. The curve in Figure 3 of this report shows the curve for the metasedimentary rock. The lower point on this curve, which is in the weathered zone, is assumed to be a point on the curve for sedimentary rock. Various curves going through this point were tried to see which one was most compatible with the data obtained in this study as determined by overall field earthwork factor.

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For the various seismic velocities encountered on this project, field earthwork factors were taken off the trial curves. These factors were then assigned to the volumes of excavation in the corresponding velocity zones, and the overall field earthwork factor was computed for each trial curve. The trial curve most compatible with the data obtained on this study is colinear with the curve for metasedimentary rock when plotted on a semi-logarithmic plot and gave an overall field earthwork factor of 1.00 which corresponded to the job field earthwork factor. (See Figure 2.)

The use of this curve for sedimentary rock should give design earthwork factors more reliable than the methods that have been used in the past.

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GEOLOGICAL DESCRIPTION OF CUTS

The geological descriptions for the cuts made on this project are as described below. The earthwork factor graph in Figure 2 should only be applied to similar materials until more experience has been gained with sedimentary rock.

Sta. 301 to 311 (Santa Ana Canyon Road)

Weathered loosely cemented sandy clayey conglomerate.

Sta. 350 to 354 (Santa Ana Canyon Road)

Weathered sandy silt and sandy gravelley clay.

Sta. 358 to 360 (Santa Ana Canyon Road)

Weathered clayey sandstone.

Sta. 46 - 50 (off ramp 5)

Weathered sandy clay.

Sta. 355 to 371

Material is weathered near surface, grading to moderately weathered at a depth of about 50 feet. From Sta. 355 to 368, material is mostly sandstone with some shale. From Sta 368 to 369 + 50 material is hard laminated shale and sandstone, dipping approximately 70°. The material from Sta. 369 + 50 to 371± is all thin bedded moderately hard shale, with the same approximate 70° dip.

Sta. 380 to 395

Sta. 380 to 387. Material is loosely cemented reddish brown sandy conglomerate.

Sta. 387 to 395. Material is chiefly moist weathered fine grained sandstone with iron and sulfur staining. There are thin to moderately thick interbeds of weathered claystone.

Sta. 435 to 440

The material is predominantly buff cemented sandstone with a thick nearly flat lying bed of red pebbly sandstone and pebbly conglomerate in the middle of the cut face.

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Sta. 515 to 526

The material is mostly buff loosely cemented sandy shale and sandstone. In the deepest portion of the cut is a very hard dark gray shale.

Sta. 529 to 540

Sta. 529 to 531. Buff loosely cemented clayey sandstone.

Sta. 531 to 540. Chiefly buff loosely cemented clayey gravelly sandstone with some loosely cemented sandy conglomerate. In the deepest portion of the cut is a minor amount of very hard dark gray shale.

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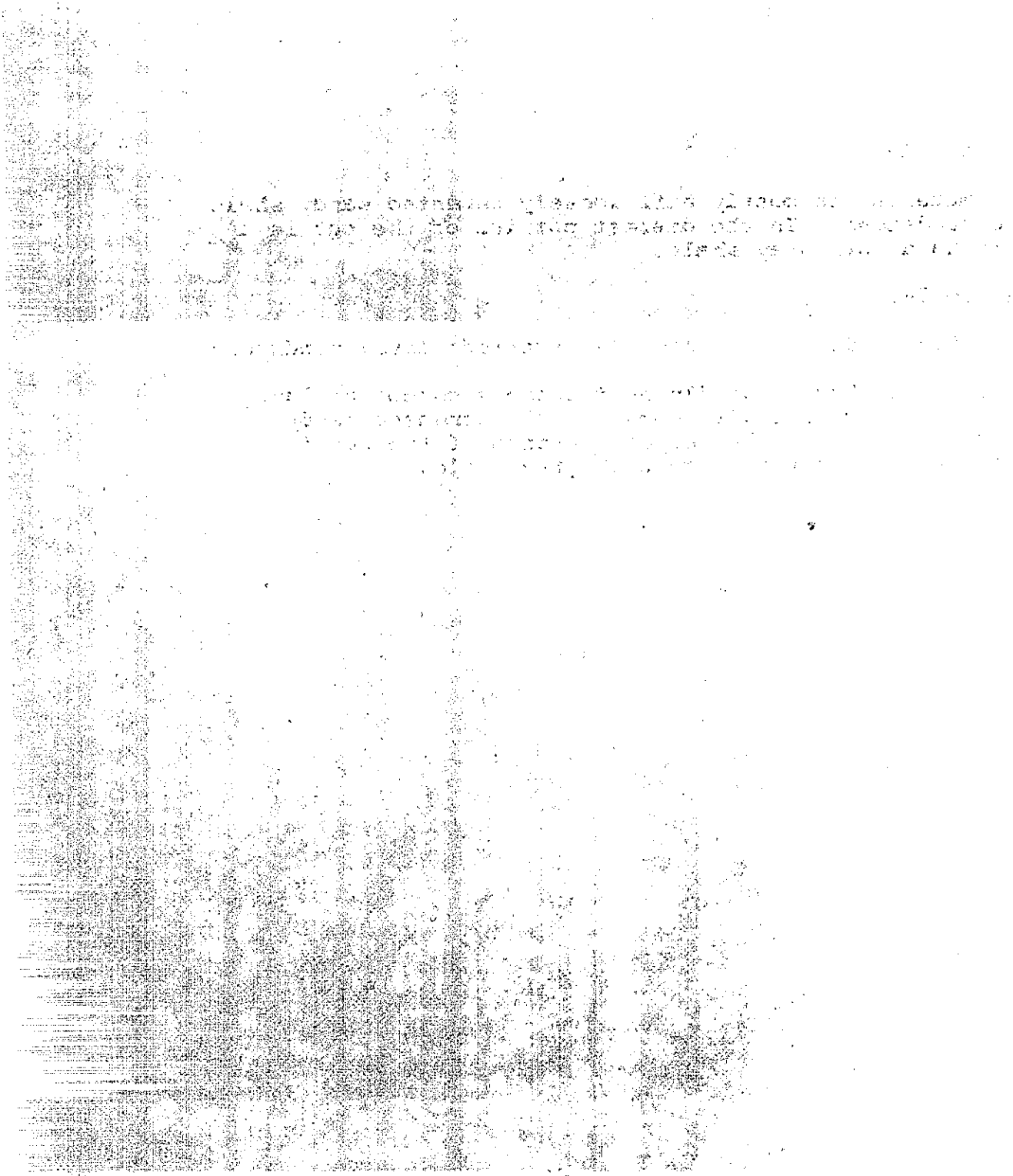

