CRUSHED SANDSTONE FROM EAST TEXAS STONE COMPANY'S BLUE MOUNTAIN PIT, FREESTONE COUNTY, TEXAS

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Geologist II

TP-11-70-MR
July 1970

TEXAS HIGHWAY DEPARTMENT

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PREFACE

This report is the result of quarry, jobsite, and laboratory examinations of a coarse aggregate material which has been widely used in concrete structures and bituminous mixtures on Texas Highway Department projects in the eastern part of the State.

CONTENTS

SUBJECT

The evaluation of a widely used coarse aggregate material based upon observations of the physical and chemical effects of destructive influences on the organic and inorganic components, coupled with examinations of the deleterious effects of these components when the aggregate is used in concrete structures, coverstone, and paving materials, is the subject of this study.

PURPOSE

The purpose of this report is to illustrate by examinations of highway structures and paving surfaces, in addition to regular pit-run material, that extensive concentrations of deleterious materials—namely, lignite and iron pyrite—are present in a crushed sandstone aggregate produced in Freestone County and widely used in East Texas highway projects.

SUMMARY AND CONCLUSIONS

Deleterious components of a coarse sandstone aggregate being quarried at East Texas Stone Company's Blue Mountain pit in Freestone County have been examined petrographically, chemically, and physically. In addition, their physical and aesthetic effects on Texas Highway Department projects have been noted.

Quarry-site studies indicate that substantial amounts of lignite and pyrite occur throughout the deposit. Petrographic analysis shows that the deposit is basically a fine-grained calcareous quartzitic sandstone. Its gritty texture is due to grain shape and character of cementing agent. Chemical data compliments the petrology as to mineral composition. Results of physical tests suggest that variation in wear and soundness values are brought about by degrees of lignite content and particle lamination.

Riprap, concrete structures, and asphaltic surface treatments reflect the deleterious effects of aggregate containing lignite and iron pyrite. Stains and popouts caused by pyrite alteration were noted on concrete structures, which had been in place from less than one year to about 15 years and contained aggregate from the Blue Mountain pit. The degree of staining and popout frequency appeared to be directly related to the age of the structure; the older the structure, the greater the deterioration and number of popouts. Lignite popouts reflected a high degree of physical changes brought about by particle expansion probably caused by wet-dry cycles.

RECOMMENDATIONS

1. There should be a thorough and extended program of restrictive quarrying at the Blue Mountain Pit to control the amounts of lignite and pyrite in the processed material destined for Texas highway projects.

2. The continued use of the crushed stone aggregate for surface courses (Items 302, 304, 320, etc.), asphaltic mixes (Items 340, 350, etc.) will be permitted as long as quality control of the material is maintained.

3. The material should be excluded for use as stone protection unless custom selected by a qualified inspector to assure minimum amounts of lignite and/or pyrite.

DISCUSSION

A. Source location and geologic setting:

The materials source examined for this study is located about 20 miles east of Fairfield and 3 miles north of US 84 in eastern Freestone County (see Figure 1). The open-pit quarry operation, presently conducted by East Texas Stone Company, is situated on the northern perimeter of the Butler Salt Dome and along the southwestern edge of the Trinity River floodplain. The local topography is characterized by marsh areas adjacent to near-by Blue Lake, formed from the damming of Gaston Branch, and having frequent outcrops of slight to steeply dipping bedrock. One such feature over the dome area is called Blue Mountain.

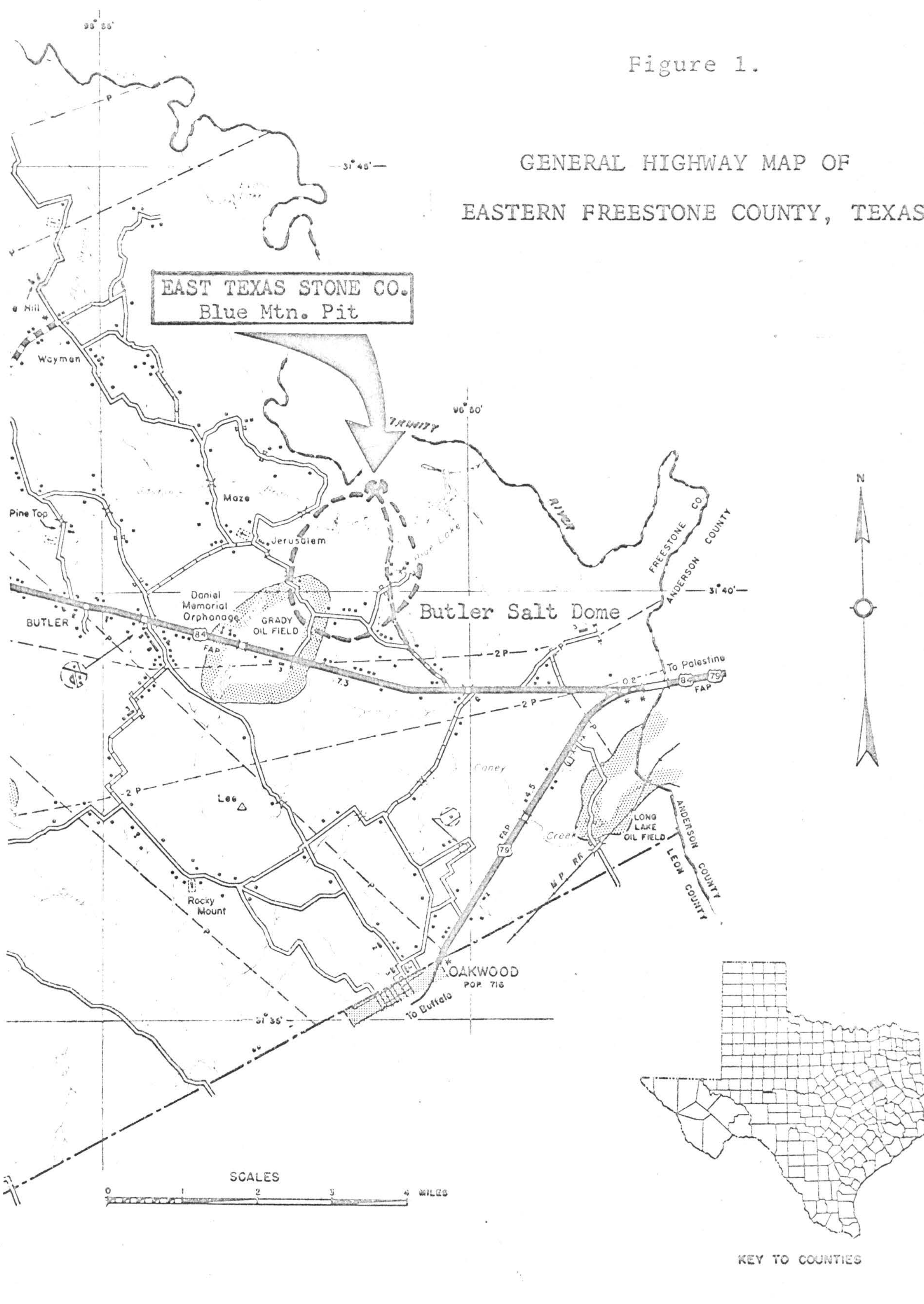
Although the depth to the salt is just over 300 feet, salines and solution sinks are present in and around the dome area. As the salt forced its way toward the surface, overlying sedimentary rocks were influenced causing a disturbed area some 3 miles in diameter. The oldest sediments exposed at the surface are upper Cretaceous age and are located toward the center of the dome. The surrounding rock formations, as well as those on the outer edge of the dome, are Eocene age. The quarry production is from the Carrizo sandstone formation, Wilcox group, middle Eocene.

Other domal structures (about 30 or so) related to salt intrusions are concentrated along the axis of the East Texas Embayment in ten near-by Counties. Nine such salt domes are situated in Anderson and Leon Counties only a few miles from the Butler Dome.

Figure 1.

GENERAL HIGHWAY MAP OF

EASTERN FREESTONE COUNTY, TEXAS



B. Present quarry operations:

Essentially all of the mining activities at the Blue Mountain pit have taken place since East Texas Stone Company began its operation about 1954. Quarrying and processing of the crushed stone involves a series of steps, namely, stripping overburden, blasting, excavation and loading, hauling, crushing, conveying, screening and washing, and finally stockpiling.

Figure 2 shows a portion of the 15-20 acre pit including stripping of the overburden (25-30 feet thick) and two working-face levels; one about 60 feet, the lower about 15 feet. In addition to illustrating excavation and loading, Figure 3 shows the use of a "headache ball" to reduce oversize boulders.

From the working face Euclid dump trucks take the stone to a 42" x 48" jaw crusher for primary reduction.. A scalping screen removes the plus 10" material for riprap; the smaller size is handled by a secondary 30" x 42" jaw crusher. Other auxiliary roll and cone crushers are used to further process the material in preparing it for final screening and washing before stockpiling. Figures 4 and 5 show the jaw crushers and some of the screening equipment.

For better than 15 years production going to State highway projects has included aggregate for surface treatments, hot-mix asphaltic concrete, riprap, and portland cement concrete.

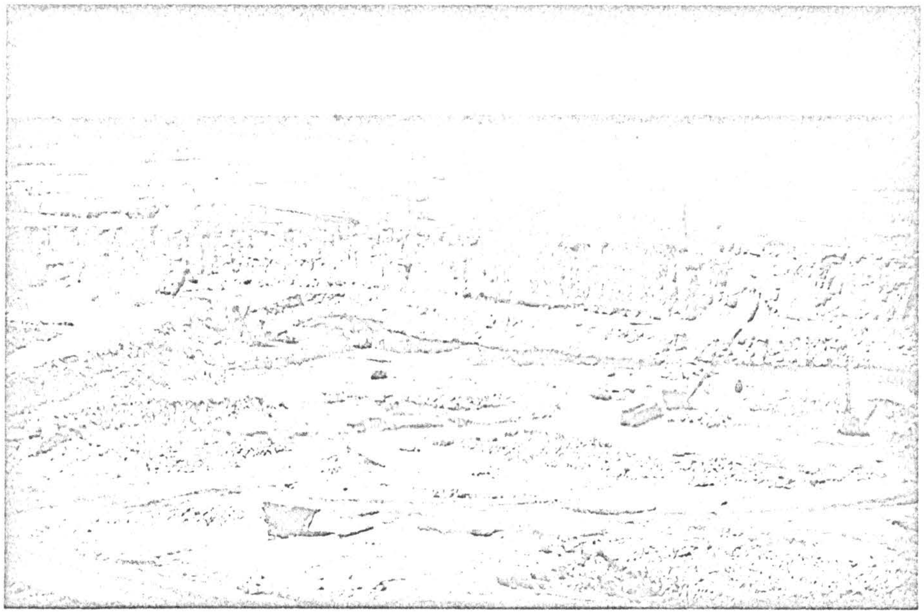


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Figure 2. Looking north at a portion of open-pit quarry.

