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HIGHWAY RESEARCH REPORT

PRESPLITTING

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72-20

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

CA-HWY-MR632955-2-72-20

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

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

May 1972
Lab Auth 632955

Mr. R. J. Datel
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

PRESPLITTING

Interim Report 2

Under general direction of ..... Travis Smith
Supervised by ..... Marvin L. McCauley
Principal Investigator ..... Ronald W. Mearns
Report prepared by ..... Thomas P. Hoover

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

REFERENCE: Smith, Travis; McCauley, Marvin; Mearns, Ronald; and Hoover, Thomas. "Presplitting, Interim Report 2," State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report CA-HWY-MR 632955(2)-72-21, May, 1972

ABSTRACT: This report on presplitting highway cuts by the California Division of Highways discusses and analyzes the construction methods and problems, the specifications, and the economics involved with the presplitting of granitic rocks. It is the second report in a series on presplitting in different materials. The first report, of similar content, discussed presplitting of metamorphic rocks.

KEY WORDS: Construction methods, evaluation, cuts, slopes, rock presplitting, specifications.

ACKNOWLEDGEMENTS

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Special thanks are extended to Mr. R. R. McDonell, Resident Engineer on this project, for his cooperative and dedicated assistance in obtaining the information required to prepare this report.

This work is being done in cooperation with the U.S. Department of Transportation, Federal Highway Administration; Federal Program No. HPR-1(5) F-8-7. The opinions, findings and conclusions presented in this publication are those of the authors and not necessarily those of the Federal Highway Administration.

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Introduction

Presplitting consists of developing a fracture surface along the plane of the desired slope by drilling a row of holes in this plane and detonating light charges in these holes before production blasting. Proper application of this technique results in a smooth relatively undisturbed cut face.

The use of the presplitting method has been discussed in a Materials and Research report titled "Presplitting," November 1970, by Travis Smith, Marvin McCauley, and Ronald Mearns. That report, the first of a series of interim reports, discussed presplitting in metamorphic rocks on Road 02-Sis-5, near Yreka. It contained background information which together with the experience gained on those projects resulted in the specifications now included in the Standard Special Provisions of the California Division of Highways. In it the authors concluded that presplitting can produce a steeper, smoother slope which requires less scaling, lower excavation quantities and is more stable than a similar slope constructed by normal blasting methods.

The present report, the second in the series of interim reports, summarizes the Division's experience in presplitting granitic rocks. Most of the Division's experience with presplitting granitic rocks has been obtained in the Kern River Canyon on Road 06-Ker-178. This report analyzes three cut areas (Plate 1) between Post Miles 37.7 and 38.7 on this road (see Plates 2 to 9). The first, a sidehill cut, is at Sta. 2550+00, the second at 2557+00, also a sidehill cut, used a different spacing, and the last, a through cut, is at Sta. 2570+00. Cut statistics are in Table 1.

The cut areas are all in granitic material with the rock being medium to coarse grained gray granodiorite or quartz diorite. Numerous randomly oriented pegmatitic and aplitic dikes cut the relatively massive granitic rock. Both joints and fractures are widely spaced. Weathering has progressed downward from the surface and outward from the joints and fractures.

A presplitting technique was tried on granitic rock with all degrees of weathering from very fresh to disintegrated granite. Although this work was not performed as a controlled experiment, it was possible to make the following observations. The size of the charges used on this project worked perfectly in the least weathered rock. In the most weathered material on the project the same size charge resulted in loosening of material in the cut face. Rounding and cleanup work were required in these areas. For the remainder of the materials which were somewhere between these two extremes of weathering, the charge size appears to be slightly too large, resulting in a crack into the face of the cut.

Other completed presplit cuts in granitic rock are pictured in Plates 10 to 22. These pictures show what results can be obtained with the presplitting technique.

CONCLUSIONS AND RECOMMENDATIONS

The Division's use of presplitting up to this time has produced steeper cut slopes with a smoother appearance, the need for less scaling and what appears to be, after three to five years of weathering, more stable slopes.

To realize the maximum benefit from the presplitting technique, it is necessary to use the proper combination of bore hole diameter, spacing and length of bore holes, and proper type, size, and spacing of explosives. The required combination of these variables must be determined by experimentation in each cut. Using the specifications as a guide is helpful, but previous experience in presplitting results in less wasted effort and lower costs.

The slight increase in direct construction costs using the presplitting technique are almost balanced by reduced excavation quantities. However, reduced right-of-way costs, anticipated decreases in maintenance cost, and improved safety are additional benefits. Based upon the experience gained with granitic rocks, more extensive use of presplitting is recommended.

IMPLEMENTATION

Presplitting has been specified on several other state highway projects, primarily on the recommendation of the Materials and Research Department. Instruction and consultation by Materials and Research Department personnel is being utilized by District and Headquarters Design and Construction Departments to extend the knowledge and experience of the Division of Highways in the field of presplitting.

Information obtained in presplitting granitic rocks has indicated a need for changing the specifications contained in the Standard Special Provisions in the following areas: alignment, spacing, stemming materials, and payment. These changes are discussed in the specification section. These changes will be incorporated into the recommended specifications and presented to the Specifications Committee for inclusion into the Standard Special Provisions.

METHOD

In presplitting, six variable factors require consideration; they are:

1. Boring diameter
2. Boring spacing
3. Boring length and alignments
4. Type of explosive
5. Quantity of explosive
6. Pattern of placement of explosive

It is obvious that these factors are interrelated. On this project as on those previously investigated we did not try to completely define this relationship. The intent was to construct satisfactory cut slopes and the operation which first yielded such slopes was used to complete each cut. The following discussion of the variables includes comments on field observations and results.

Boring Diameter - Three-inch diameter holes were used on this project. There is no explanation for this size other than it works, and that compatible equipment and explosives are readily available.

Boring spacing - On this job the contractor tried spacings of: 27", 30", 36", and 48". The 27-inch and 30-inch spacing produced some overbreak in between the holes.

The 36-inch spacing eliminated most of the overbreak, but produced a vertical crack perpendicular to the slope, Plate 7. This crack is probably caused by an excess of explosive energy for the hardness of the rock. Even with this crack the 36-inch spacing yielded a smooth slope within the required tolerances.

The 48-inch spacing, Plate 4, was tried upon the recommendation of the Hercules Powder Co. While this spacing did not exhibit perpendicular cracking, it also did not produce the planar presplit slope. The 48-inch spacing was, therefore, abandoned and the project was finished with 36-inch spacing.

Boring Length and Alignment - Both 20- and 30-foot lifts were tried on this project, with the 30-foot lifts giving the better looking slopes. The better slope is due to the fact that the top four feet of each lift is spalling away. This is probably caused by placing the top charge too close to the collar. Another contributing factor could be the degree of fracturing and the uneven weathering of these rocks.

The alignment specifications call for 3% of the length as horizontal tolerance. The longer holes yielded better alignment because workmen took more time and exercised more care setting up the drill rigs. The best alignment is achieved when the contractor has a level and smooth pad to work from.

Type of Explosive - The contractor on this project elected to use Hercosplit, a solid column type explosive with approximately 1/4-lb of explosives/foot. It is manufactured by the Hercules

Powder Co. in 7/8" x 24" 40% cartridges. Also used was Gelimite, a 60% dynamite manufactured by Hercules.

Quantity of Explosives - This project used one column of Hercosplit per hole with three sticks of Gelimite at the bottom.

Explosive placement - One stick of Gelimite was placed at the bottom of each hole for every 10 feet of depth to assure breakage at the bottom. The smaller cartridges were then joined and inserted in the hole with the top of the column three feet below the collar.

CONSTRUCTION PROBLEMS

Stemming - Stemming, the backfilling of bore holes after the charge has been placed, was an undesirable added expense when applied in material which was on the borderline of blasting or removing by ripping. In the opinion of the Resident Engineer, which is supported by personal observation, stemming in soft or highly fractured material does little to achieve a good slope, therefore, the specifications should give the Resident Engineer the authority to determine when stemming is necessary to obtain the desired results.

Testing - Testing to determine the correct explosive and bore hole spacing is imperative. If the contractor does not do so, the Engineer may have to require it to achieve the desired results.

Scaling - Presplitting leaves significantly less loose material on the slopes. Since presplit slopes are steep by nature, the contractor elected to allow winter rains to wash as much of the loose material off as possible. This washing coupled with the smaller original quantity reduced the time spent scaling on this project to what the Resident Engineer estimated to be approximately 20% of that normally required.

Failures - After three winters the only failures on this project other than minor rockfall can be attributed to procedural shortcomings. The first failure, the falling of 10- to 15-ton rocks, occurred in the largest cut at the east end. Water from rain and melting snow filled the shot holes, joints and fractures at the time of production blasting. This apparently transmitted some explosive energy across the presplit surface to open the joints and fractures in the cut face. This type of slope is conducive to rock fall.

The other failure was the sliding of the west end of the first cut completed. This failure was probably caused by the use of too much explosive energy for the degree of weathering present.