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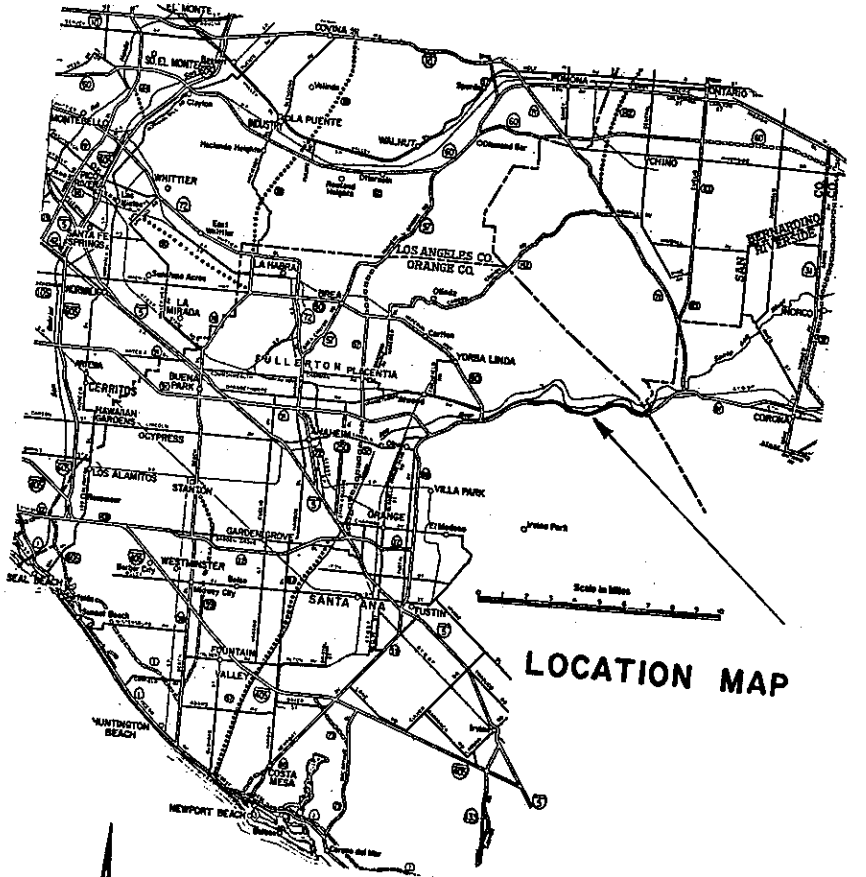
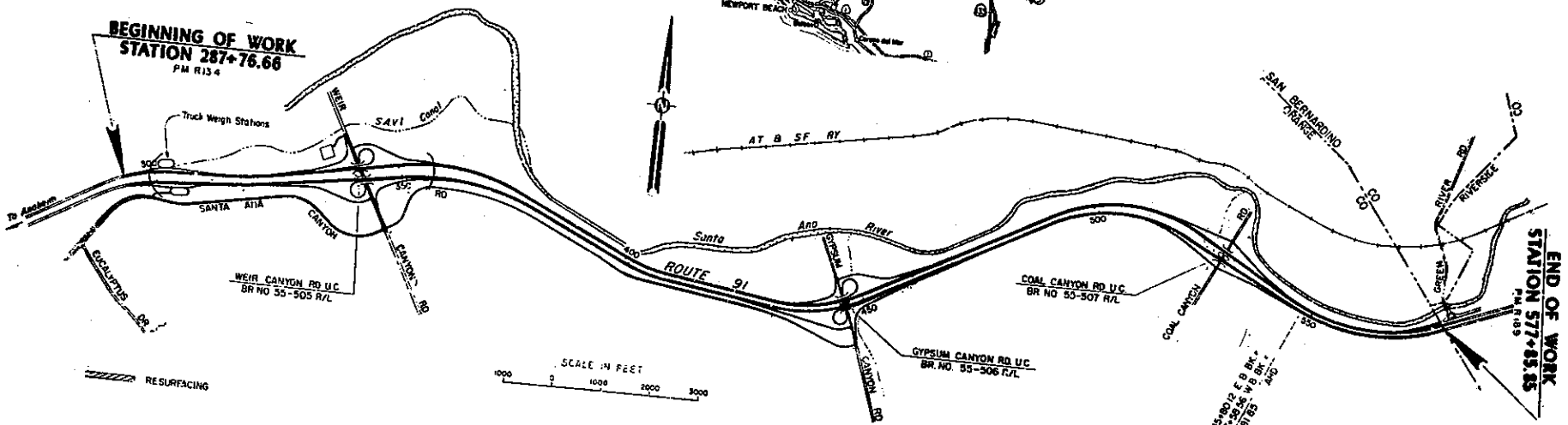