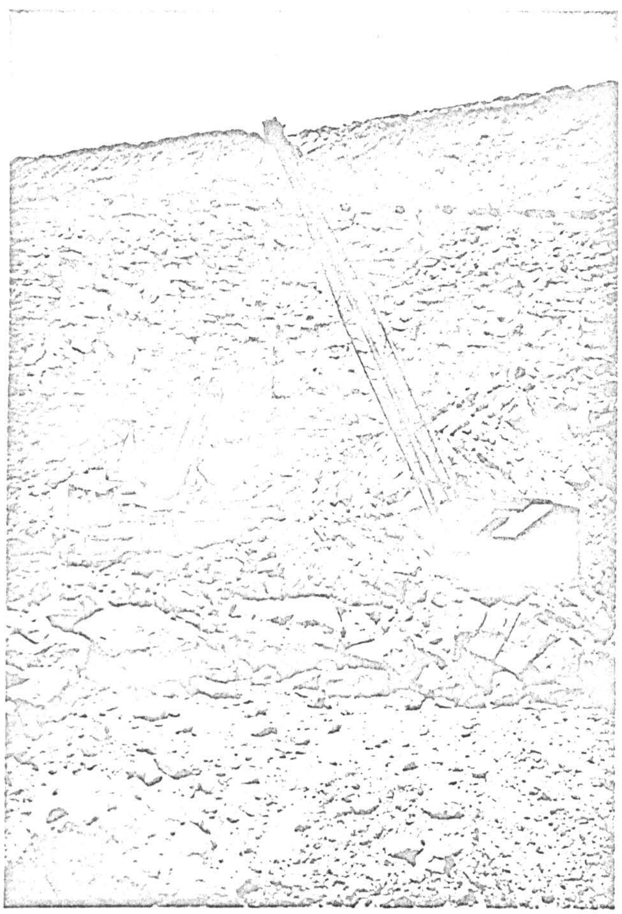

Figure 3. View of excavation and loading operations with overburden visible above indicated contact.

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Figure 4. Primary and secondary jaw crushers.

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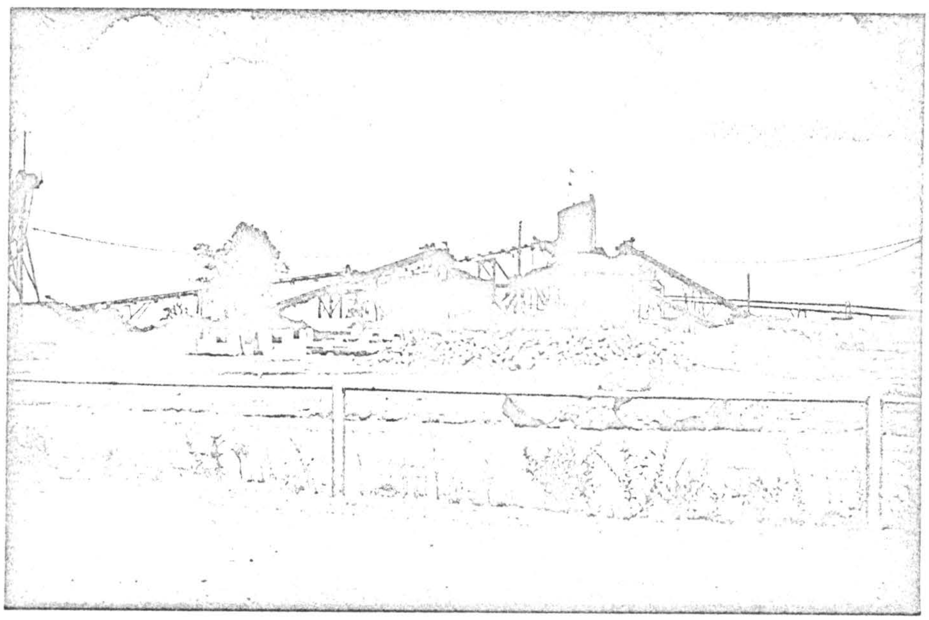

Figure 5. View of some of the screening equipment.

C. Petrographic studies:

Both reflected and transmitted (plane and polarized) light microscopy were employed for this study. The samples utilized were taken from the quarry face, stockpiles, and material submitted to the Materials and Tests Division Laboratories for routine testing.

In general, the Carrizo sandstone quarried at the Blue Mountain pit consists of a fine-grained, subrounded to subangular crystalline quartz (SiO_2) sand which has been cemented with calcite ($CaCO_3$). Other components include milky amorphous quartz (chalcedony), minor amounts of dark colored amphiboles, mica and clays, with varying amounts of iron pyrite (FeS_2), fossil plant remains and lignite (brown coal).

The shape of the quartz grains is mainly subrounded, as seen in Figure 6, but angular grains are abundant. The latter form possibly resulting from fracturing

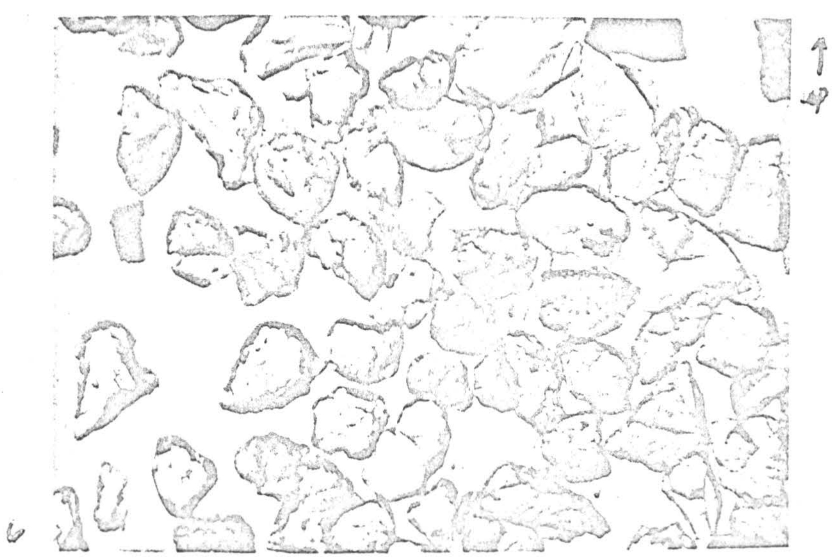

Figure 6. Sand grains with the cement removed. (52X)

during salt dome activity. The texture is gritty and sugary to the feel which is especially noticeable in specimens deficent in cementing material.

Figure 6 illustrates the relatively uniform shape and size of the quartz grains. The cementing material was removed with a weak solution of hydrochloric (HCl) acid.

Iron pyrite can be found as rounded nodules (varying in sizes up to about 3 inches), irregular veins replacing carbonized plant remains, or as discrete crystals. Figure 7 shows a hand specimen (taken from pit-run material prior to crushing) containing bands of lignite, which form bedding planes, and plainly visible pyrite nodules.

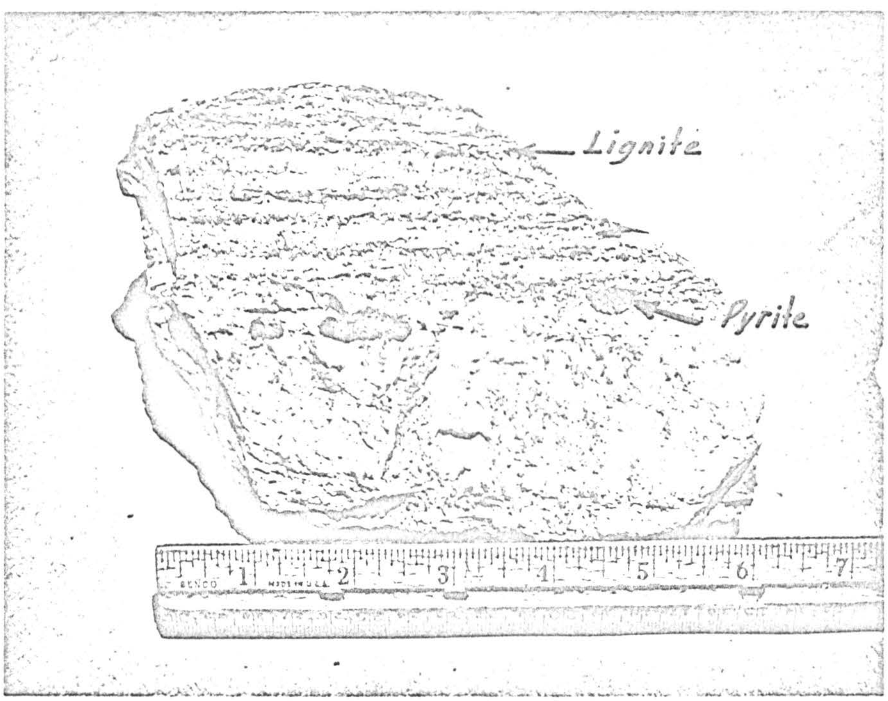

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Figure 7. Hand specimen containing lignite and pyrite.

Upon microscopic examination of the lignite bands, pyrite is noted in association with the plant tissue as seen in Figure 8. A polished section through one of the nodules reveals that the pyrite has replaced the calcite cementing agent. In Figure 9, quartz grains can be seen incorporated by the pyrite.

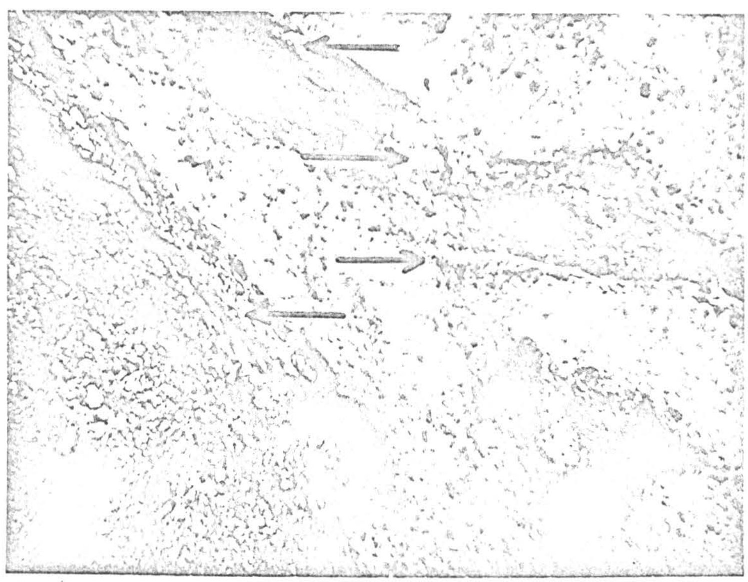

Figure 8. Lignite with veins of pyrite as indicated. Light area is quartz grains cemented with calcite. (7.5X)

Figure 9. Polished section of a pyrite nodule with included quartz grains. Dark area is quartz cemented with calcite. (23X)

D. Laboratory results:

In addition to several chemical and physical tests which have been conducted, future tests (freeze-thaw and others) are planned to aid in evaluating this material source. During earlier testing of the Blue Mountain pit material by D-9 Laboratories, the following chemical analysis was reported:

	% by Wt.
Loss by Ignition	16.49
SiO_2	61.52
CaO	21.00
$CaCO_3$ (from CaO)	37.48
Other oxides	0.57

Tests performed during the past two years indicate that the sandstone has a weight per cubic foot averaging about 92 lbs. Los Angeles abrasion tests for the same period are as follows:

Type of Wear and Percentage Loss

"A"	"C"	"D"
42.90	29.30	34.20
43.62	14.97	30.20
34.20	32.20	
28.20		

Soundness loss by $MgSO_4$ on the material varies greatly depending on the amount and size of the lignite fragments, the extent of particle lamination, and degree of induration by the cementing agent. During the past two years, tests show that percentage loss by $MgSO_4$ for submitted samples have ranged up to 7.7%. Recent investigations indicate that on fresh (pit-run) samples, lignite has the greatest influence on the relative soundness for a particle (as illustrated

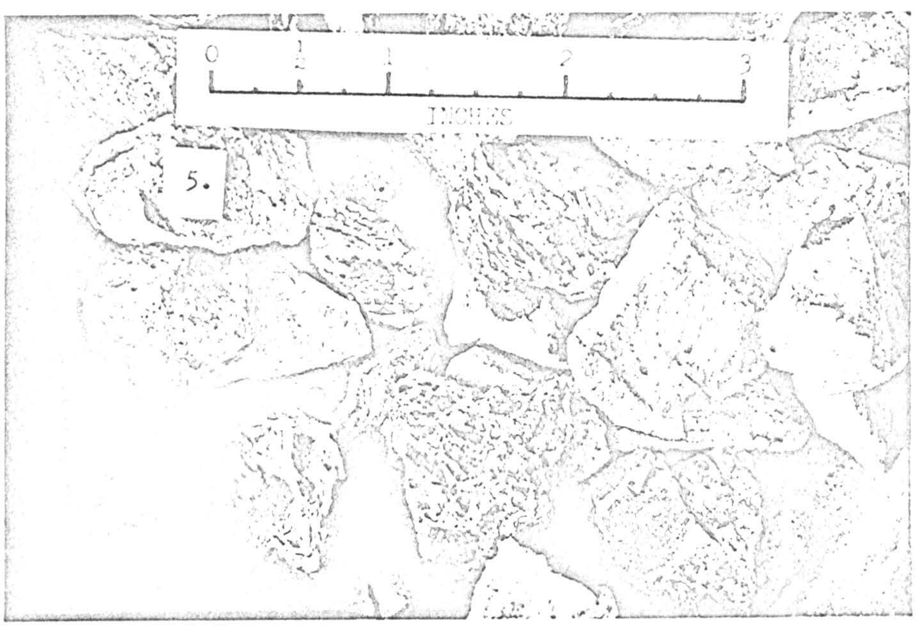

Figure 10. Sample prior to testing.

in Figures 10, 11, and 12) whereas, upon periods of exposure, pyrite has just as much, and possibly more, influence on the material's soundness.