Another indication of the probability of overshooting is the vertical crack perpendicular to the slope (Plate 7) which is present in many holes. The solid column explosive used on this project was the lightest commercially available charge at that time. Partial sticks of explosive connected by detonating cord provide lower energy inputs and might have been more successful in eliminating the crack at the back of the hole.

ECONOMICS

The cost of presplitting includes expenditures for drilling, loading, and shooting the extra holes, as well as the increased engineering costs attributed to the additional inspection required. It is anticipated that this increased cost will be more than balanced by reduced earthwork quantities using steeper slopes, reduced right of way requirements, a lower excavation bid, aesthetic considerations, increased safety of the traveling public and a probable reduction of maintenance costs.

Earthwork quantities - The bid prices for presplitting on this project ranged from $0.75 to $1.53 per foot with the successful bidder, Gibbons & Reed Corp., bidding $1.25 per foot. Construction costs on this project attributable to presplitting are $50,625 plus approximately $3,000 in increased engineering expenses for a total increased cost of $53,625.

Construction of these cuts, which are at .6:1, with stable slopes and no presplitting would have been at 1:1 as recommended by the Materials and Research Department, increasing the roadway excavation quantity by approximately 47,235 cubic yards. At the bid price of 98 cents per cubic yard this increased excavation would have cost $46,290.30. Thus, the cost of drilling and blasting the presplit slopes was approximately $7,350 greater than if the slopes had been constructed through conventional means.

The economics of earthwork quantities on this project indicate that presplitting only slightly increased the cost of cut construction. Other factors less amendable to monetary evaluation or not analyzed at this time, which are discussed in the following text, increase the desirability of presplitting.

Right-of-way - The steeper cut slopes that are possible using presplitting techniques result in reduced right-of-way requirements. This, in many cases, could result in reduced right-of-way costs if the Right of Way Department is aware of this decreased requirement early enough in the design stage. This would in turn reduce the impact of highway construction on property holders and local tax revenue.

Excavation Bids - The bid price for excavation on highway contracts includes scaling and slope cleaning. Since presplitting produces smoother cleaner slopes it would seem that they would be cheaper to clean and should allow the contractor to reduce his bid price for roadway excavation.

Safety - The construction of a cut slope in rock creates a potentially hazardous situation. The rock is standing at a steeper angle than had developed naturally and has been disturbed by the construction procedures. Construction of such a slope using the presplitting technique virtually eliminates disturbance of the remaining rock and will result in significantly more stable slopes. It has also been reported by the State of Washington that steep cut slopes will help reduce the number of rocks falling onto the traveled way.

It has been impossible to put a value on this safety aspect, however, it is obvious that rocks falling or rolling onto the road cause accidents, and it is the responsibility of the Division of Highways to do everything it can to reduce the possibility of such accidents.

Aesthetics - While impossible to attach a dollar value to the appearance of cut slopes or to design cut slopes which have a universally accepted appearance, some aspects of the subject of aesthetics do deserve mention.

A presplit slope has a generally smooth, clean appearance as opposed to the rough irregular appearance of a normally constructed cut slope.

The traces of the presplit borings in general are readily visible on the cut face (see Plates 2 and 3) and give the rock an unnatural appearance.

The steeper cut slopes yield a smaller overall scar in the area.

These features of presplit slopes are evaluated in different ways by different people and no attempt has been made to analyze such evaluations.

Maintenance - No maintenance work has been done in this area at this time, therefore, no cost data is available. It should, however, be noted that there is less potential for rockfall or major failures, and lower maintenance costs are anticipated.

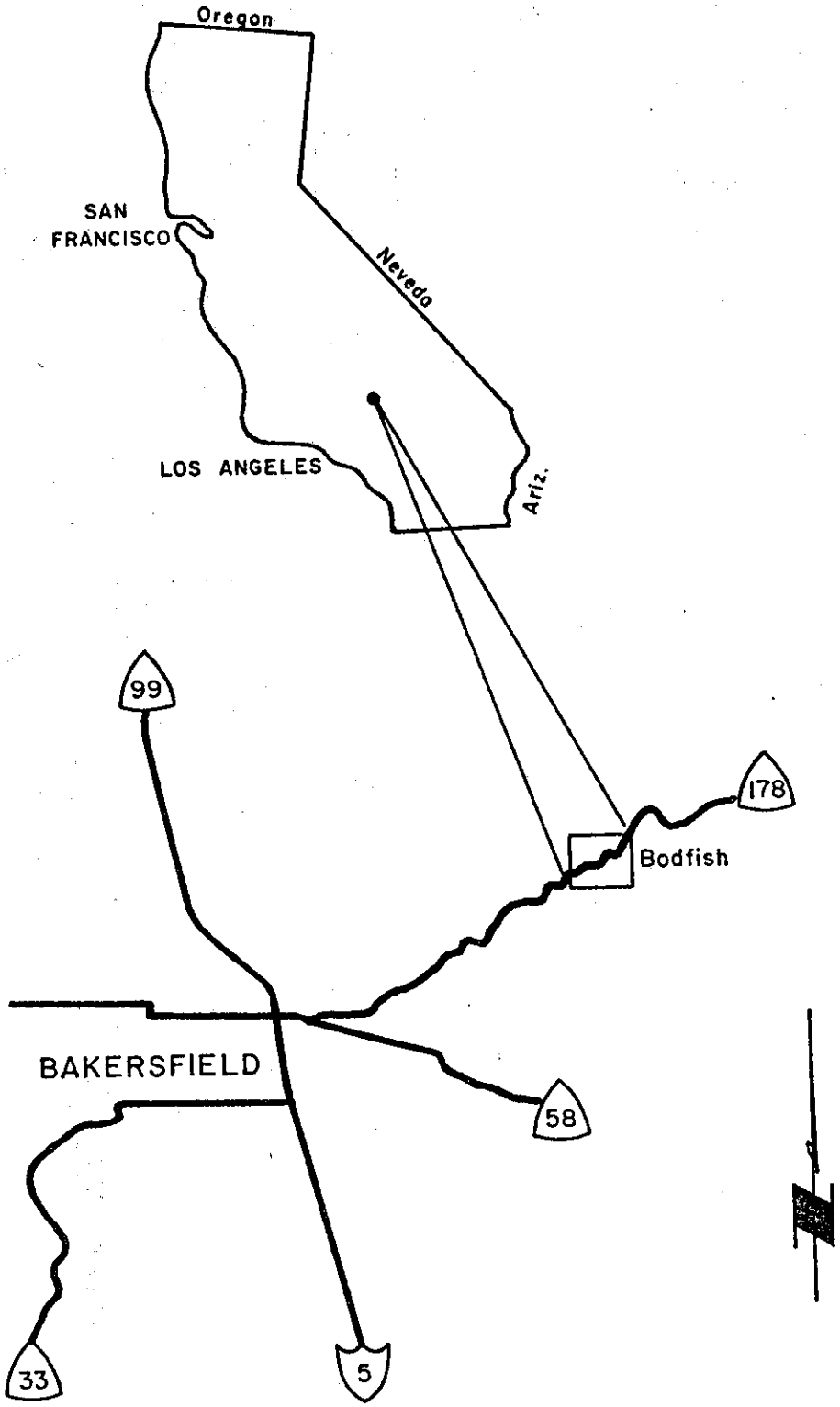
SPECIFICATIONS

The specifications used on this project are listed in Appendix No. I. These specifications were written in the early stages of the Division's presplitting experience. As the Resident

Engineer experienced problems with these specifications, he made note of the situation and forwarded this information to this office.

Changes in the specifications have been proposed. These changes were arrived at from both the experience gained on this project and the information obtained in interviews with all those Resident Engineers who used original proposed specifications. These changes include: the spacing of holes, the tolerance of alignment, the stemming material, and the method of payment. One of the reasons for these changes was to permit drilling patterns as shown in Plates 13 and 18. The specifications which include changes are listed in Appendix II. These proposed specifications will be submitted to replace those currently included in the Standard Special Provisions. The current specifications in the Standard Special Provisions are listed in Appendix III.