LOCATION MAP



PROJECT MAP

Figure 1

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Figure 2

RELATIONSHIP BETWEEN SEISMIC VELOCITIES AND EARTHWORK FACTORS FOR SEDIMENTARY ROCK

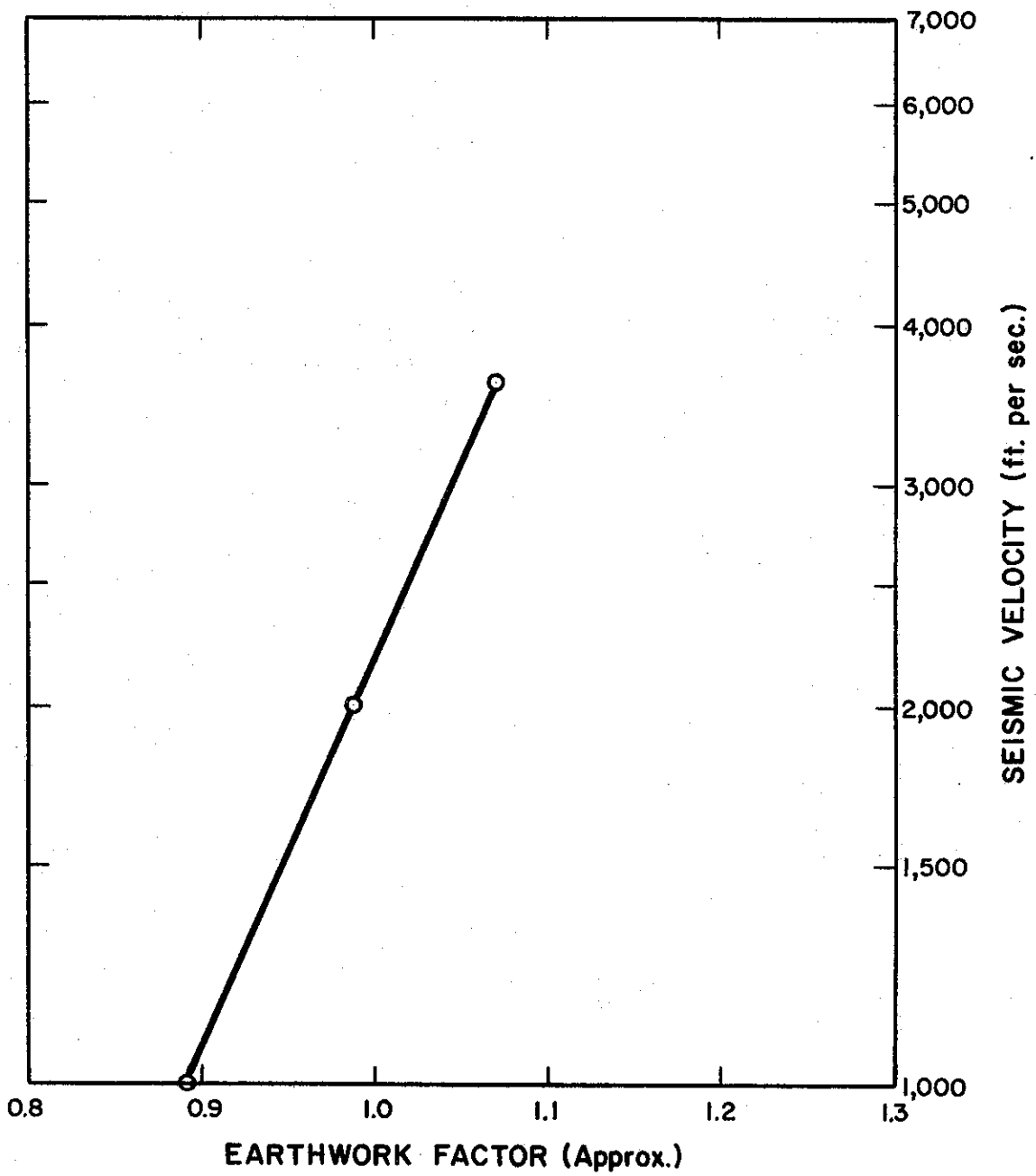

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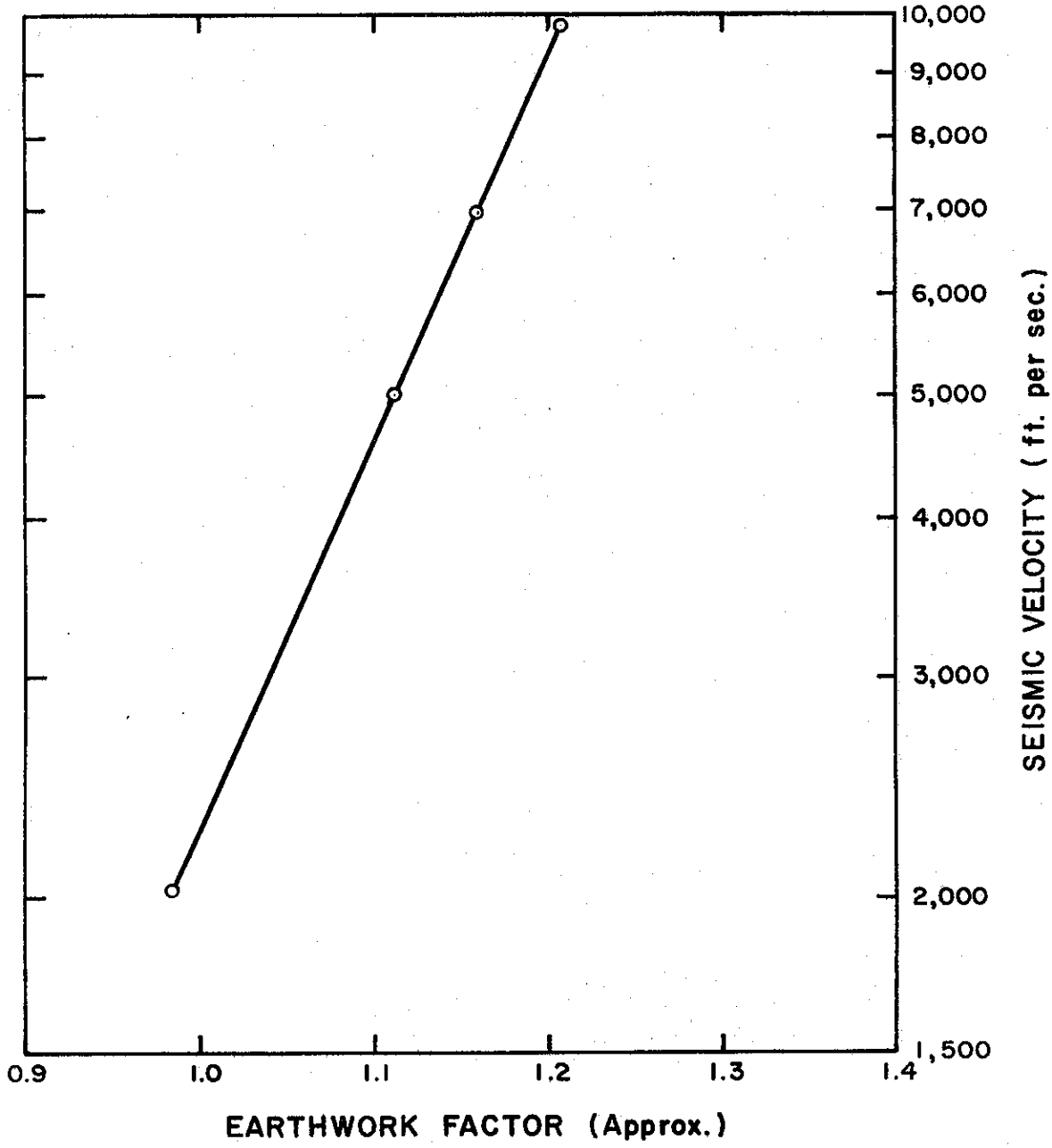
Figure 3