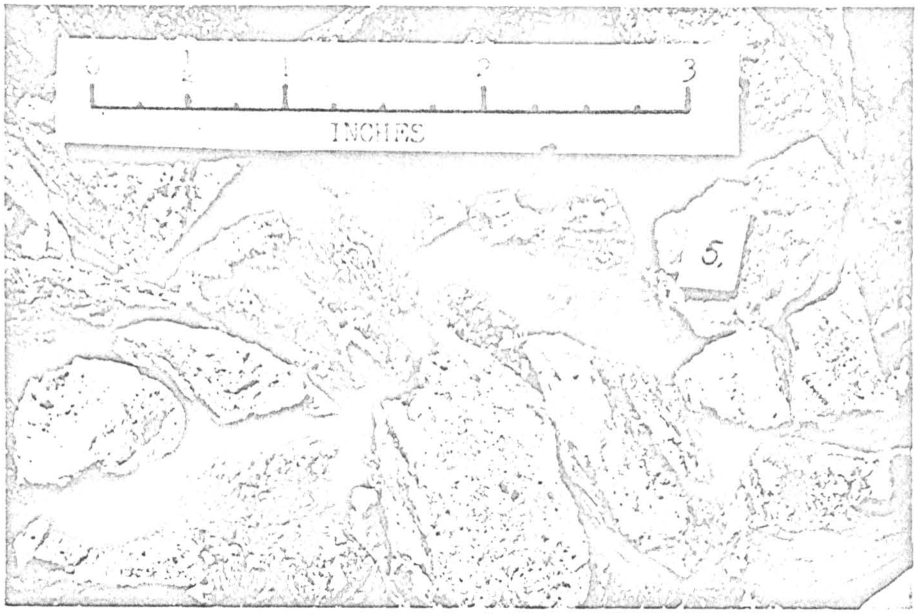

Figure 11. Sample after five cycles of $MgSO_4$.

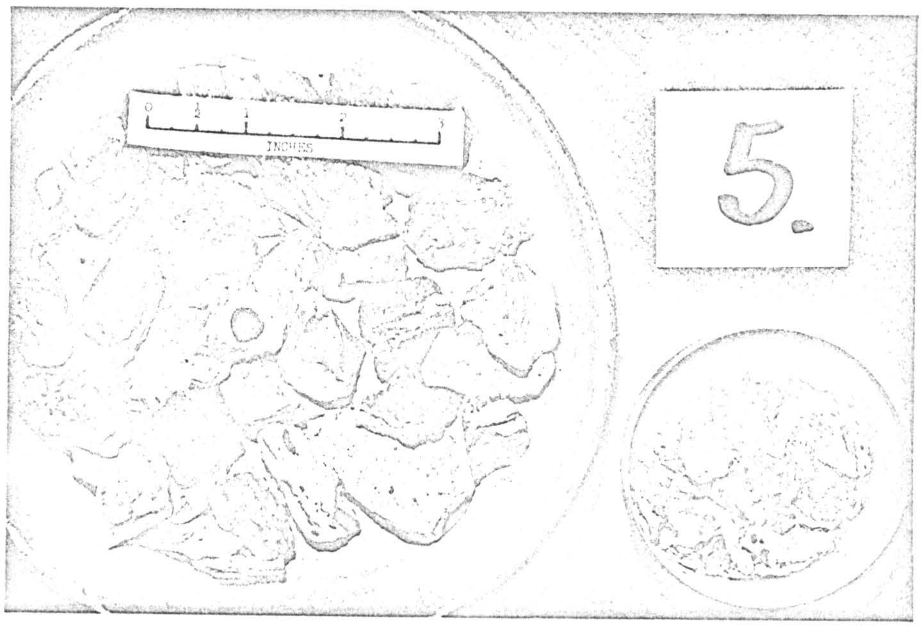

Figure 12. Sample on left retained on screen; on right that amount lost (15%).

E. Field observations:

Careful observations of the quarry face and excavated material at the Blue Mountain pit point out that substantial amounts of lignite and iron pyrite occur throughout the deposit (Figures 13, 14, and 15).

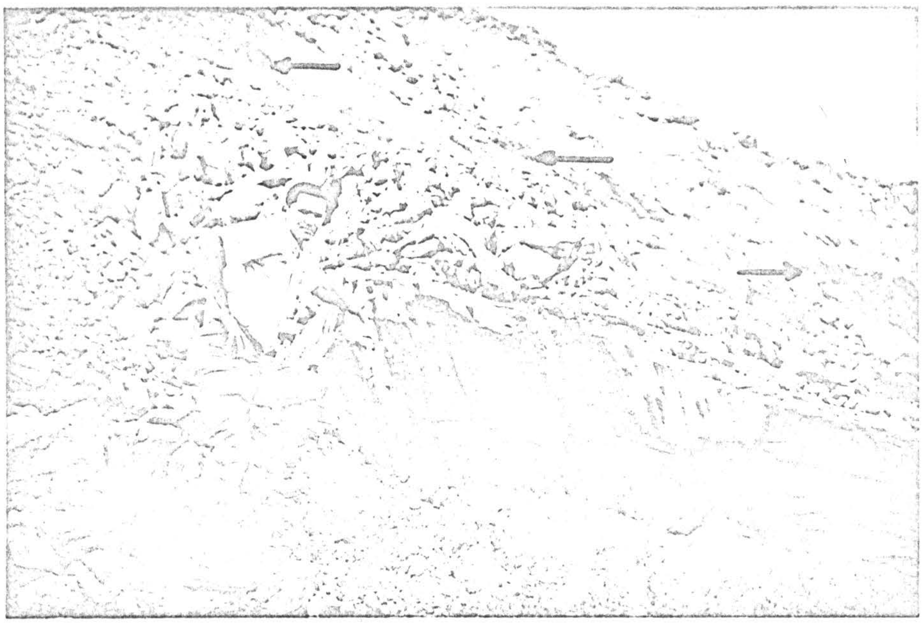

Figure 13. Pyrite stains and lignite seam within quarry.

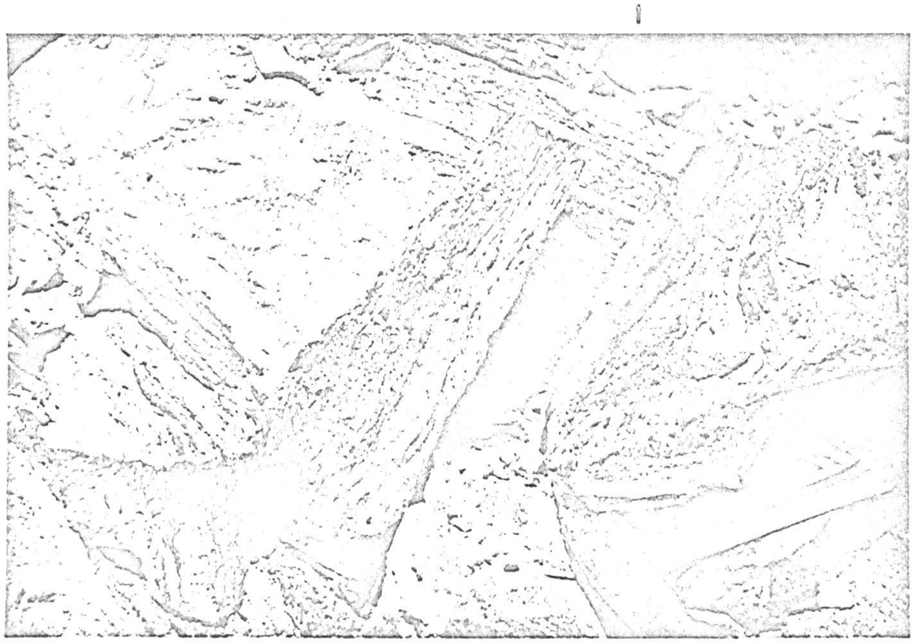

Figure 14. Lignite on bedding planes.

Figure 15. Boulder showing extensive uncemented "sugary" areas and scattered fossilized plant fragments and leaf imprints.

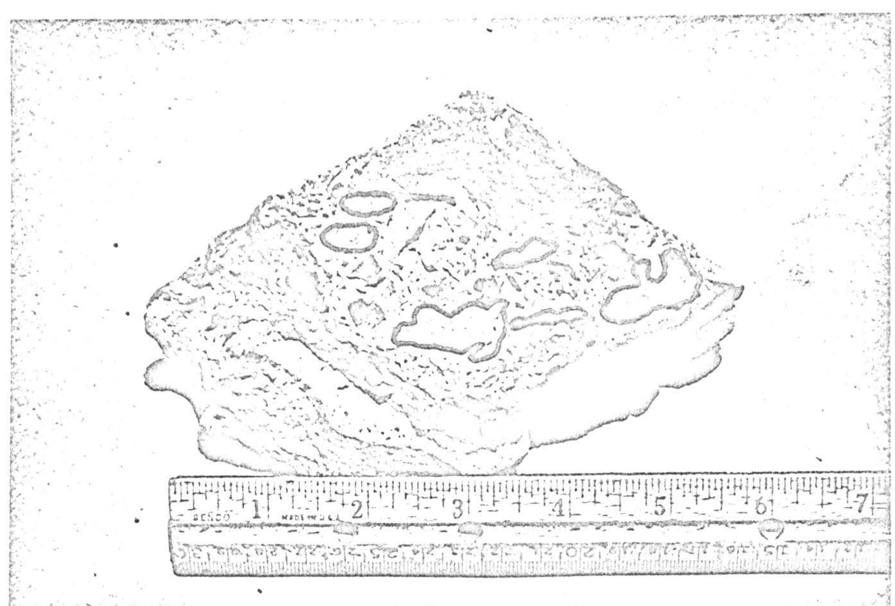

Figure 16. Hand specimen having irregular shaped pyrite nodules in association with lignite. Pyrite outlined.

Several emplacement sites have been studied for the deleterious effects of lignite and pyrite. In September 1968, riprap quarried from Blue Mountain pit and placed on SH 103 crossing Sam Rayburn Reservoir (southern Nacogdoches County) was examined. According to contract records, the material had been placed as shoulder protection in 1963-64, or roughly 4-5 years prior to this inspection. About 50% of the material was in advanced stages of deterioration either from exfoliation due to physical changes of the lignite or chemical decomposition from the weathering of the pyrite (Figures 17, 18, and 19). Recent examinations point out that the riprap along SH 64 at Lake Tyler is experiencing decomposition at about the same rate and degree.