Figure 1



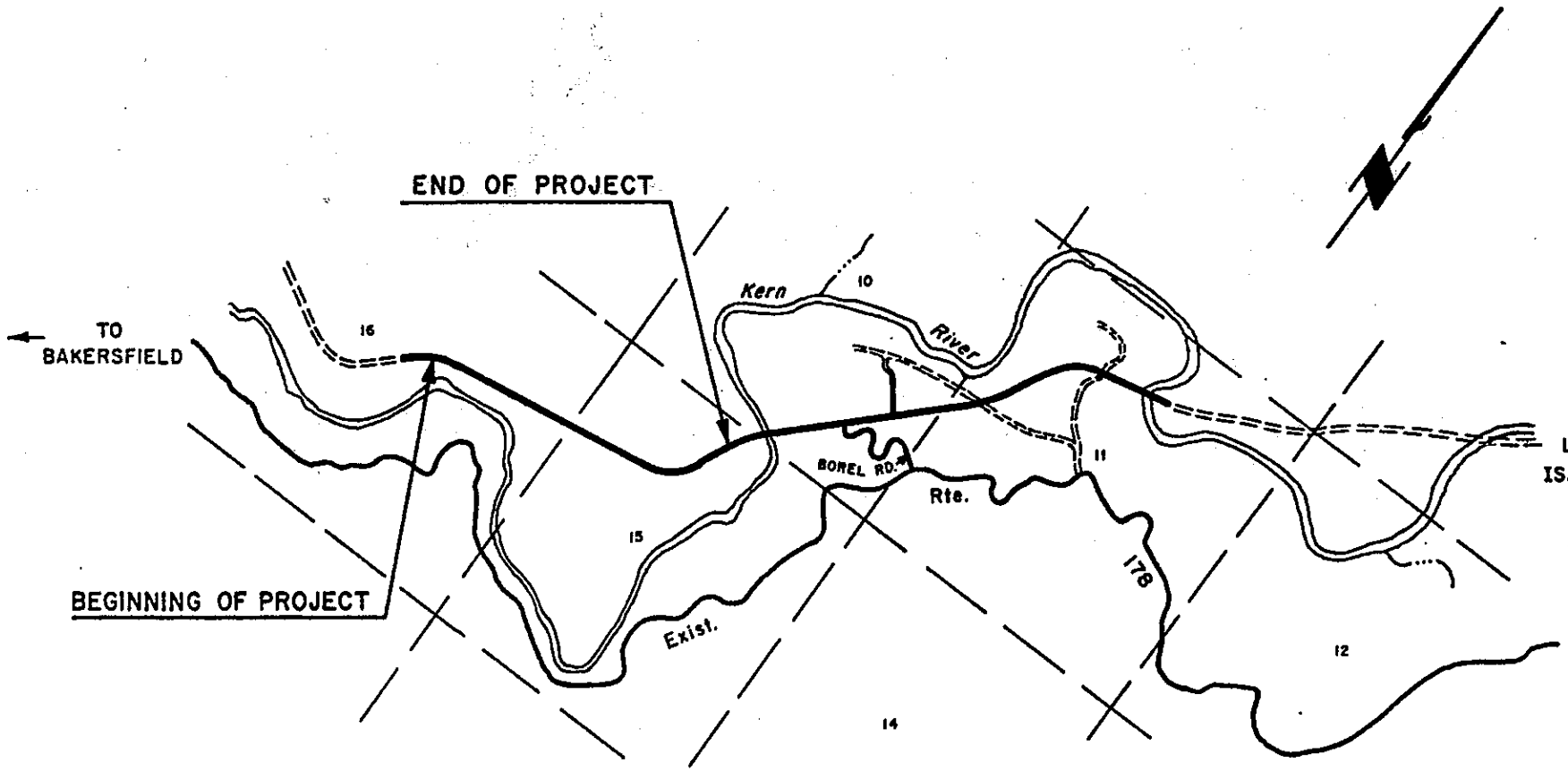


Figure 2

PROJECT MAP

TABLE I

Cut Statistics

Station Limits	Maximum Centerline Height (ft.)	Excavation Quantity Cu. Yds.	Slope Design and Type of Cut
2548+22 to 2552+35	62	58,504	.6:1 slope Left side only
2560+50 to 2564+00	54	20,860	.6:1 slope Left side only
2565+00 to 2575+00	152	499,724	.6:1 slope Through cut

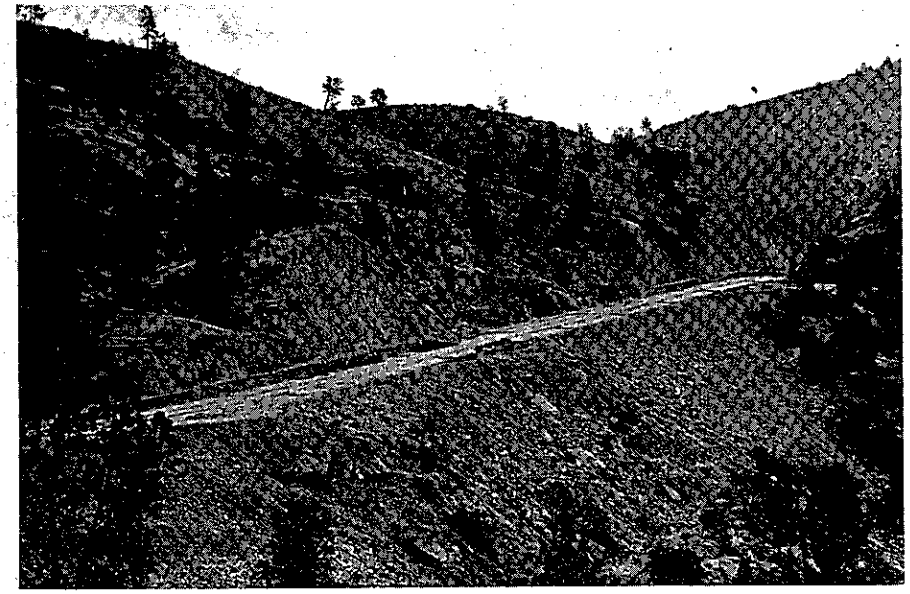


Plate 1 - Overall view of the three cuts
06-Ker-178 P.M. 37.7 to 38.7.

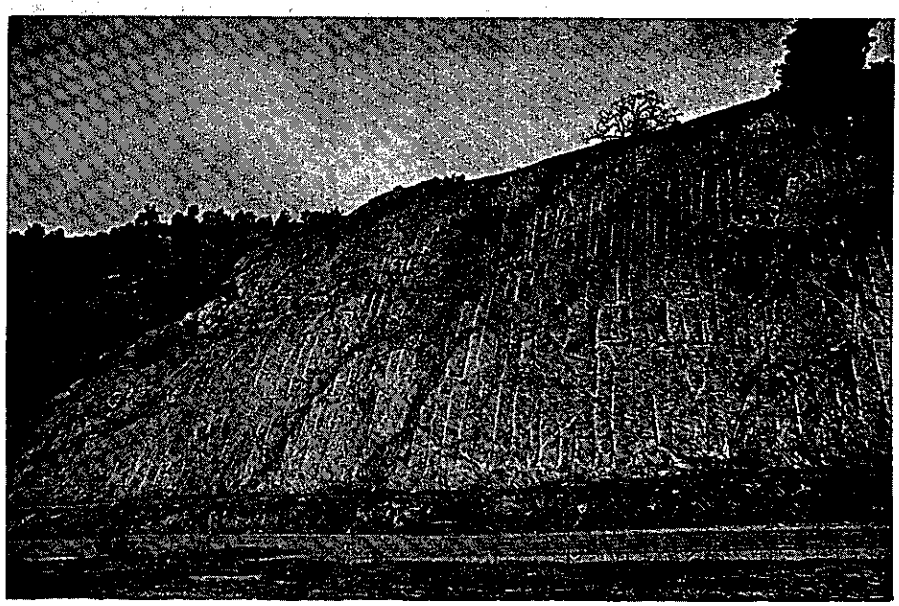


Plate 2 - West end of cut at Sta. 2550±

Plate 3 - East end of cut at Sta. 2550±

Plate 4 - Used 48" spacing for holes
Sta. 2562±

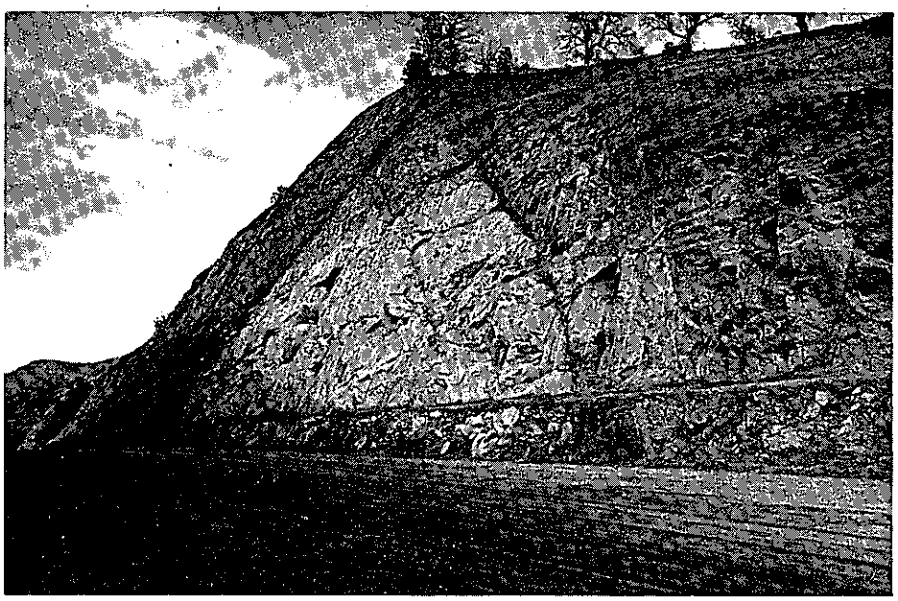


Plate 5 - North side of cut at Sta. 2570±,
looking west. (Note blockyness
at right center)