RELATIONSHIP BETWEEN SEISMIC VELOCITIES AND EARTHWORK FACTORS FOR METASEDIMENTARY ROCK



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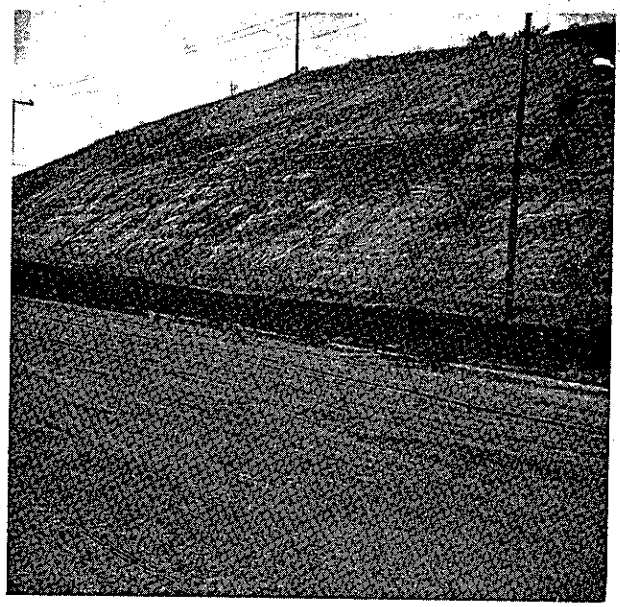
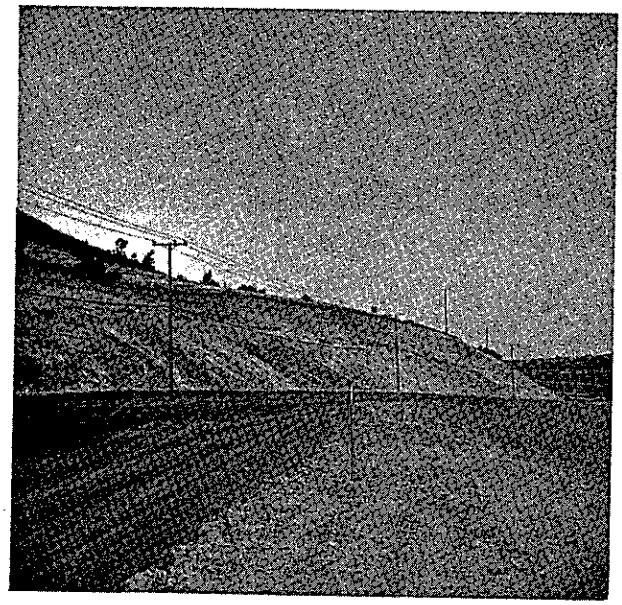


Sta. 301 Santa Ana Canyon



Sta. 312 Santa Ana Canyon

Plate 1.

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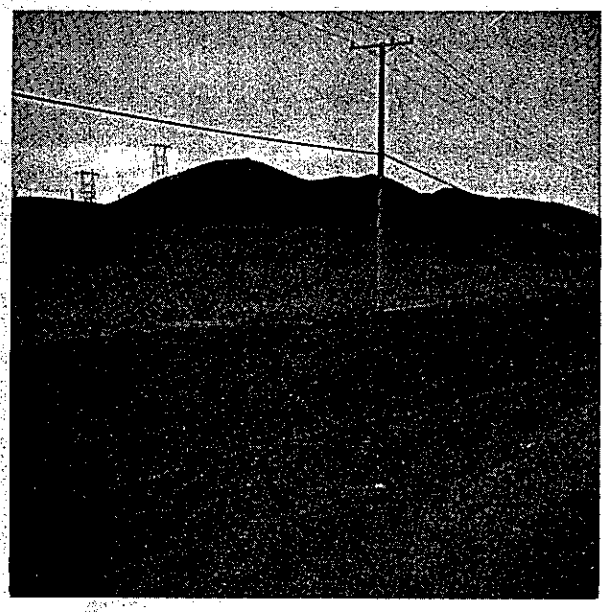
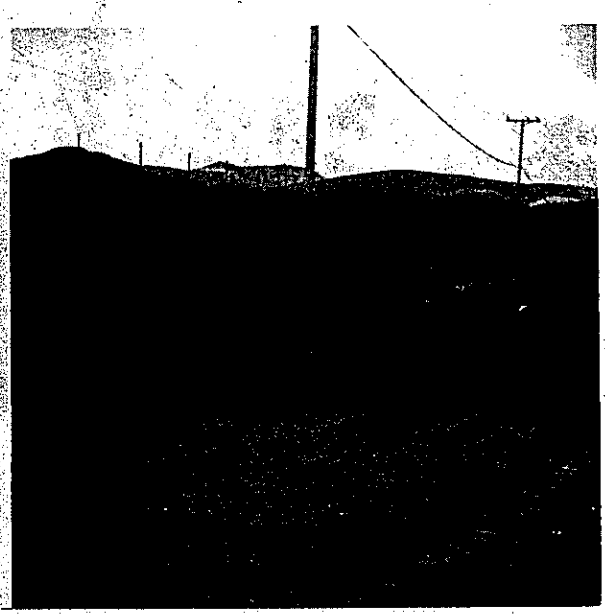


Sta. 327 Santa Ana Canyon



Sta. 361 Santa Ana Canyon

Plate 2.