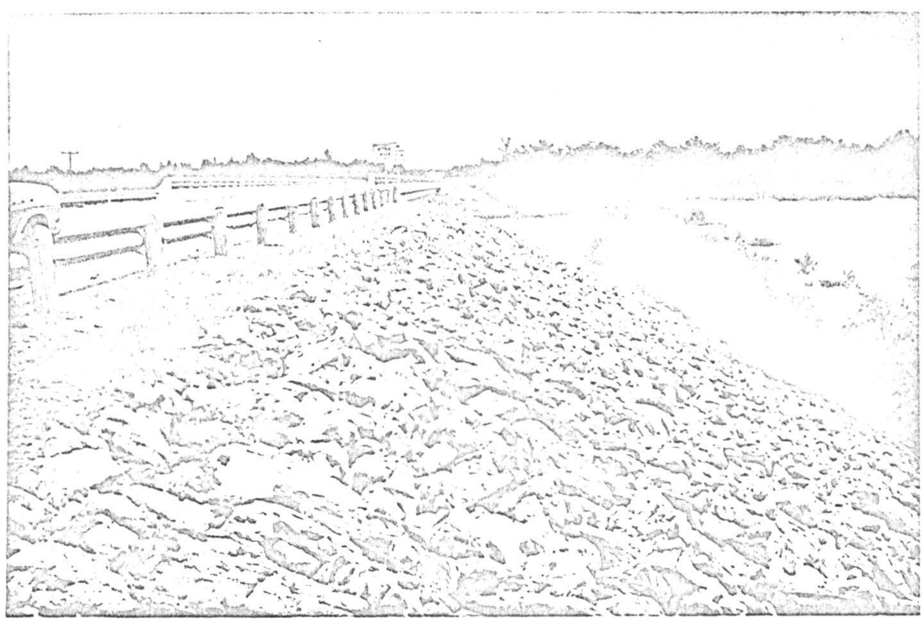

Figure 17. Riprap used as shoulder protection at Attayac Bayou.

Figure 18. Deterioration of riprap. Pyrite is indicated.

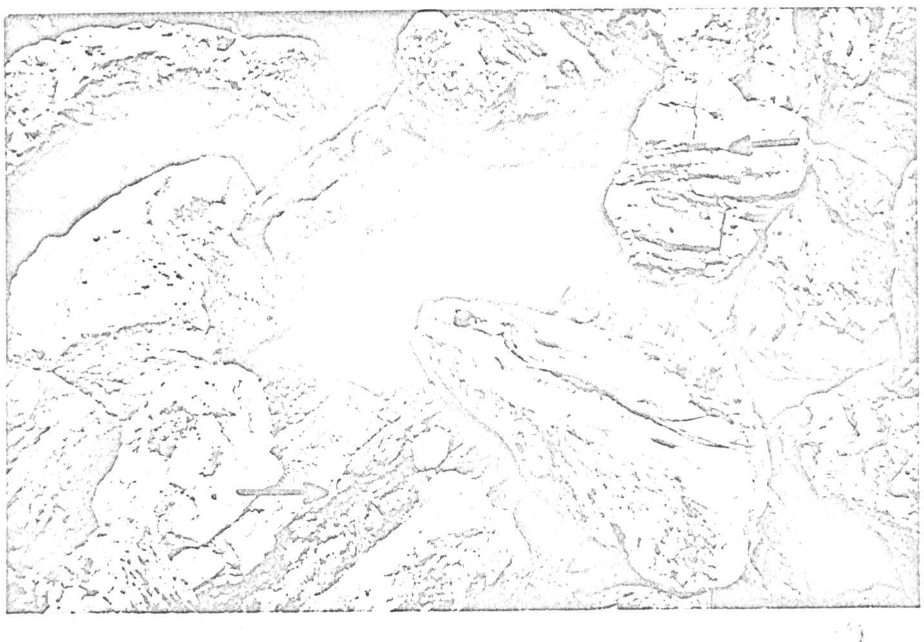

Figure 19. Deterioration by splitting and corrosion. Lignite seams are indicated.

Concrete bridges and accessory structures containing coarse aggregate from Blue Mountain pit have recently been examined for this report. Concrete structures placed from one to fifteen years were noted to have extensive staining and popouts resulting from the deleterious effects of lignite and pyrite. Typically, the extent ranged from only slight on those structures 1-2 years old to extreme on those over 8-10 years old. The following figures illustrate the effects these two reactive components have on concrete structures.

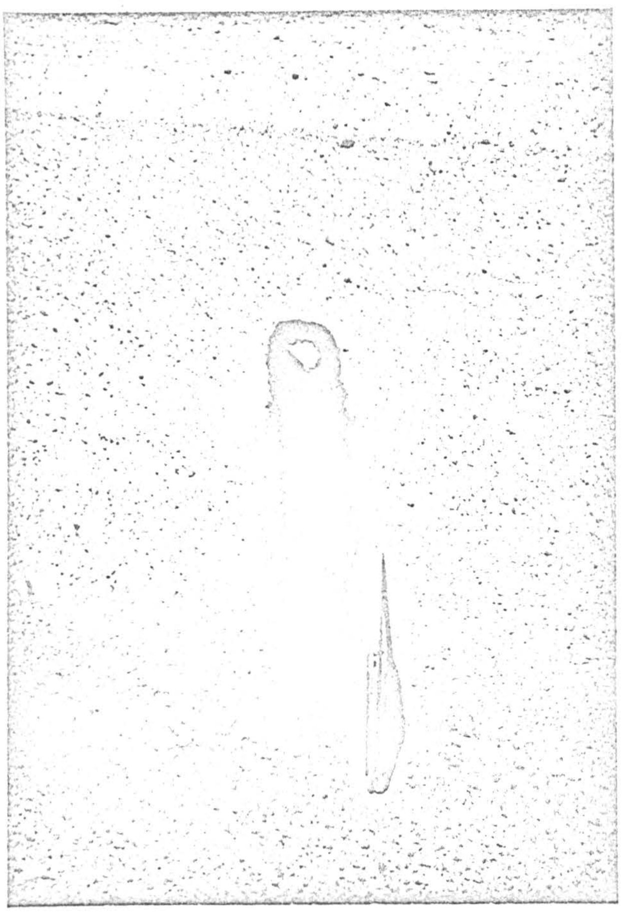

Figure 20. Typical cavity and stain caused by the chemical alteration of pyrite to limonite (rust).

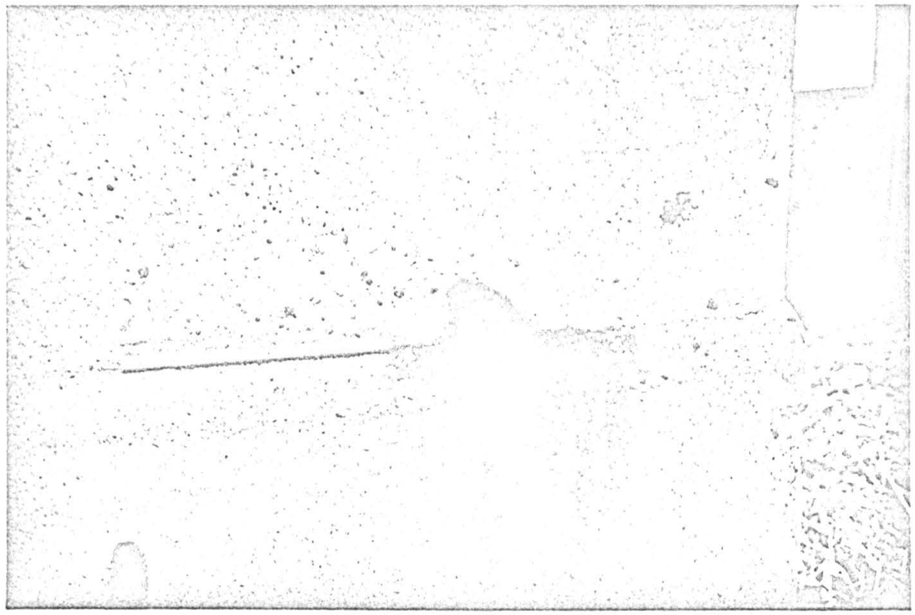

Figure 21. Pyrite stains and popouts.

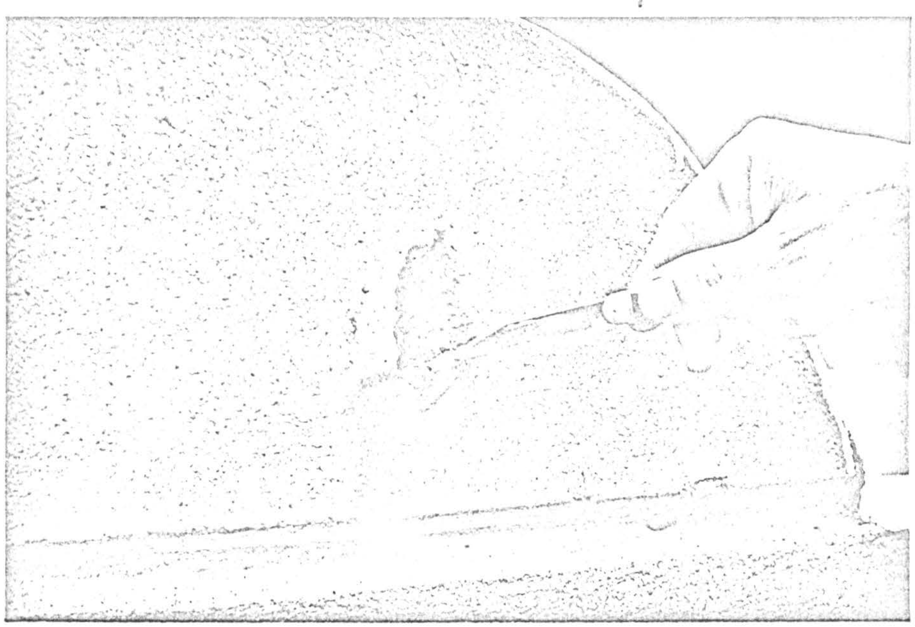

Figure 22. Pyrite popout.

Figure 23. Lignite and pyrite popout.

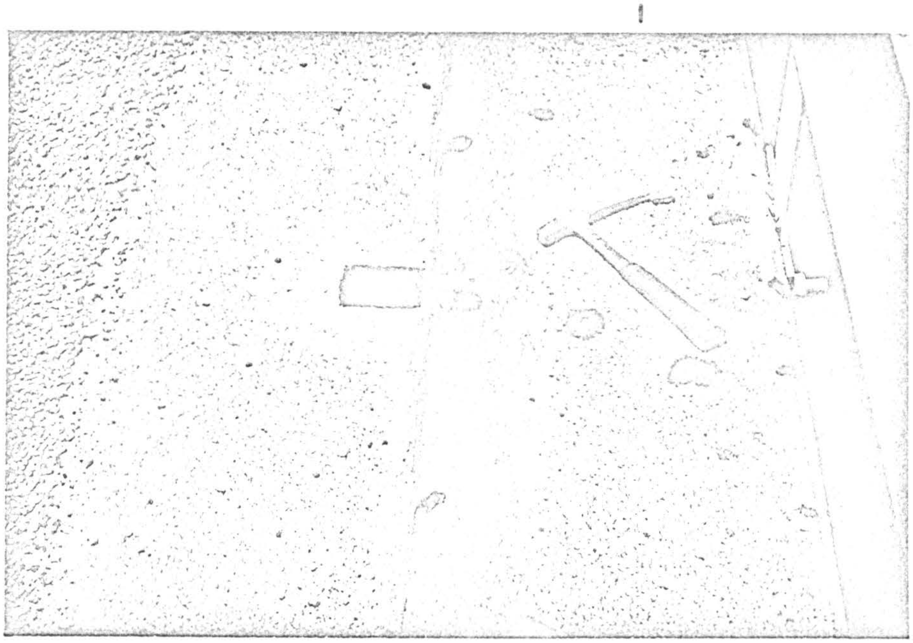

Figure 24. Pyrite popouts along bridge curbing.