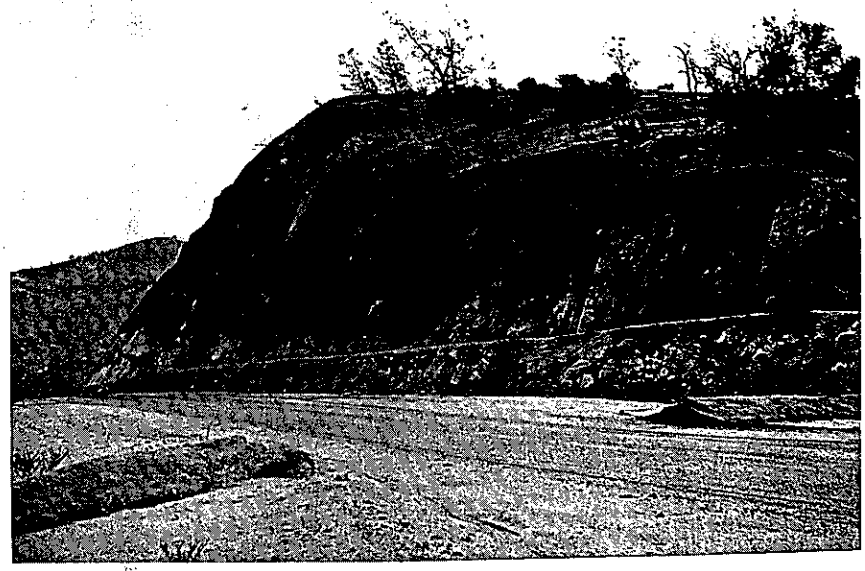
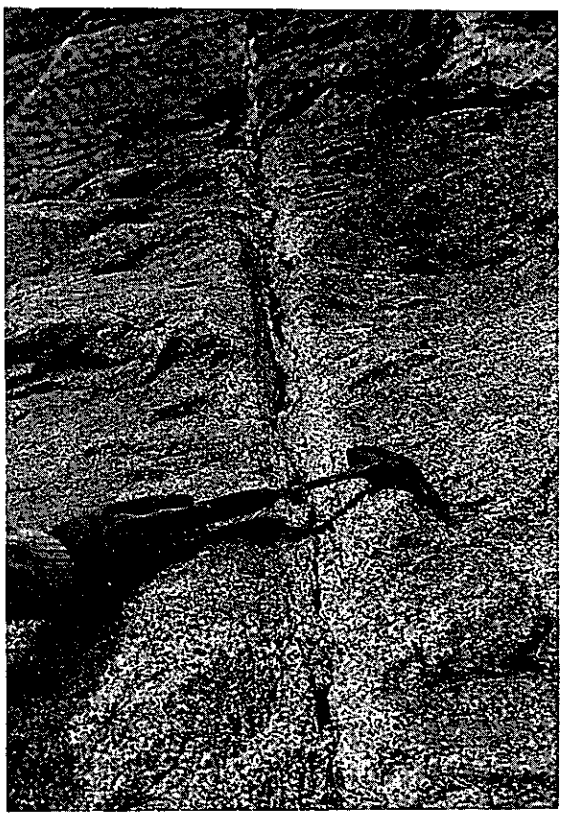


Plate 6 - South side of cut at Sta. 2570± looking east

Plate 7

Perpendicular cracking in 36" spaced holes



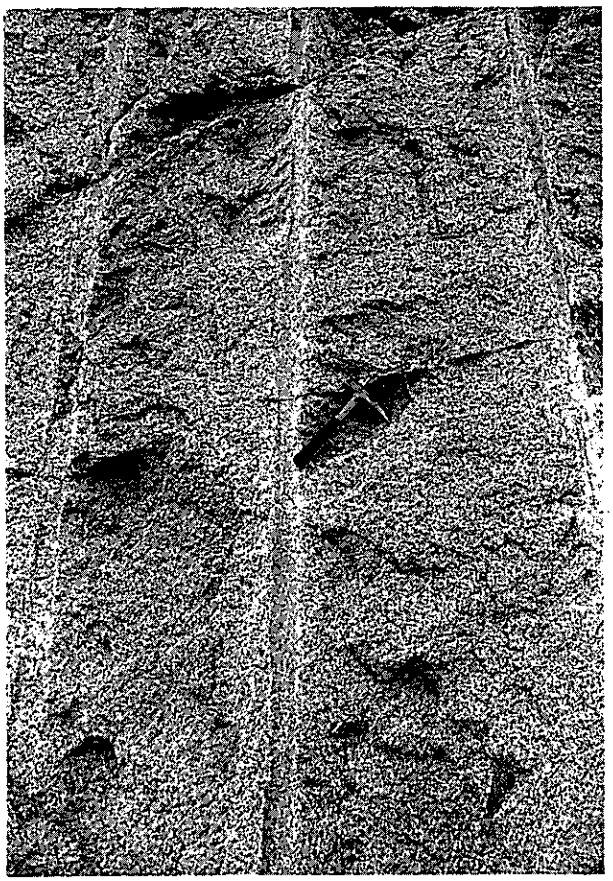


Plate 8

Hole trace without crack

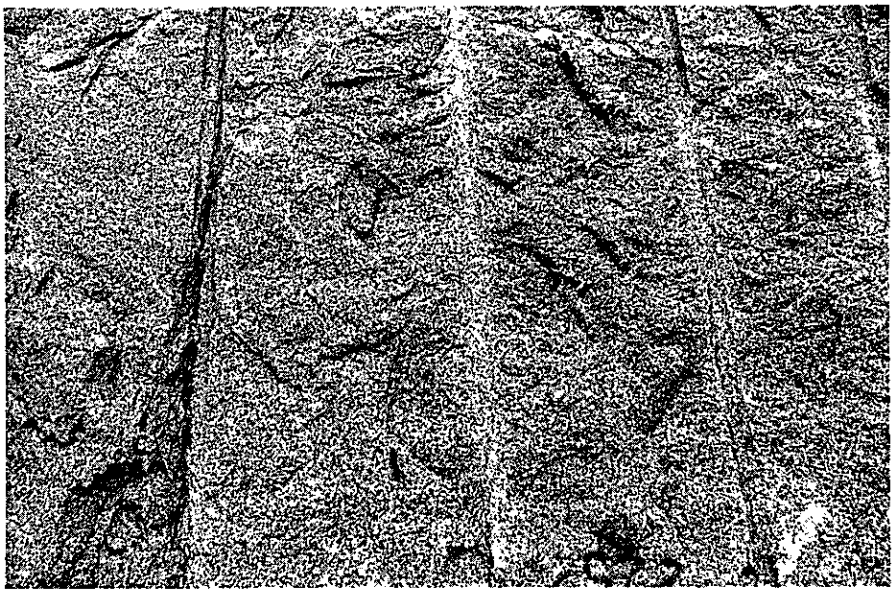


Plate 9 - Parallel traces with and without cracking

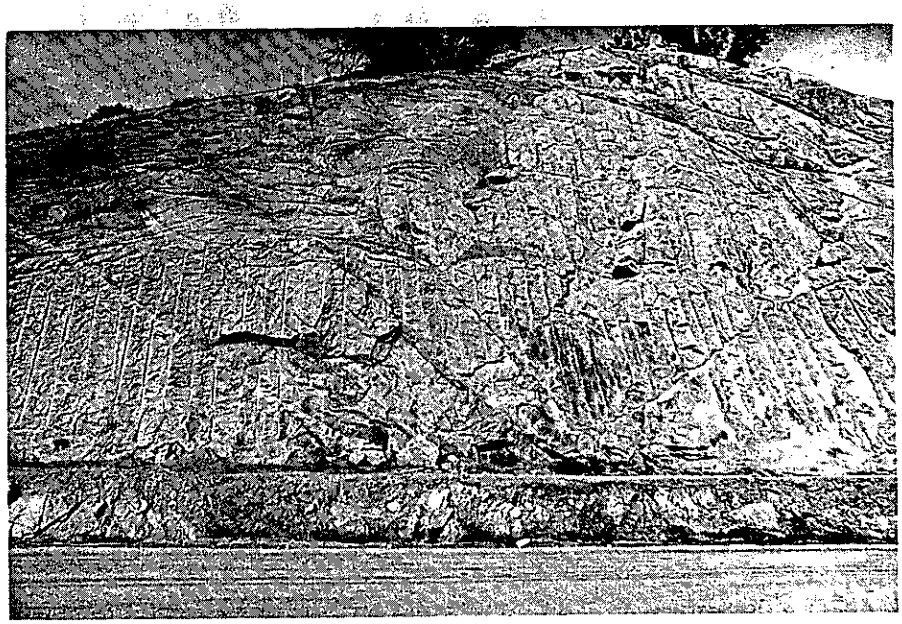


Plate 10 - Presplitting by Oberg Construction using fractional sticks connected with Prima-Cord. 06-Ker-178 Sta. 2613