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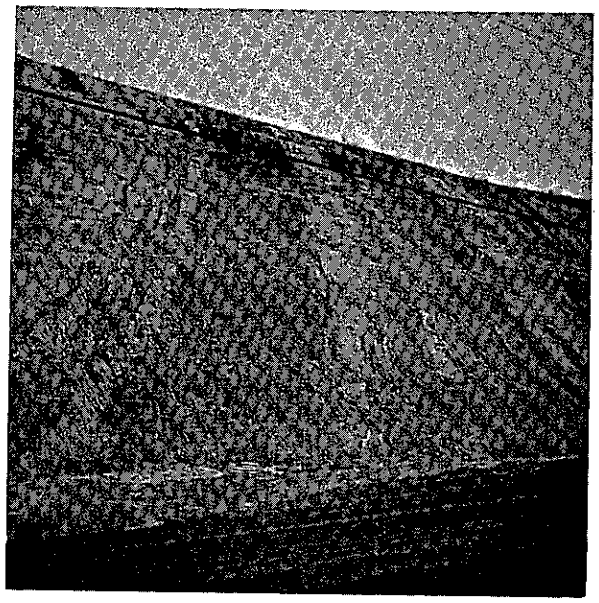
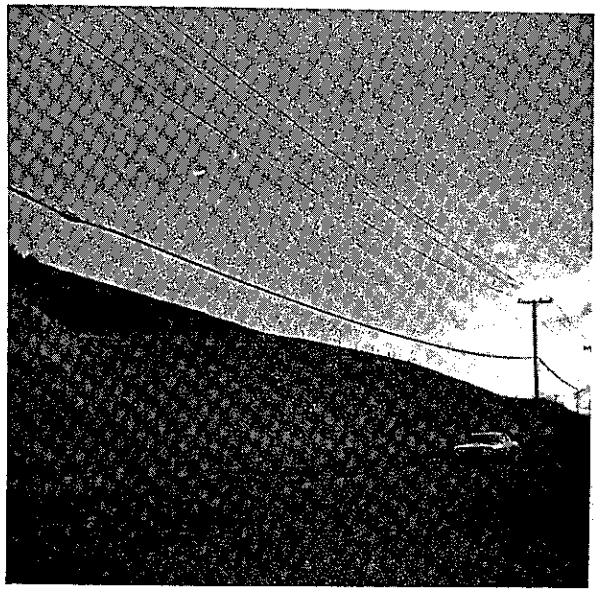


Sta. 370 Santa Ana Canyon



Sta. 391 Santa Ana Canyon

Plate 3.

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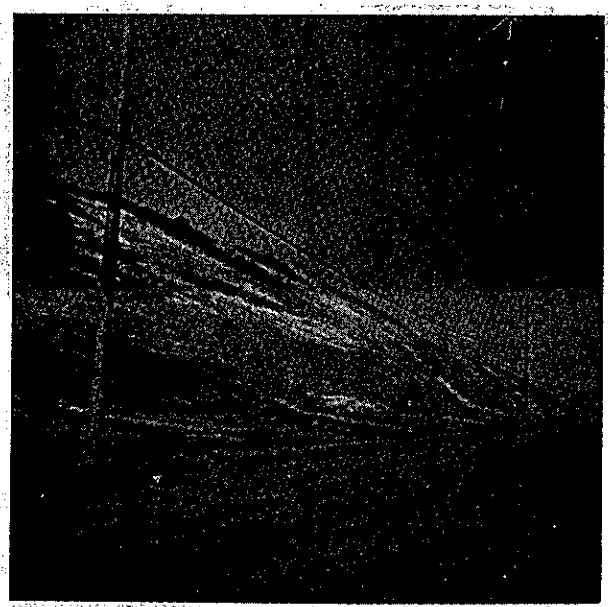
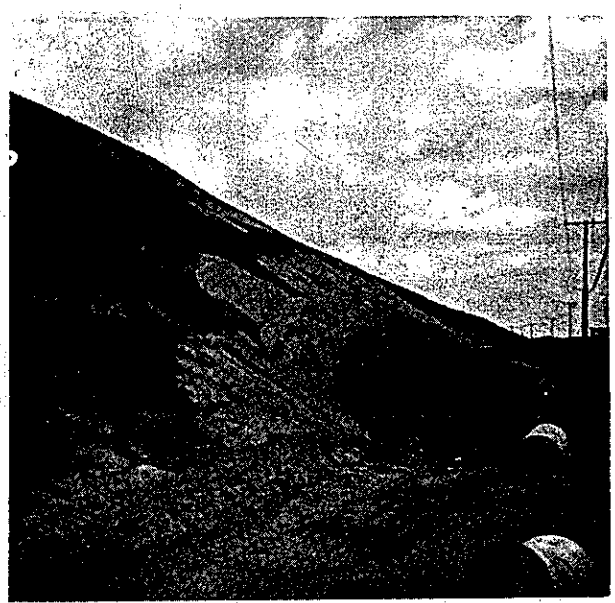


Sta. 393 Santa Ana Canyon



Sta. 394 Santa Ana Canyon

Plate 4.