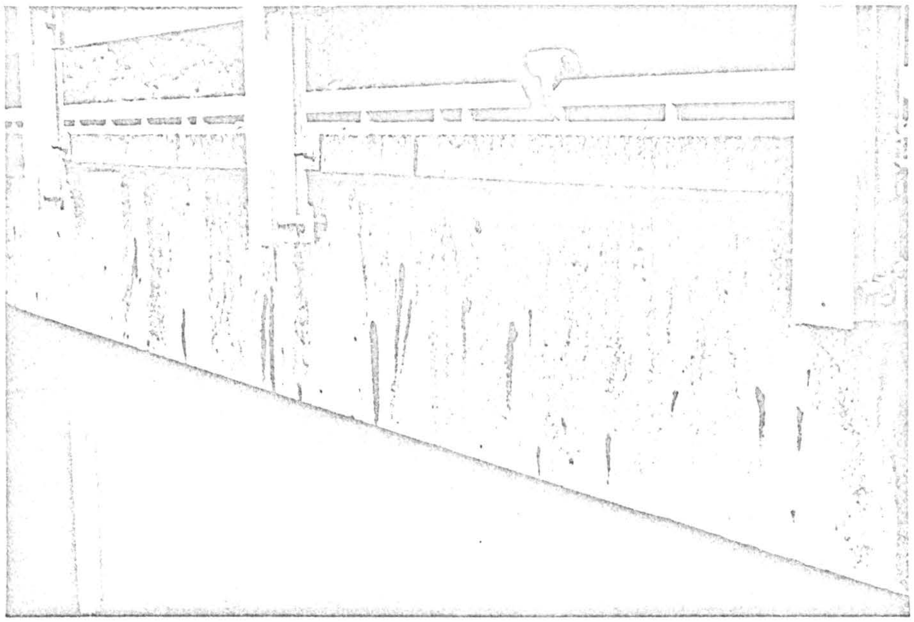

Figure 25. Popouts and staining on bridge side.

Figure 26. Extensive staining along bridge riprap.

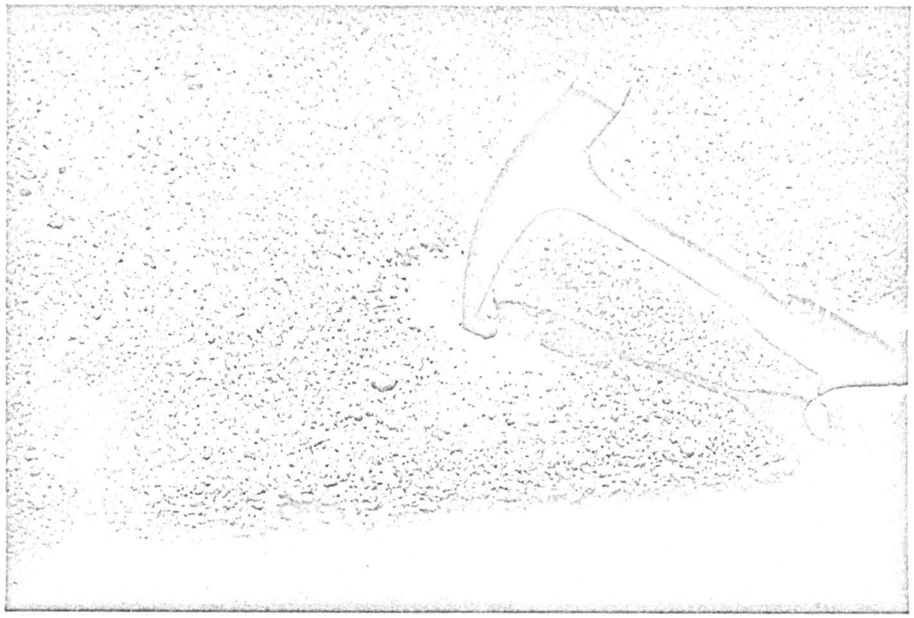

Figure 27. Close-up of stained area and corrosion of concrete.

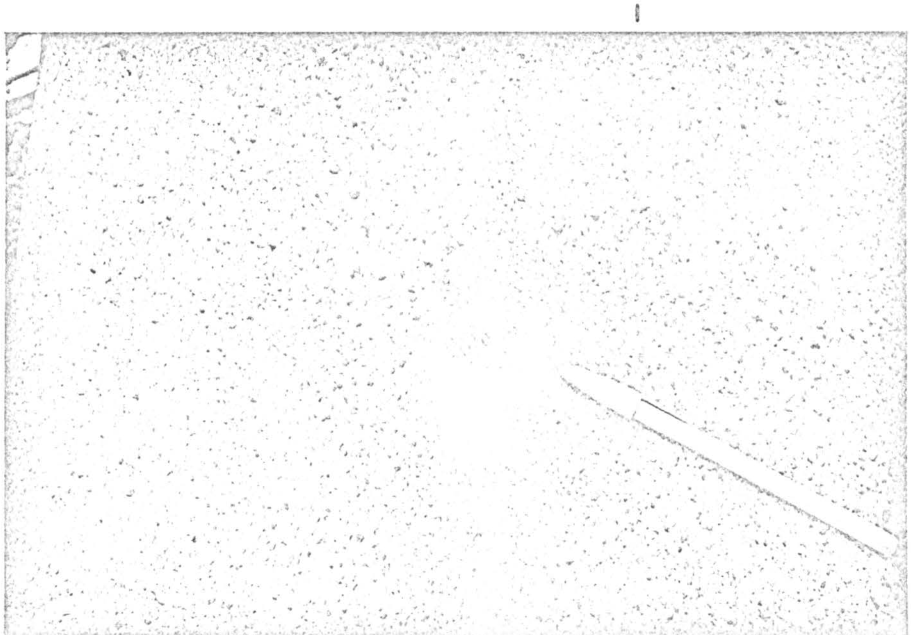

Figure 28. Lignite popout.

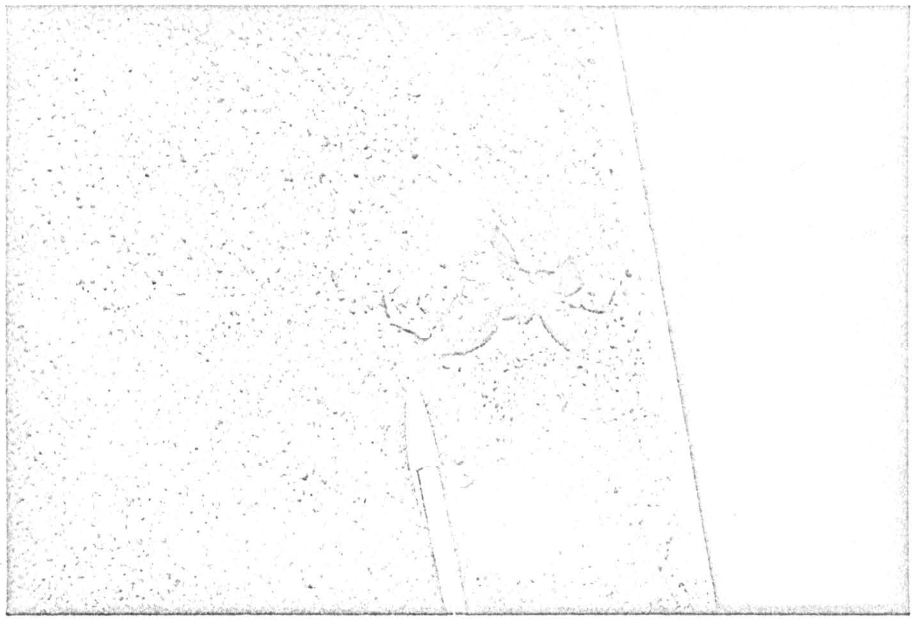

Figure 29. Lignite popout.

The following figures show the effects of lignite and pyrite on surface courses having the subject crushed sandstone as an aggregate.

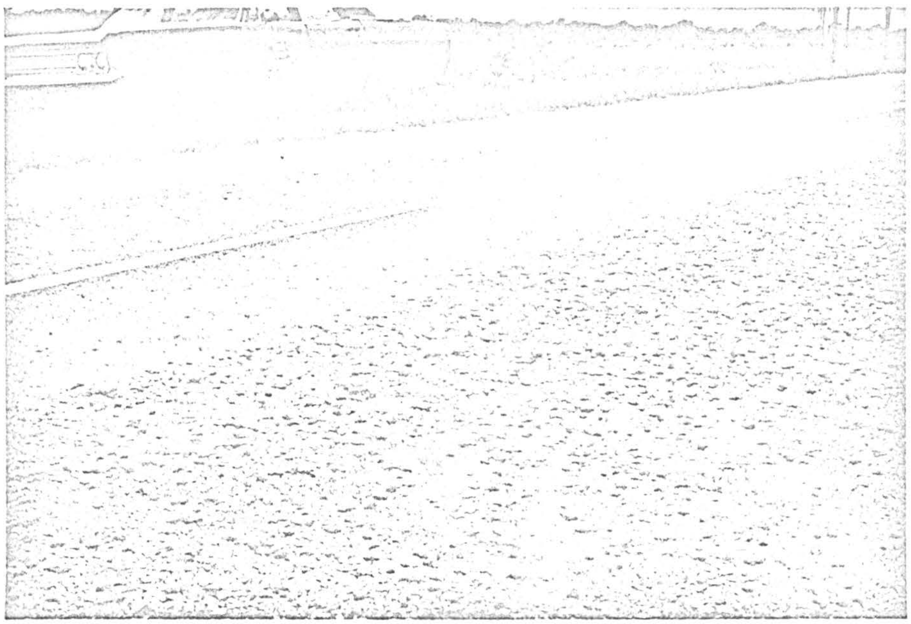

Figure 30. Low-angle view of surface having popouts.

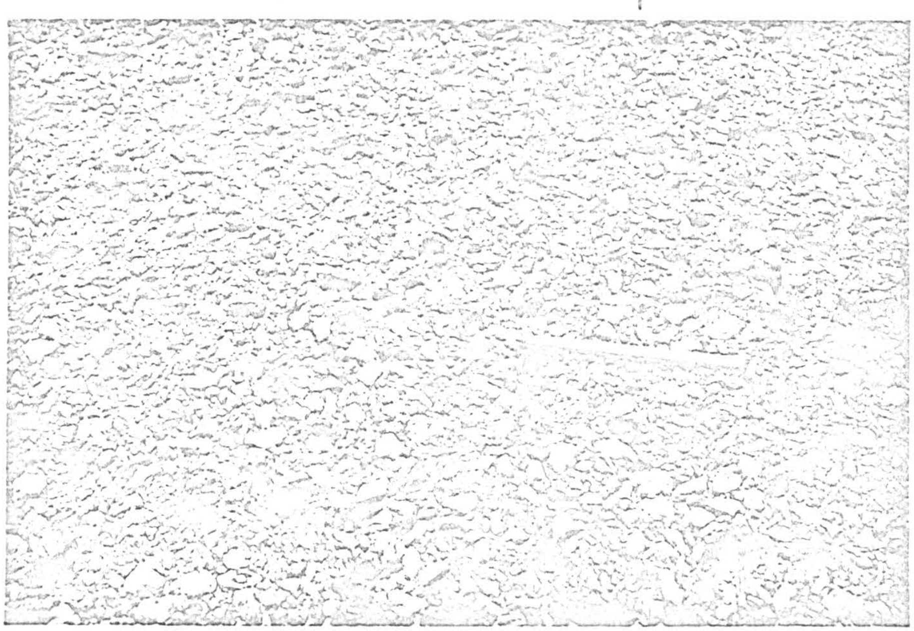

Figure 31. Close-up of surface showing popouts.