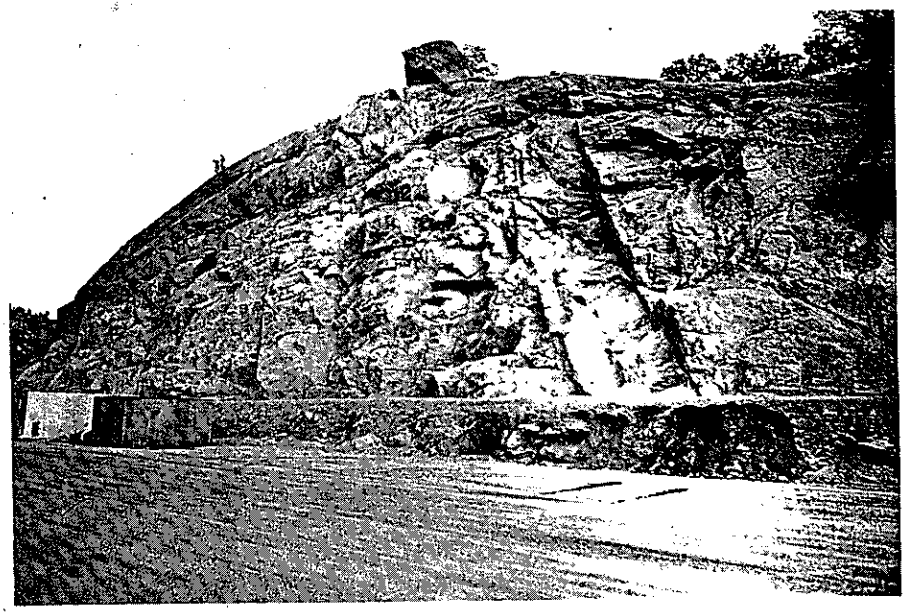


Plate 11 - A nonpresplit slope in material similar to Plate 10

Plate 12 - Presplitting by C. W. McGrath, Inc.
06-Ker-178 - P.M. 33.4 to 37.7
Sta. 2378± to 2408±