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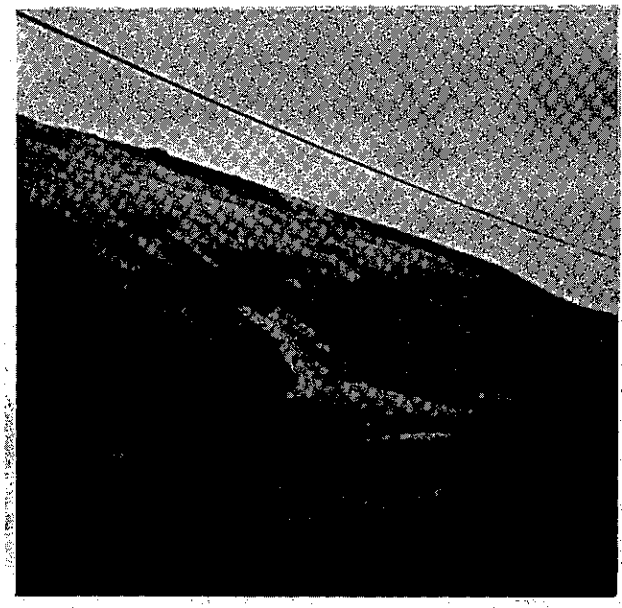
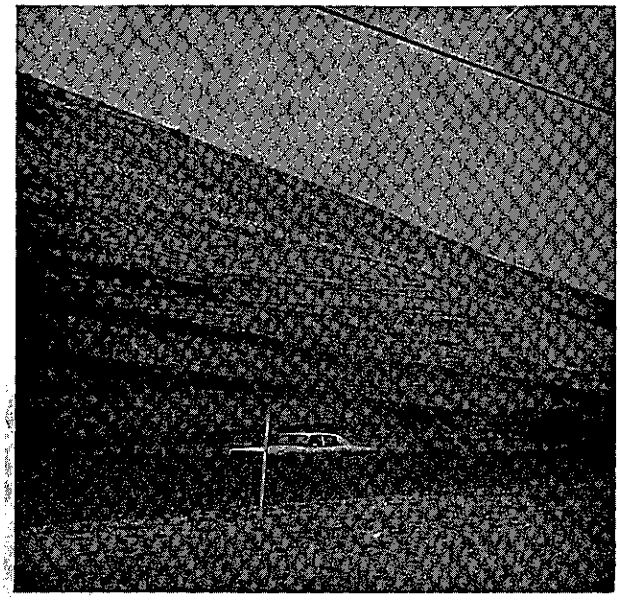


Sta. 400 Santa Ana Canyon



Sta. 402 Santa Ana Canyon

Plate 5.

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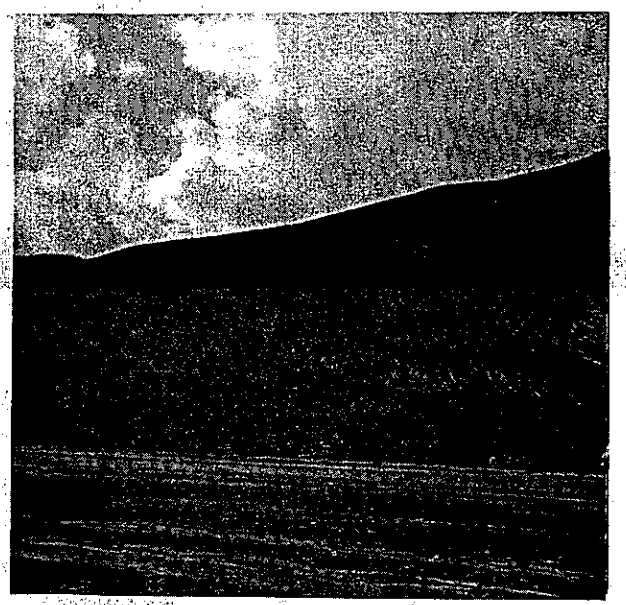
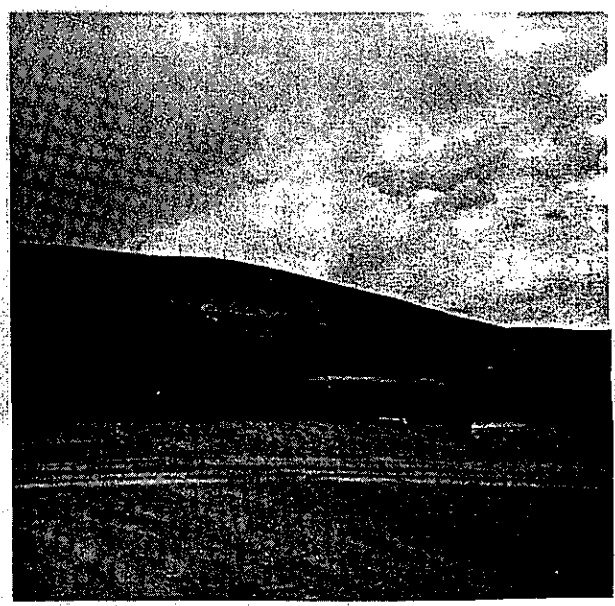