Figure 32. Pyrite stains on surface.

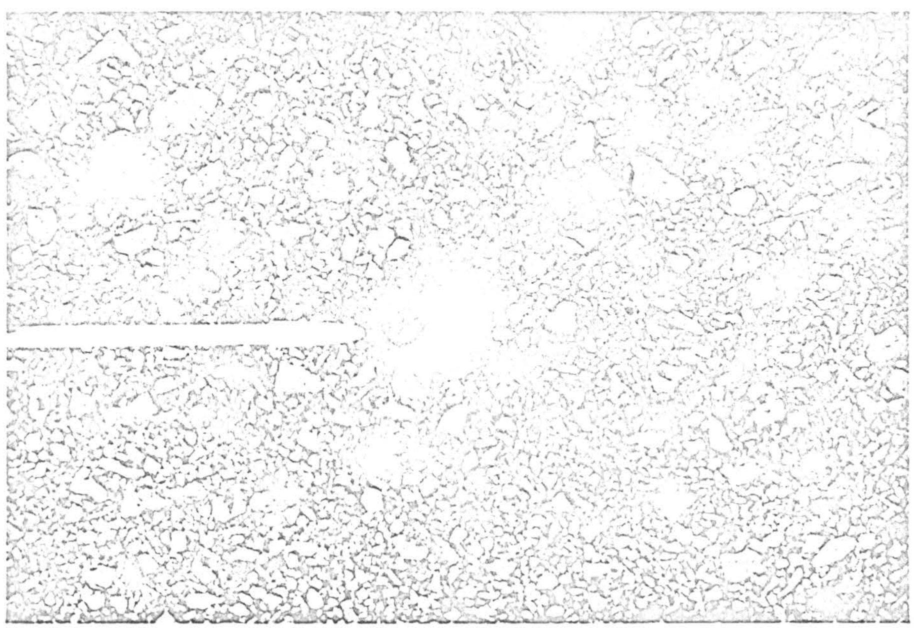

Figure 33. Close-up of pyrite staining and popout.

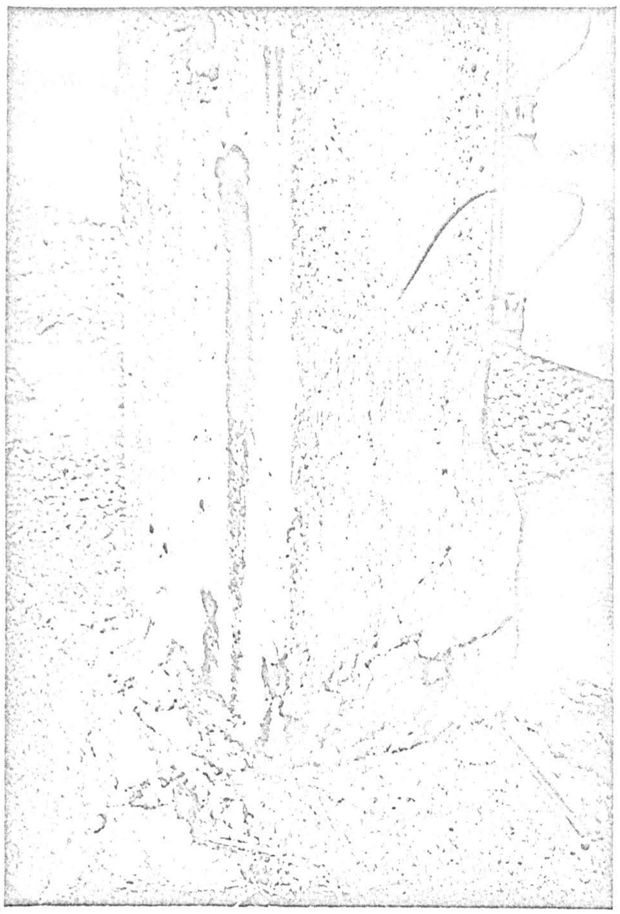

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Figure 34

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Figure 35

Close-up of guard-rail post on opposite sides of bridge.
Note cracking and exfoliation.

Figure 36. Bridge deck with initial stages of pyrite-popout developing.

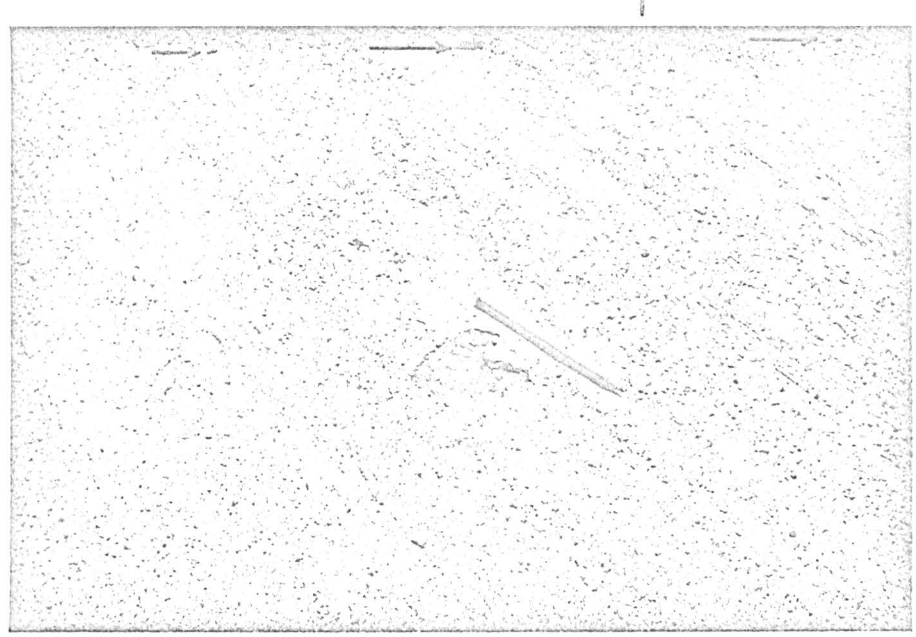

Figure 37. Bridge deck with more advanced stage of pyrite-popout. Other reactive areas are indicated.

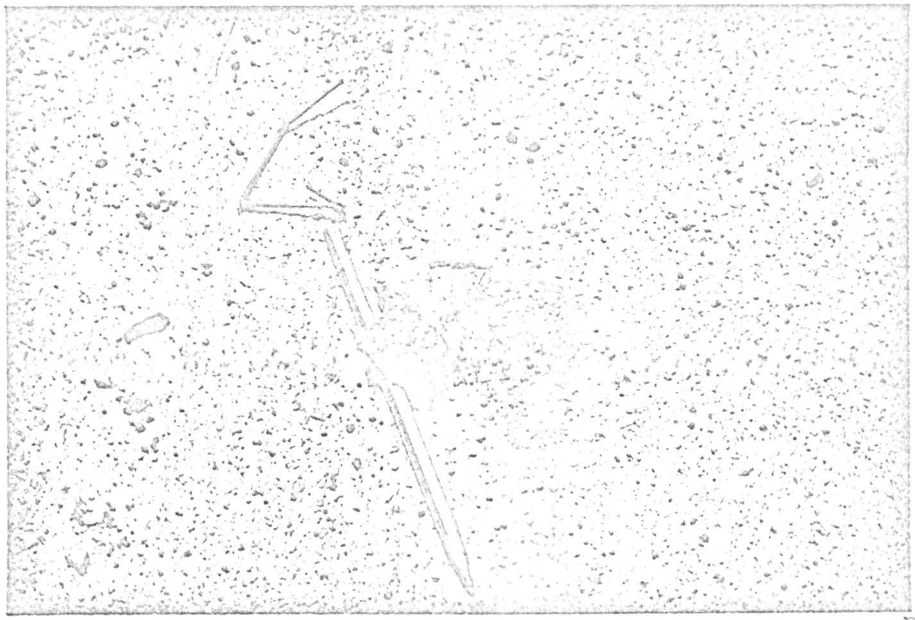

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Figure 38. Pyrite popout in bridge deck showing reaction rings around pyrite nodule and characteristic stain.

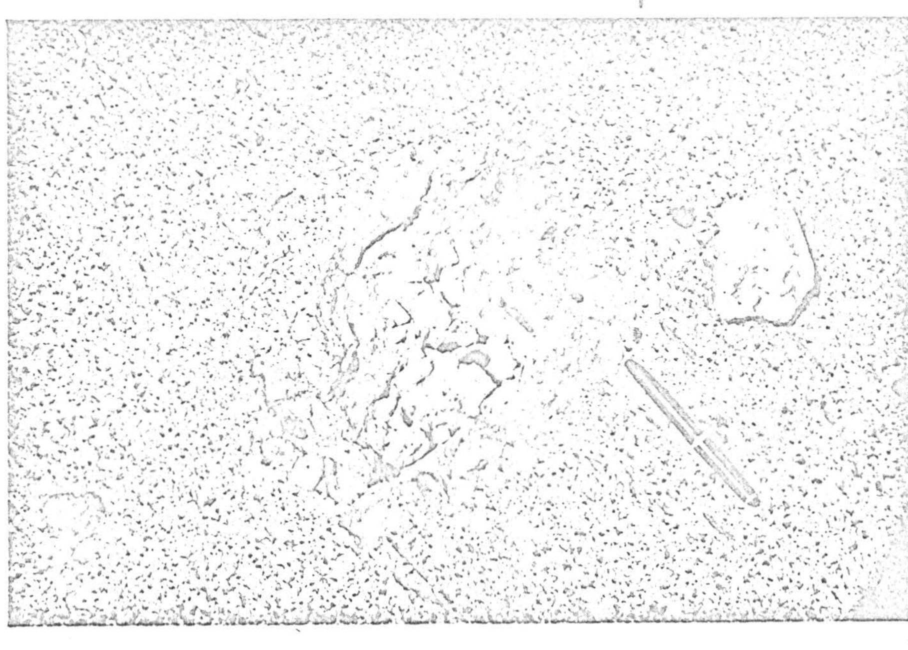

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Figure 39. Large bridge-deck failure exposing rebars; the coarse aggregate shows the characteristic pale blue-gray color of the sandstone.

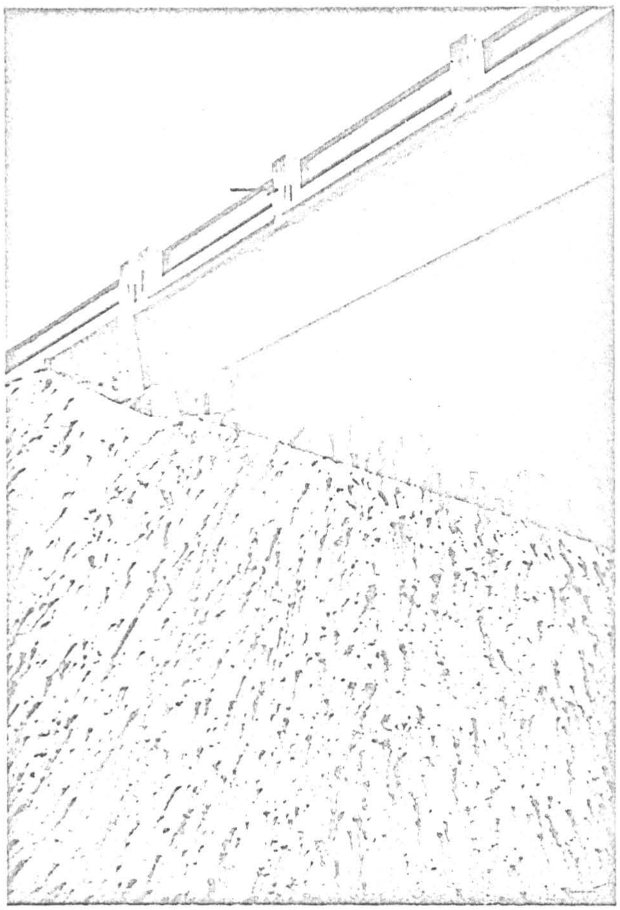

Figure 40

Figure 41

Extensive popout and staining on riprap area, guard-rail post, bents, and underdecking. Note cracking in columns.