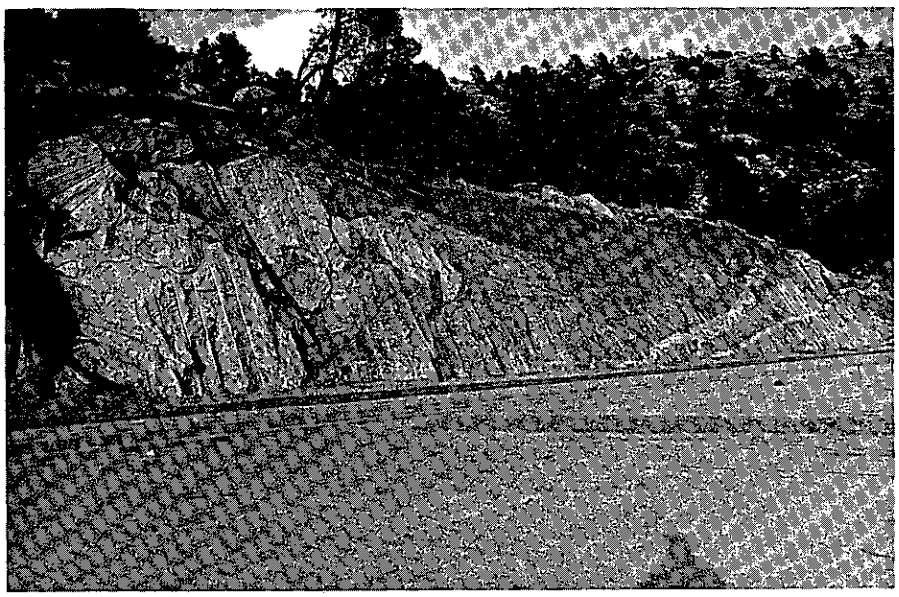


Plate 13 - Presplitting by McGrath showing
fanning (top left) Sta. 2382±

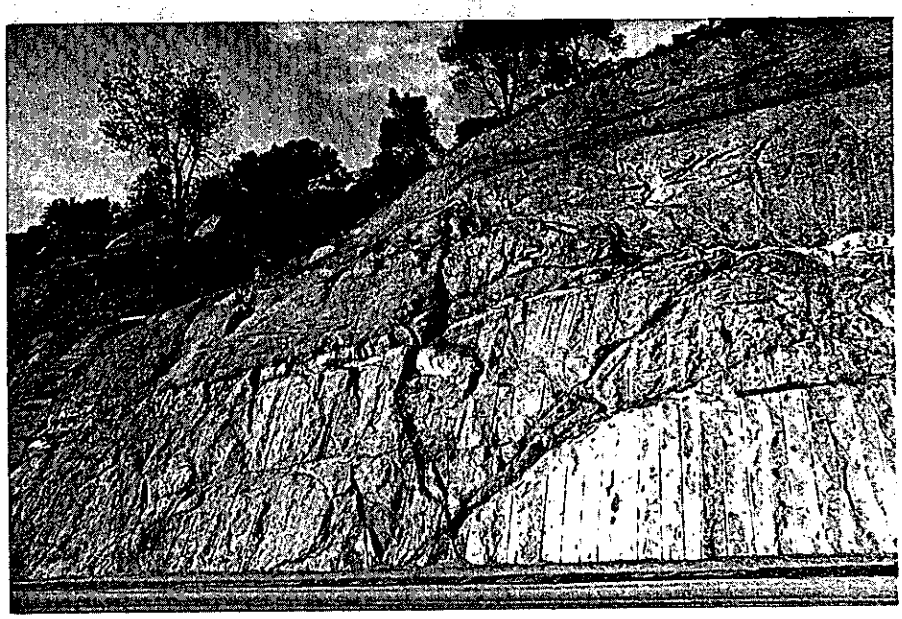


Plate 14 - Presplitting by McGrath - Sta. 2389

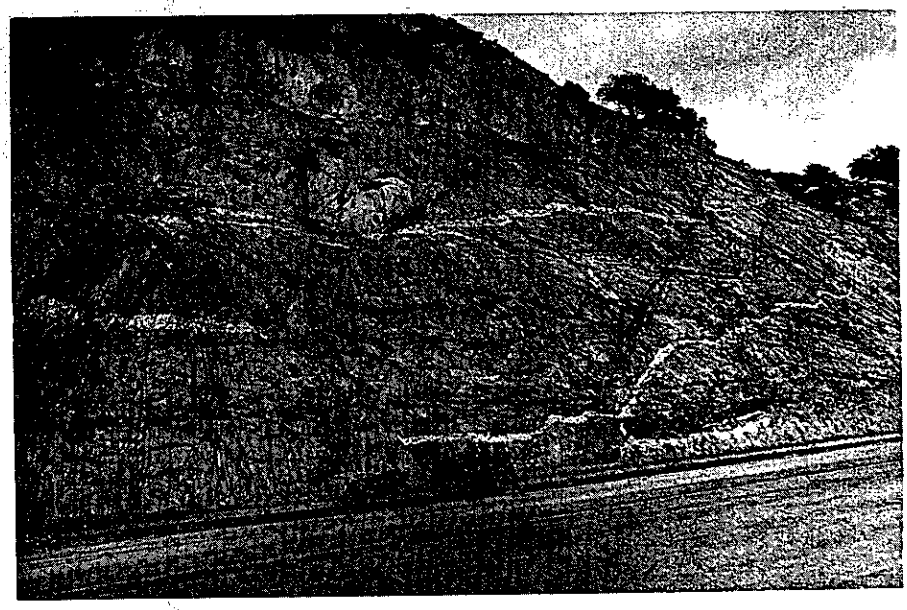


Plate 15 - Presplitting by McGrath - Sta. 2398

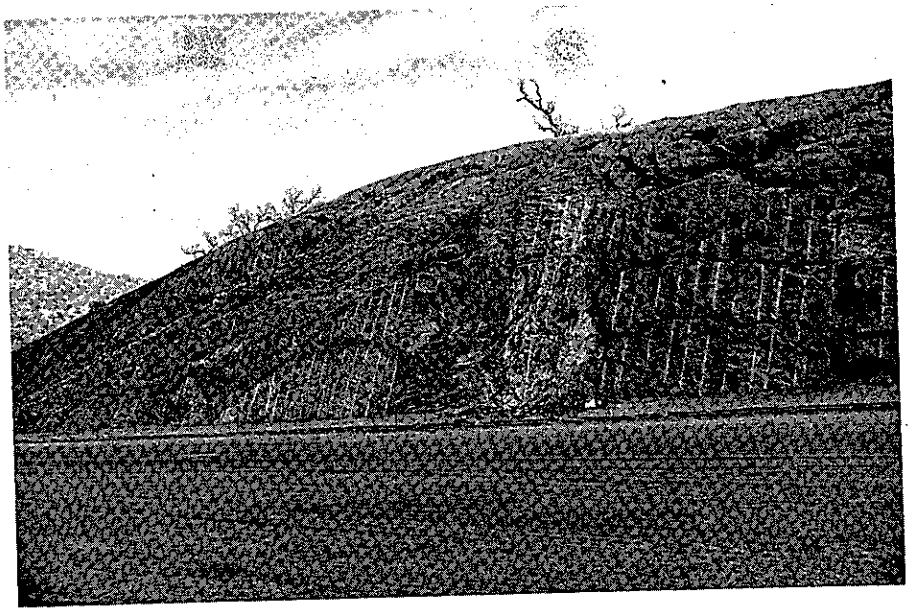


Plate 16 - Traces from presplitting by McGrath
Sta. 2338±

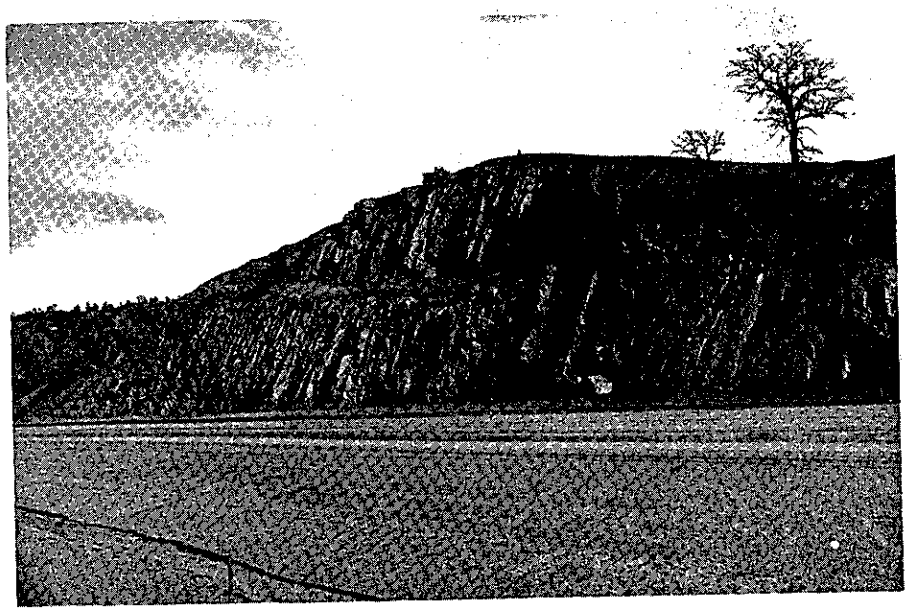


Plate 17 - Presplitting combined with ripping
at right end - Sta. 2327±

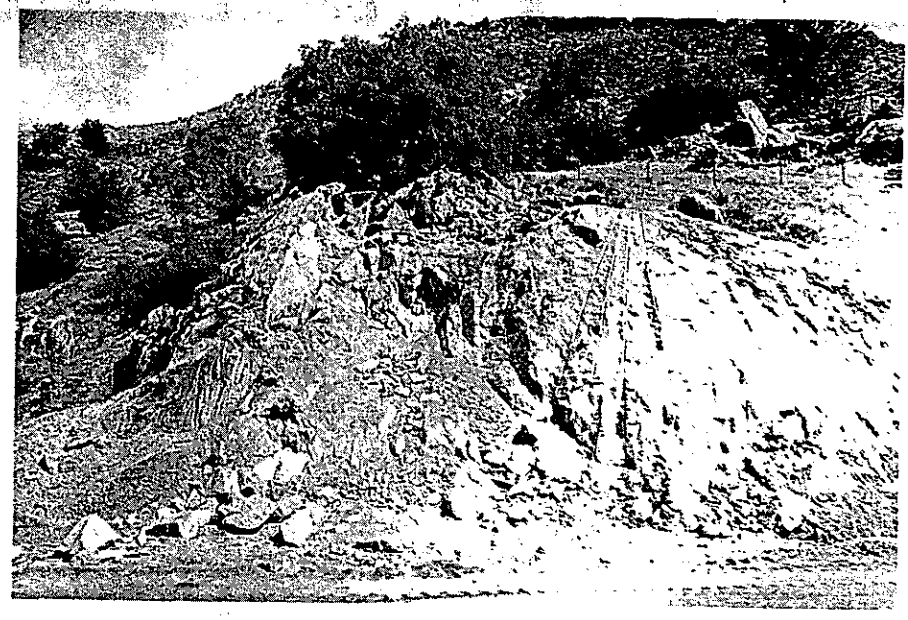


Plate 18 - Fanning by McGrath at Sta. 2305

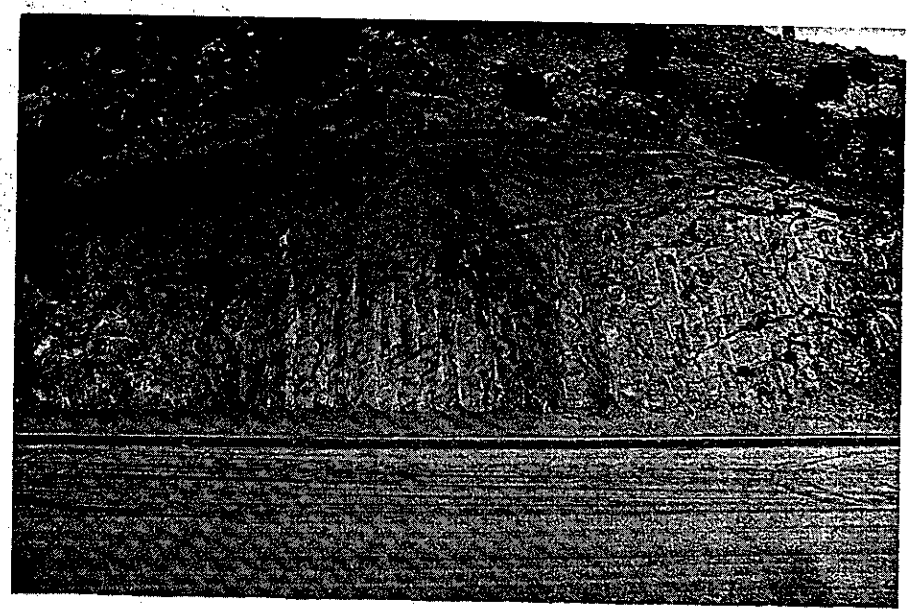


Plate 19 - Presplitting in borderline material by McGrath at Sta. 2300±

Plate 20 - Presplitting by Isabell
11-SD-95 - 50±
near Campo looking east

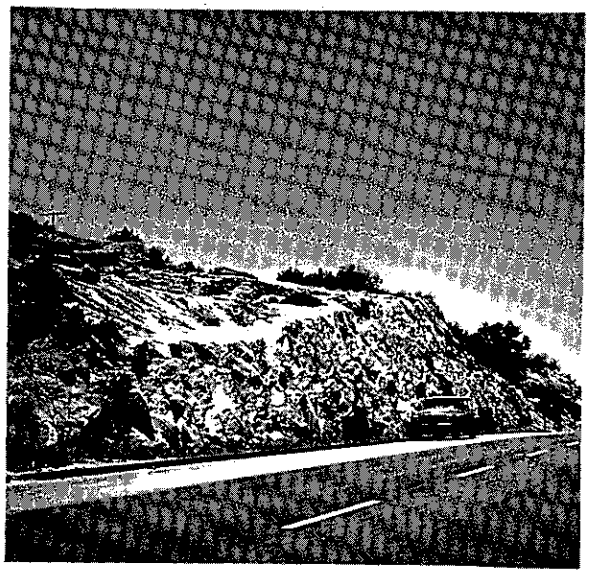


Plate 21 - Looking west

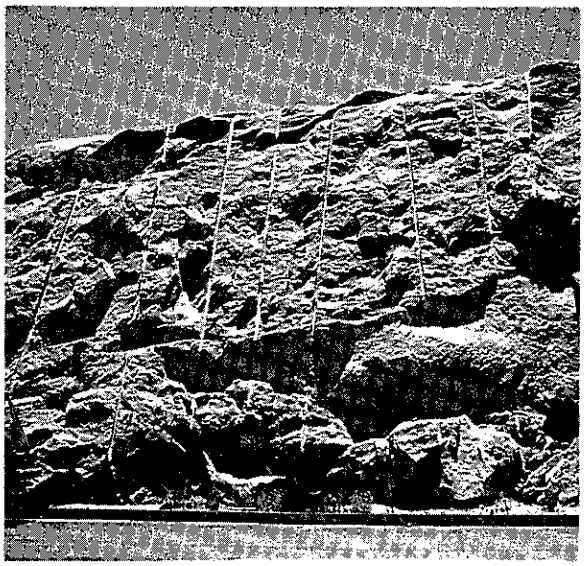


Plate 22 - Cut face
(Contractor initiated)

APPENDIX I

Specifications Used On This Project

SECTION 11-2. DRILLING HOLES (PRESPLITTING)

11-2.01 Presplitting Rock Cut Slopes.- Presplitting rock cut slopes shall be performed at the locations described herein in accordance with the provisions in Section 19, "Earthwork", of the Standard Specifications and these special provisions.

Presplitting is defined as the establishment of a free surface or shear plane in rock along the specified cut slope by the controlled usage of explosives and blasting accessories in appropriately aligned and spaced drill holes.

The presplitting technique, as covered herein, shall be used for forming rock cut slopes between the following limits:

Station 2548+22 to Station 2552+35, Lt. of Centerline.
Station 2568+00 to Station 2572+50, Lt. of Centerline.
Station 2568+00 to Station 2572+50, Rt. of Centerline.
Station 2611+50 to Station 2615+50, Lt. of Centerline.
Station 2611+50 to Station 2615+50, Rt. of Centerline.