Sta. 405 Santa Ana Canyon



Sta. 447 Santa Ana Canyon

Plate 6.

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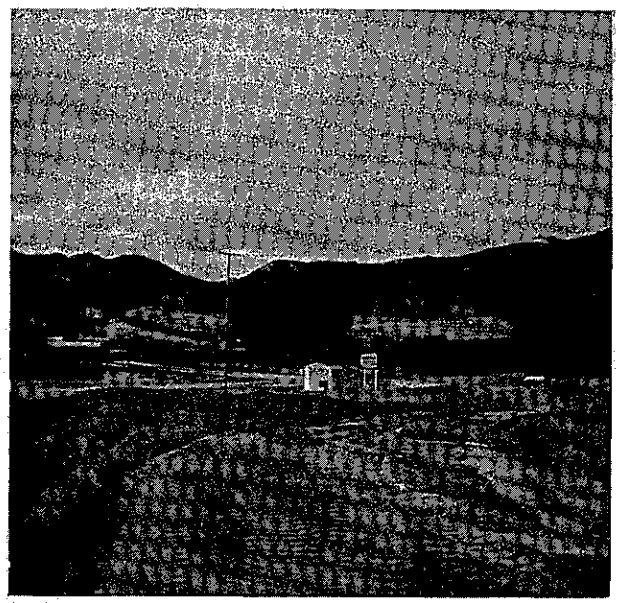
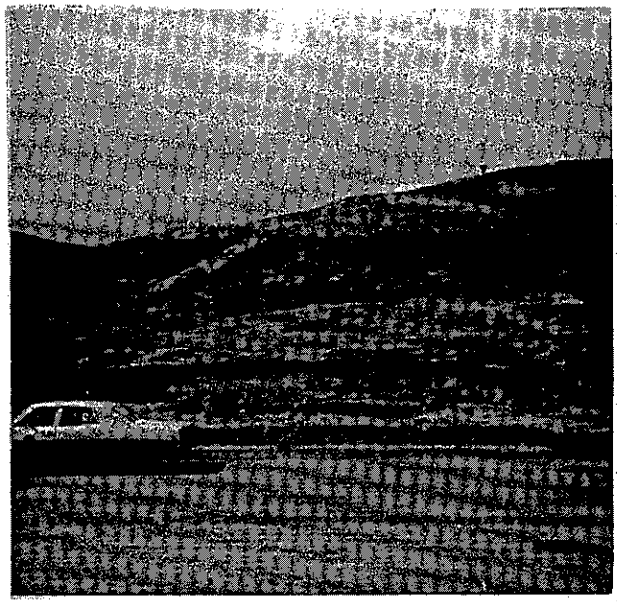


Sta. 452 Santa Ana Canyon



Sta. 519 E.B. Freeway

Plate 7.

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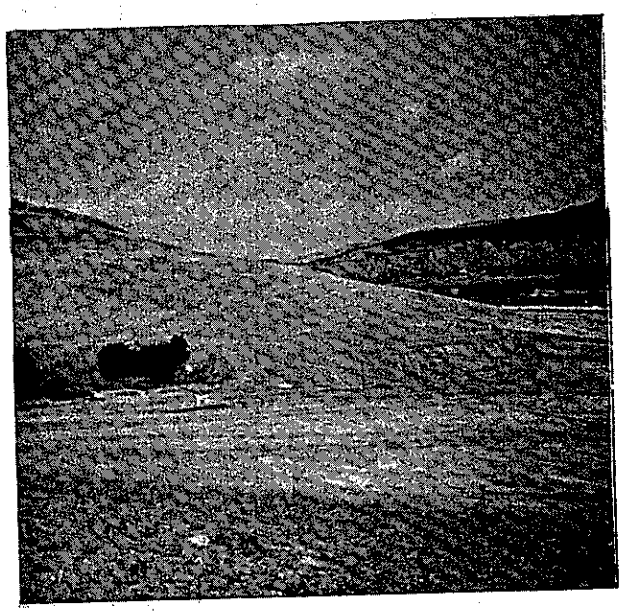

Looking back across Coal Canyon

Top of Contoured Area
East of Coal Canyon

Plate 8.

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