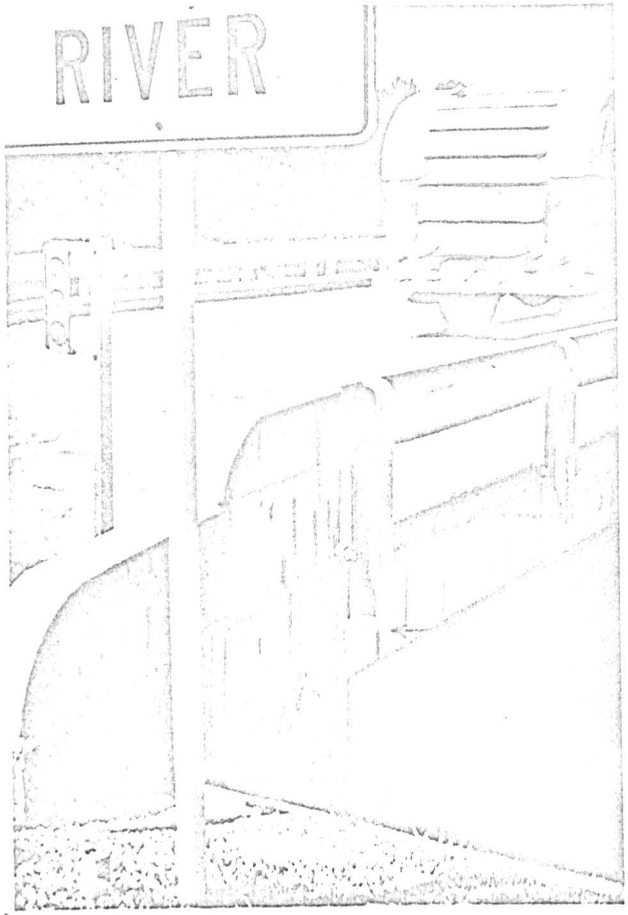

Figure 42. Reactive areas on side of bridge and on deck. Below is close-up of indicated popout.

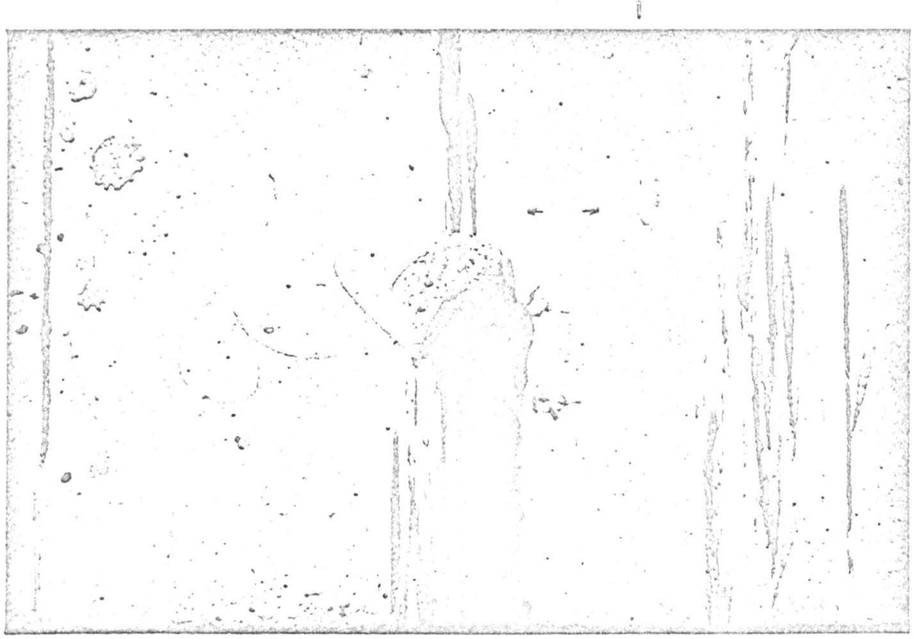

Figure 43. Close-up of cavity left from pyrite. Note reaction rings and cracks.

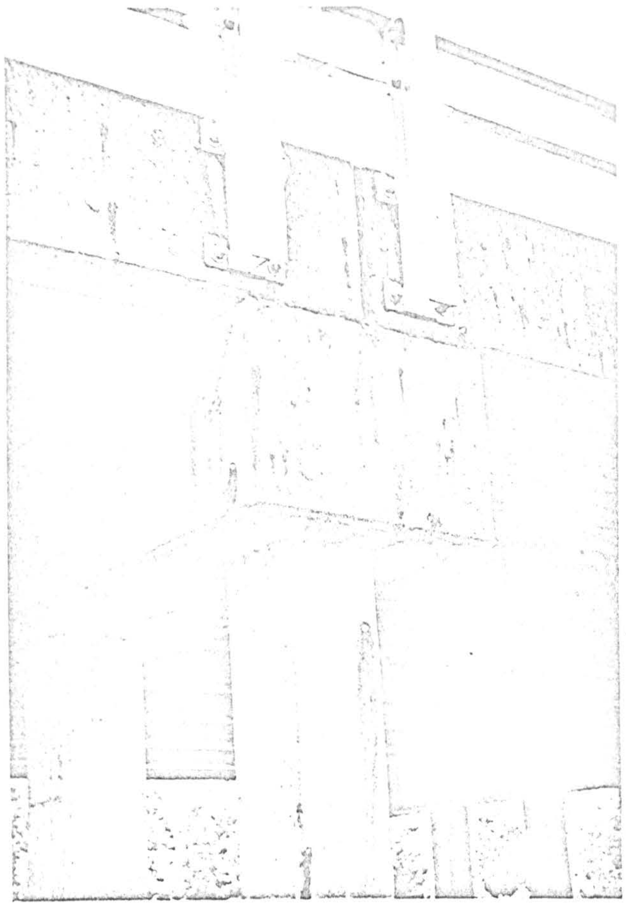

Figure 44. Numerous reactive areas on side and understructure. Note extensive staining and popouts on bridge deck (below).

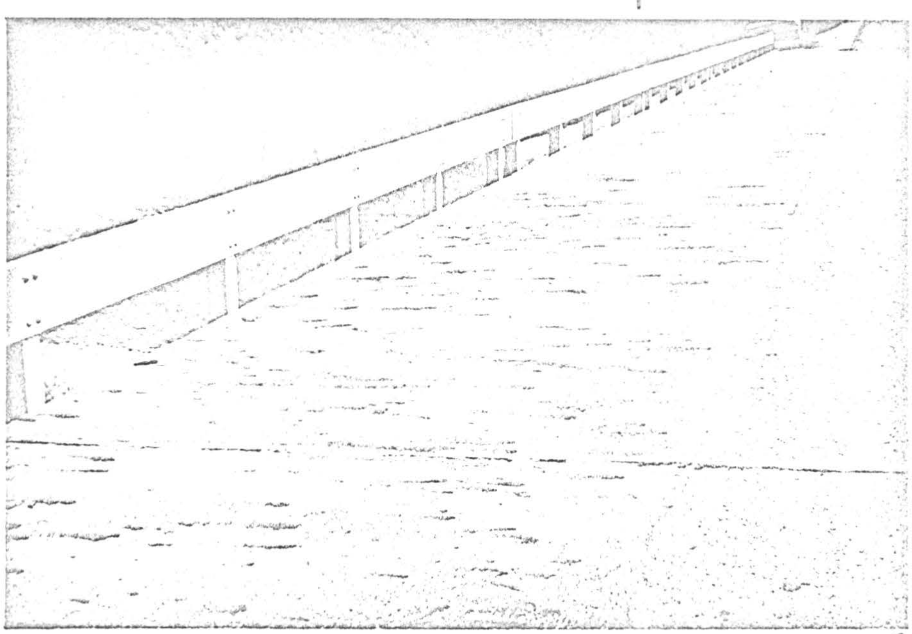

Figure 45

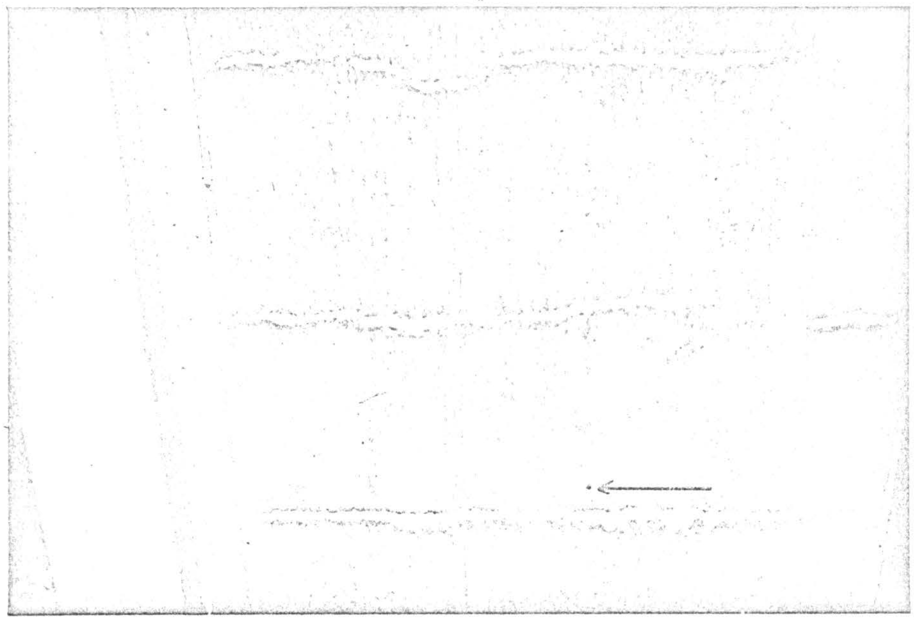

Figure 46. Crack development on underside deck of IH 20 structure with lignite popout indicated.

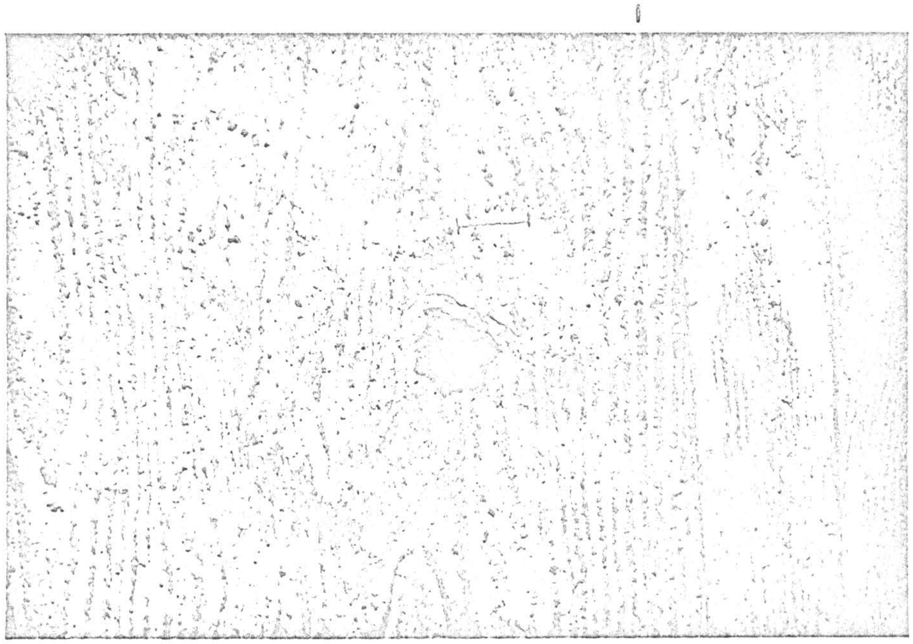

Figure 47. Close-up of lignite popout on underside of IH 45 structure not yet open to traffic.