The Contractor shall first completely remove all overburden soil along the lines of presplitting to expose the rock surface prior to drilling the presplitting holes.

Slope holes for presplitting shall be drilled along the line of the planned slope within the tolerances herein set forth. The drill holes shall be not less than 2½ inches and not more than 3 inches in diameter. Presplit holes shall be drilled and blasted in lifts not more than 20 feet in height, except that in those areas in which the Contractor has demonstrated that both the alignment and spacing of presplit holes are maintained uniform to provide a cut face on a single uniform plane, the lift thickness may be increased up to a maximum of 30 feet upon written approval of the Engineer.

The Contractor will not be required to use the presplitting technique on slopes 1:1 or flatter.

Drilling and blasting for presplitting shall be kept between 30 and 50 feet in advance of adjacent production blasting operations.

A maximum offset of 24 inches will be permitted for a construction working bench at the bottom of each lift, for use in drilling the next lower presplitting pattern.

The Contractor shall control his drilling operations by the use of proper equipment and technique to insure that no hole shall deviate from a line passing through the hole collar formed by the intersection of the specified slope plane and

a vertical plane normal to the specified slope, by an amount greater than 3 percent of the length of the hole being drilled. The Contractor shall adjust his drilling operations to compensate for drift of previous levels and for the offset at the start of new levels to maintain the specified slope plane, and such adjustments will not be classified as deviation prohibited by this paragraph.

Presplitting drill holes shall be spaced between 1½ feet and 3 feet on centers, as directed by the Engineer.

Auxiliary drill holes along the presplit line, not loaded or stemmed, may be ordered by the Engineer. Except for spacing, auxiliary drill holes shall conform to the provisions for presplit holes.

The Contractor shall presplit and excavate short sections (50 feet to 100 feet in length) to determine optimum spacing and loading of holes at the beginning of each cut and wherever the character of rock changes appreciably.

The Contractor shall place the adjacent line of production holes inside the presplit line (or lines) in such a manner as to minimize damage to the presplit face. The bottom elevation of the production holes shall not be lower than the bottom of the presplit holes.

No portion of production holes shall be drilled within 8 feet of a presplit plane, except as approved by the Engineer.

The Contractor will be required to drill the first line of production holes parallel to the slope line, if necessary to reduce shatter and overbreak of the presplit surface.

Only standard cartridge explosives, prepared and packaged by explosive manufacturing firms, will be permitted for use in presplit holes. These may consist of either fractional portions of standard cartridges affixed to the detonating cord in the field or solid column explosives jointed and affixed to the detonating cord in the field.

The maximum diameter of standard explosives used in presplit holes shall not be greater than 1/2 the diameter of the presplit hole.

If fractional portions of standard explosive cartridges are used, the cartridges shall be firmly affixed to a length of detonating cord equal to the depth of the drill hole, so that the cartridges will not slip down the detonating cord nor cock across the hole and bridge the flow of stemming material. Spacing of cartridges along the detonating cord shall be approximately 12 inches to 18 inches on centers.

If a solid column type of explosive is used, the column shall be assembled and affixed to the detonating cord in accordance with the explosive manufacturer's instructions, a copy of which shall be furnished to the Engineer.

A charge of 2 to 3 times the strength of line charges shall be placed in the bottom of the hole. The Contractor will be required to reduce this bottom loading if overbreak occurs.

The top charge of the presplitting hole shall be placed 3 feet from the collar of the drill hole.

Before placing the charge the Contractor shall determine that the hole is free of obstructions for its entire depth. All necessary precautions shall be exercised so that the placing of the charge will not cause caving of material from the walls of the hole.

After a charge is prepared it shall be lowered into the hole and stemmed completely with clean stone chips, all of which pass a 3/8" sieve and at least 90 percent of which are retained on the No. 8 sieve. All presplitting holes shall be completely filled to the collar with stemming material.

All charges in each presplitting pattern shall be detonated simultaneously.

The presplit face shall not deviate more than one foot from the plane passing through adjacent drill holes, except where the character of the rock is such that in the opinion of the Engineer, irregularities are unavoidable. The requirements in Section 19-2.05, "Slopes," of the Standard Specifications shall not apply to cut slopes where presplitting is specified.

As long as equally satisfactory presplit slopes are obtained, the Contractor may either presplit the slope face prior to drilling for production blasting or presplit the slope face and production blast at the same time, provided that the presplitting drill holes are fired with zero delay and the production holes are delayed starting at the row of holes farthest from the slope and progressing in steps to the row of holes nearest the presplit line, which row shall be delayed at least 150 milliseconds.

Whichever method of blasting sequence the Contractor elects to use, the 30 feet minimum advance presplitting provision shall apply.

Any production blasting technique, which results in damage to the presplit surface shall be immediately discontinued.

Presplitting rock cut slopes will be measured by the actual linear feet of holes drilled, loaded, stemmed, and detonated at the locations specified herein.

Those holes that fail to meet the alignment controls specified herein will not be accepted for payment, and holes that are drilled where the finished slope does not meet the slope tolerance specified herein will not be accepted for payment. Only those holes that qualify as to alignment and slope finish and which show undistributed hole trace between the presplitting explosive charges, or if a continuous charge is used show an undisturbed hole trace for approximately 1/2 of the drilled length, will be accepted and measured for payment purposes and no compensation will be allowed for unacceptable presplit work.

The contract price paid per linear foot for drilling holes (presplitting) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in drilling, loading, stemming, and detonating, as shown on the plans, as specified in these special provisions and the Standard Specifications, and as directed by the Engineer.

Auxiliary drill holes along the presplit line, ordered by the Engineer, not loaded or stemmed, shall not be considered as presplit holes and shall be paid for as extra work as provided for in Section 4-1.03D of the Standard Specifications.

APPENDIX II

Proposed Specifications
For Inclusion Into The
Standard Special Provisions

Recommended Specifications for Presplitting

Rock Cut Slopes

Presplitting rock cut slopes shall be performed at the locations described herein in accordance with the excavation provisions in Section 19 "Earthwork" of the Standard Specifications and these special provisions.

Presplitting is defined as the establishment of a free surface or shear plane in rock along the specified cut slope by the controlled usage of explosives and blasting accessories in appropriately aligned and spaced drill holes.

The presplitting technique, as covered herein, shall be used for forming rock cut slopes when designated in the plans.

The contractor shall first completely remove all overburden soil and weathered rock along the top of the cut for a distance of at least 50 feet prior to drilling the presplitting holes. Particular care and attention shall be directed to the beginning and end of cuts to insure complete removal of all overburden soil and weathered rock and to expose fresh rock to an elevation equal to the bottom of the adjacent lift of presplitting holes being drilled.

Slope holes for presplitting shall be drilled along the line of the planned slope within the tolerances herein set forth. These tolerances also apply to auxiliary holes which are identical to presplitting holes except they are not loaded with explosives. The drill holes shall be not less than 2½ inches and not more than 3 inches in diameter. The Contractor shall control his drilling operations by the use of proper equipment and technique to insure that no hole shall deviate from the plane of the planned slope by more than 12 inches nor shall any holes in the plane of the slope be within one-third of the planned horizontal spacing of any other hole.

The length of presplit holes for any individual lift shall not exceed 30 feet unless the Contractor can demonstrate to the Engineer that he can stay within the above tolerances and produce a uniform slope, then the length of holes may be increased to a maximum of 60 feet upon written approval of the Engineer.

The spacing of presplit holes shall not exceed 36 inches on centers and shall be adjusted to result in a uniform shear face between holes.

The Contractor shall place the adjacent line of production holes inside the presplit lines in such a manner as to avoid damage to the presplit face.

The Contractor may be required to drill the first line of production holes parallel to the slope line at the top of the cut and at each bench level thereafter if necessary to reduce shatter and overbreak of the presplit surface.

Any blasting technique, which results in damage to the presplit surface, shall be immediately discontinued.

No portions of production holes shall be drilled within 8 feet of a presplit plane except as approved by the Engineer. The bottom of the production holes shall not be lower than the bottom of the presplit holes.

A maximum offset of 24 inches will be permitted for a construction working bench at the bottom of each lift for use in drilling the next lower presplitting pattern.

The Contractor shall adjust his drilling operations to compensate for drift of previous levels and for the offset at the start of new levels to maintain the specified slope plane.

If at any time the methods of drilling and blasting do not produce the desired results of a uniform slope and shear face without overbreak, all within the tolerances specified, the Contractor shall be required to drill, blast and excavate short sections, up to 100 feet, until a technique is arrived at that will produce the desired results.

The maximum diameter of explosives used in presplit holes shall not be greater than 1/2 the diameter of the presplit hole.

Only standard cartridge explosives prepared and packaged by explosive manufacturing firms will be permitted for use in presplit holes. These may consist of fractional portions of standard cartridges to be affixed to the detonating cord in the field or solid column explosives joined and affixed to the detonating cord in the field.