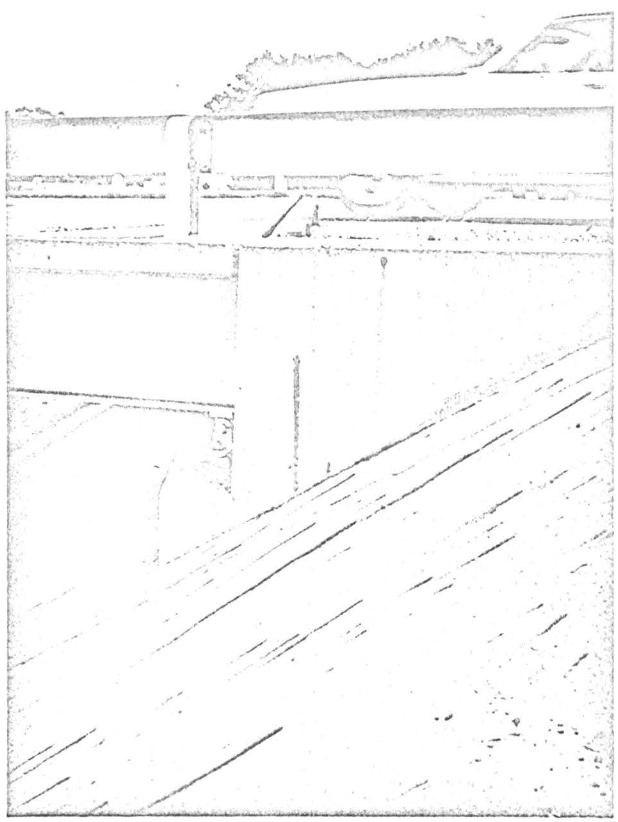

Figure 48

Figure 49

Reactive areas on IH 20 overpass thats been open to traffic about four years.

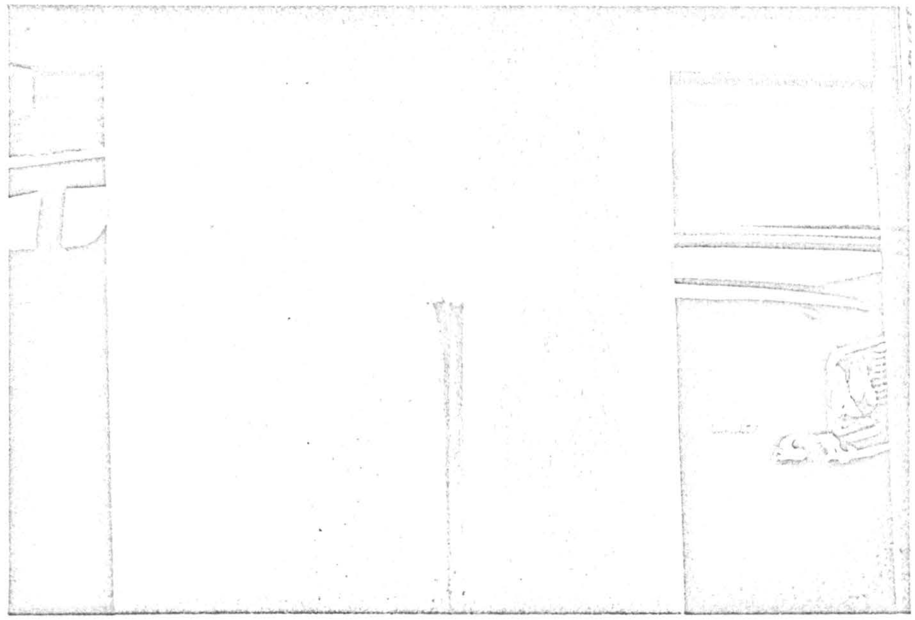

Figure 50. Pyrite reactive area on recently opened IH 45 structure.

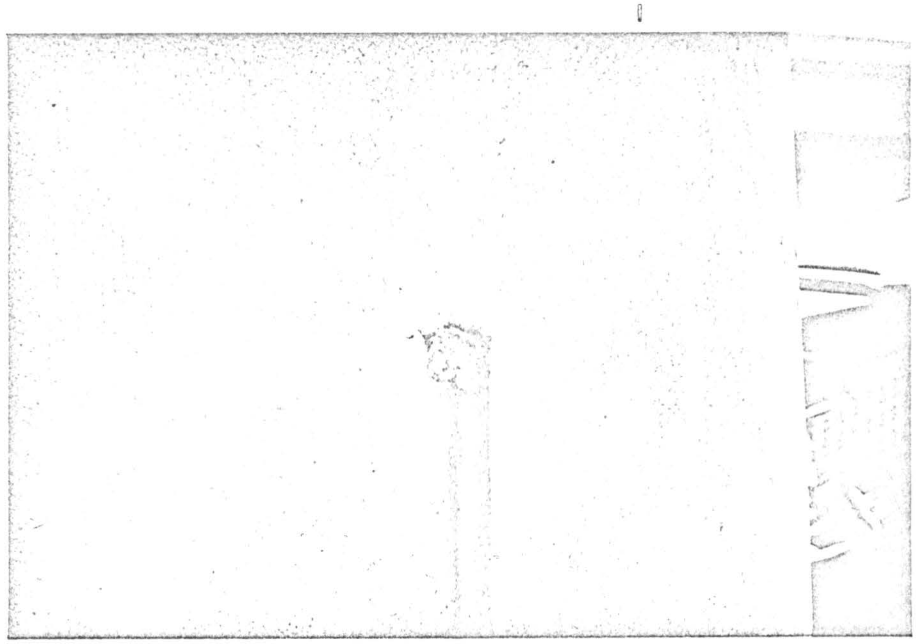

Figure 51. Close-up of the exposed popout area showing reactive ring around pyrite nodule.

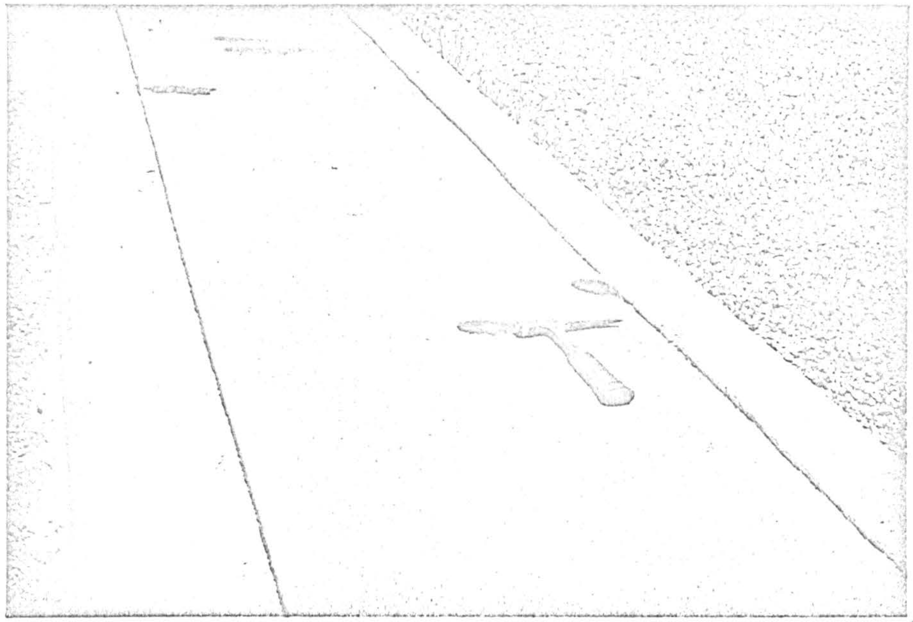

Figure 52. Pyrite popouts and staining of intersection median.

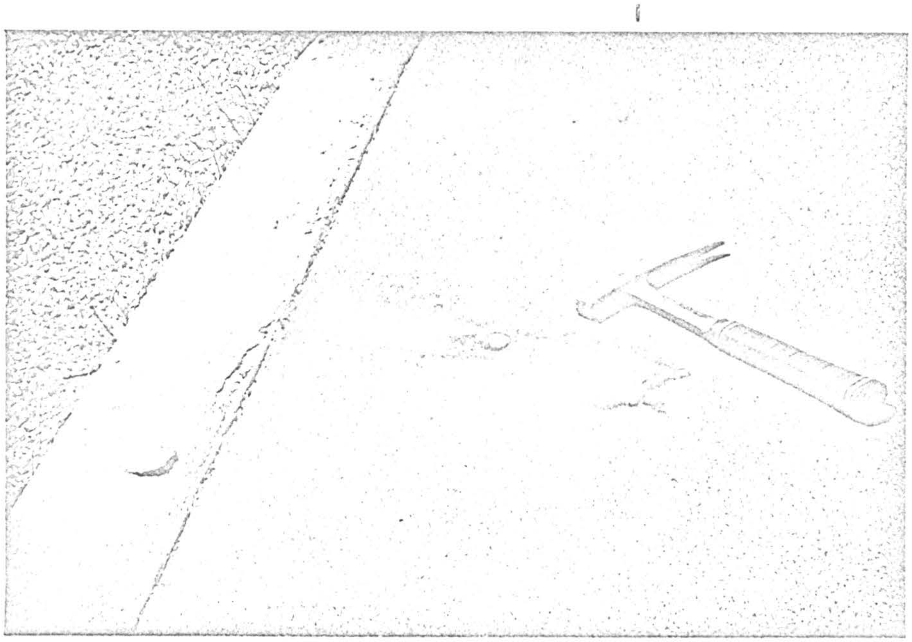

Figure 53. Close-up of pyrite popouts.
Note popout occuring under painted surface.

F. Concluding remarks:

The value of a material for use as a coarse aggregate in highway construction depends largely on the extent to which it will resist the primary destruction influences——traffic and the weather——as well as be coexistant with other paving components with which it is used. The crushed sandstone aggregate produced at the Blue Mountain pit has been shown to contain two highly unstable components——lignite and iron pyrite——which lower its ability to withstand these destructive influences.

The quarrying and crushing activities at the Blue Mountain source have been conducted for better than 15 years and the processed material, whether specified as aggregate for hot-mix, coverstone, or portland cement concrete, has inherently contained deleterious components. Samples of the freshly blasted sand stone examined at the quarry face often contain discrete seams of the brown to black colored lignite; most of which is eliminated in the initial scalping and screening stages. However, the aggregate which makes it to the stockpiles will, almost without exception, contain lignite either in minute bedding planes or as disseminated flakes. On the other hand, iron pyrite, being metallic silver to gray in color, is extremely difficult to recognize to the untrained eye in the quarry and freshly processed aggregate. But generally after a few weeks of exposure, and shorter during wet periods, the pyrite begins to have a "telltale" color resulting from the hydration of the iron-sulfide compound. This chemical alteration, as shown photographically, "grows" in intensity with exposure time, whether the material is present in a coverstone or housed in a hardened cement paste in close proximity to an exposed surface. Field observations point-out that when aggregates containing these two reactive substances are used in highway construction, either in concrete structures or paving materials, reaction is inevitable, and the degree of this reaction, as well as deleterious effects, is directly related to the time in place.