If fractional portions of standard explosive cartridges are used, the cartridges shall be firmly affixed to a length of detonating cord equal to the depth of the drill hole so that the cartridges will not slip down the detonating cord nor cock across the hole and bridge the flow of stemming material. Spacing of cartridges shall not exceed 30 inches and shall be adjusted to give the desired results.

If a solid column type of explosive is used, the column shall be assembled and affixed to the detonating cord in accordance with the explosive manufacturer's instructions, a copy of which shall be furnished to the Engineer.

The bottom charge of a presplit hole may be larger than the line charges but shall not be large enough to cause overbreak. The top charge of the presplitting hole shall be placed far enough below the collar to avoid overbreaking the surface.

Before placing the charge the Contractor shall determine that the hole is free of obstructions for its entire depth. All necessary precautions shall be exercised so that the placing of the charge will not cause caving of material from the walls of the hole.

Stemming may be required by the Engineer whenever necessary to achieve a satisfactory presplit face. Stemming materials shall be dry free-running material all of which passes a 3/8-inch sieve and 90 percent of which is retained on a #8 sieve. Stemmed presplit holes shall be completely filled to the collar.

All charges in each presplitting pattern shall be detonated simultaneously.

The tolerance requirements of Section 19-2.05 "Slopes" of the Standard Specifications shall not apply to presplit surfaces of cut slopes where presplitting is specified. The presplit face shall not deviate more than one foot from the plane passing through adjacent drill holes, except where the character of the rock is such that in the opinion of the Engineer, irregularities are unavoidable. When completed the average plane of the slopes shall conform to the slopes indicated on the plans and no point on the completed slopes shall vary from the designated slopes by more than one foot. Completed slopes within 10 feet of grade shall not be more than 0.5 foot full. These tolerances shall be measured perpendicular to the plane of the slope. In no case shall any portion of the slope encroach on the roadbed.

As long as equally satisfactory presplit slopes are obtained, the Contractor may either presplit the slope face prior to drilling for production blasting or may presplit the slope face and production blast at the same time, provided that the presplitting drill holes are fired with zero delay and the production holes are delayed starting at the row of holes farthest from the slope and progressing in steps to the row of holes nearest the presplit line, which row shall be delayed at least 50 milliseconds. In either case the presplitting holes shall extend either to the end of the cut or for a distance of not less than 50 feet beyond the limits of the production holes to be detonated.

Those holes that fail to meet the alignment controls specified herein will not be accepted for full payment and holes that are drilled where the finish slope does not meet the slope tolerances specified herein will not be accepted for payment. Only those holes that qualify as to alignment and slope finish and which show a hole trace for approximately one-half of the drilled length will be accepted and measured for full payment purposes. Those holes which produce an acceptable slope and

meet all tolerances and requirements except alignment within the plane of the slope shall be paid for at a rate of 75% of bid price. Auxiliary holes shall be paid for at a rate of 75% of the bid price. No compensation will be allowed for unacceptable presplit work. Evaluation of presplit holes qualifying for payment should be made after excavation but before any slope trimming or cleanup work.

Measurement of presplitting hole length for payment of acceptable holes shall be by theoretical slope length as computed from elevations taken before detonating each lift, to be presplit, and a plane 3 feet below finish grade. No payment shall be made for drilling more than 3 feet below finish grade unless directed by the Engineer.

The contract price paid per linear foot for drilling holes (presplitting) shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all the work involved in drilling, loading, stemming and detonating, as specified in these special provisions and as directed by the Engineer.

APPENDIX III

Specifications Currently Used

With Standard Special Provisions

Recommended Specifications for Presplitting

Rock Cut Slopes

Presplitting rock cut slopes shall be performed at the locations described herein in accordance with the provisions in Section 19 "Earthwork" of the Standard Specifications and these special provisions.

Presplitting is defined as the establishment of a free surface or shear plane in rock along the specified cut slope by the controlled usage of explosives and blasting accessories in appropriately aligned and spaced drill holes.

The presplitting technique, as covered herein, shall be used for forming rock cut slopes between the following limits:

The Contractor shall completely remove all overburden soil and weathered rock along the top of cut for a distance of at least 50 feet prior to drilling the presplitting holes. Particular care and attention shall be directed to the beginning and end of cuts to insure complete removal of all overburden soil and weathered rock and to expose fresh rock to an elevation equal to the bottom of the adjacent lift of presplitting holes being drilled.

Slope holes for presplitting shall be drilled along the line of the planned slope within the tolerances herein set forth. The drill holes shall be not less than 2½ inches and not more than 3 inches in diameter. The Contractor shall control his drilling operations by the use of proper equipment and technique to insure that no hole shall deviate from the plane of the planned slope by more than 8 inches nor shall the hole deviate more than 12 inches from a vertical plane normal to the planned slope.

The length of presplit holes for any individual lift shall not exceed 40 feet unless the Contractor can demonstrate to the Engineer that he can stay within the above tolerances and produce a uniform slope, then the length of holes may be increased to a maximum of 60 feet upon written approval of the Engineer.

The spacing of presplit holes shall not exceed 36 inches on centers and shall be adjusted to result in a uniform shear face between holes.

The Contractor shall place the adjacent line of production holes inside the presplit lines in such a manner as to avoid damage to the presplit face. The bottom of the production holes shall not be lower than the bottom of the presplit holes.

No portions of production holes shall be drilled within 8 feet of a presplit plane except as approved by the Engineer.

The Contractor will be required to drill the first line of production holes parallel to the slope line at the top of the cut and at each bench level thereafter if necessary to reduce shatter and overbreak of the presplit surface.

A maximum offset of 24 inches will be permitted to a construction working bench at the bottom of each lift for use in drilling the next lower presplitting pattern.

The Contractor shall adjust his drilling operations to compensate for drift of previous levels and for the offset at the start of new levels to maintain the specified slope plane.

If at any time the methods of drilling and blasting do not produce the desired results of a uniform slope and shear face without overbreak, all within the tolerances specified, the Contractor shall be required to drill, blast and excavate short sections, up to 100 feet, until a technique is arrived at that will produce the desired results.

Only standard cartridge explosives prepared and packaged by explosive manufacturing firms will be permitted for use in presplit holes. These may consist of fractional portions of standard cartridges to be affixed to the detonating cord in the field or solid column explosives jointed and affixed to the detonating cord in the field.

The maximum diameter of standard explosives used in presplit holes shall not be greater than 1/2 the diameter of the presplit hole.

If fractional portions of standard explosive cartridges are used, the cartridges shall be firmly affixed to a length of detonating cord equal to the depth of the drill hole so that the cartridges will not slip down the detonating cord nor cock across the hole and bridge the flow of stemming material. Spacing of cartridges shall not exceed 30 inches and shall be adjusted to give the desired results.

If a solid column type of explosive is used, the column shall be assembled and affixed to the detonating cord in accordance with the explosive manufacturer's instructions, a copy of which shall be furnished to the Engineer.

The bottom charge of a presplit hole may be larger than the line charges but shall not be large enough to cause overbreak. The top charge of the presplitting hole shall be placed far enough below the collar to avoid overbreaking the surface.

Before placing the charge the Contractor shall determine that the hole is free of obstructions for its entire depth. All necessary precautions shall be exercised so that the placing of the charge will not cause caving of material from the walls of the hole.

Stemming may be required by the Engineer whenever he deems it necessary to achieve a satisfactory presplit face. Stemming materials shall be dry free-running material all of which passes a 3/8-inch sieve. Stemmed presplit holes shall be completely filled to the collar.

All charges in each presplitting pattern shall be detonated simultaneously.

The presplit face shall not deviate more than 1 foot from the plane passing through adjacent drill holes, except where the character of the rock is such that in the opinion of the Engineer, irregularities are unavoidable. The requirements of Section 19-2.05 "Slopes" of the Standard Specifications shall not apply to cut slopes where presplitting is specified.

As long as equally satisfactory presplit slopes are obtained, the Contractor may either presplit the slope face prior to drilling for production blasting or may presplit the slope face and production blast at the same time, provided that the presplitting drill holes are fired with zero delay and the production holes are delayed starting at the row of holes farthest from the slope and progressing in steps to the row of holes nearest the presplit line, which row shall be delayed at least 50 milliseconds.

Drilling and blasting for presplitting shall be kept between 30 and 50 feet in advance of adjacent production blasting.

Any blasting technique, which results in damage to the presplit surface, shall be immediately discontinued.

Presplitting rock cut slopes will be measured by the linear feet of drilled and open hole at the time of loading, at the locations specified herein.

Those holes that fail to meet the alignment controls specified herein will not be accepted for payment and holes that are drilled where the finish slope does not meet the slope tolerance specified herein will not be accepted for payment. Only those holes that qualify as to alignment and slope finish and which show a hole trace for approximately 1/2 of the drilled length will be accepted and measured for payment purposes and no

compensation will be allowed for unacceptable presplit work. Evaluation of presplit holes qualifying for payment should be made after excavation but before any slope trimming or cleanup work.

The contract price paid per linear foot for drilling holes (presplitting) shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all the work involved in drilling, loading, stemming and detonating, as specified in these special provisions and as directed by the Engineer.