EXPLOSION AT SIX BELLS COLLIERY MONMOUTHSHIRE

Report and Maps

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MINISTRY OF POWER

EXPLOSION AT SIX BELLS COLLIERY, MONMOUTHSHIRE

REPORT

On the causes of, and circumstances
attending, the explosion which occurred at
Six Bells Colliery, Monmouthshire,
on 28th June, 1960

by

T. A. ROGERS, C.B.E., M.I.Min.E.
H.M. Chief Inspector of Mines and Quarries

Presented to Parliament by the Minister of Power
by Command of Her Majesty
January, 1961

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TABLE OF CONTENTS

REPORT ON THE CAUSES OF, AND CIRCUMSTANCES ATTENDING, THE EXPLOSION WHICH OCCURRED AT SIX BELLS COLLIERY, MONMOUTHSHIRE, ON 28TH JUNE, 1960

15th December, 1960.

The Right Honourable Richard Wood, M.P.,
Minister of Power.

Sir,

1. In accordance with your direction under Section 122 of the Mines and Quarries Act, 1954, I held a public inquiry with respect to the accident which occurred at Six Bells Colliery in the County of Monmouth on 28th June, 1960.

2. I find that an ignition of firedamp occurred at about 10.45 a.m. near the face of the intake airway and loading gate of the O.10 conveyor face in W District of the Old Coal Seam, that ignited and that the explosion spread practically throughout the district. Forty-five of the forty-eight men there at the time were killed; their names are given in Appendix I. The evidence in general, and in particular the known presence of lethal concentrations of carbon monoxide, suggests that the victims lost consciousness rapidly and that death occurred within a few minutes. The three survivors were on the fringe of the explosion area and escaped with only minor injuries. There was no satisfying evidence of the initial igniting cause but, on balance, I consider it probable that the firedamp was ignited by an incendive spark caused by the impact of a quartzitic stone falling from the roadway roof near the face ripping lips onto a steel canopy provided to shelter the roadway conveyor during blasting operations.

3. I opened the inquiry in No. 2 Court of the Civic Centre, Newport, on 19th September, 1960, and sat on eight days until 28th September. The following parties were represented:—

The Minister of Power, by Mr. C. Leigh, M.I.Min.E., H.M. Divisional Inspector of Mines and Quarries, South Western Division, with Dr. E. M. Guénault, Deputy Director of the Safety in Mines Research Establishment.

The National Coal Board, by Mr. G. G. Baker, Q.C., with Mr. A. G. Davies, Barrister-at-Law.

The National Union of Mineworkers, The South Wales Area, by Mr. E. Ryder Richardson, Q.C., with Mr. I. B. Fife, Barrister-at-Law; the National Executive Committee, by Mr. W. Whitehead, President of the South Wales Area.

The National Association of Colliery Overmen, Deputies and Shotfirers, by Mr. P. Wien, Barrister-at-Law.

The National Association of Colliery Managers and the British Association of Colliery Management, by Sir Andrew Bryan, D.Sc., LL.D., F.R.S.E., M.I.Min.E.

4. Seventy-three witnesses gave evidence; their names are given in Appendix II.

GENERAL DESCRIPTION

The Colliery

5. Six Bells Colliery, formerly known as Arrael Griffin Nos. 4 and 5, is in the No. 6 Area of the National Coal Board's South Western Division and is situated at Six Bells, some twelve miles north of Newport in the Western Valley of Monmouthshire.

6. There are three shafts. One of these, a downcast and man-riding shaft known as Vivian Pit and situated nearly half a mile north, was formerly part of another mine and its existence is not material to the circumstances of this accident. The other two are at Six Bells and are both used for winding men, coal and materials. No. 4, the upcast, is equipped with an electrically driven exhausting fan with a capacity of 280,000 cubic feet per minute at 4·6 inches water gauge; No. 5 is the downcast.

7. There were 1,213 men employed below ground and 239 on the surface. The output was about 1,800 tons of saleable coal per day, about 830 tons coming from the Old Coal Seam.

8. The colliery has always been a safety lamp mine. There were 1,450 electric cap lamps, 85 flame lamps for use by workmen as firedamp detectors and 79 internal relighter type flame lamps for use by officials.

9. The Under-manager of No. 5 Pit, which included W District, was F. White, who was killed in the explosion; the Colliery Manager was V. Luther; the Group Manager, R. Williams; the Area Production Manager, A. E. Hiscox; and the Area General Manager, L. Walker.

The Old Coal Seam

10. The Old Coal Seam, the lowest worked, was 352 yards deep at the Six Bells shafts but the average depth of W District was 550 yards, the increase being due in part to seam dip but mainly to surface rise. The seam thickness averaged four feet nine inches with a middle dirt band a few inches thick. The Meadow Vein coal, some 22 yards above, had not been worked in this area. The strata between these seams were mainly strong 'clift' or shale, but included two features which call for special mention. Some five feet above the Old Coal Seam there often occurred a bed of quartzitic sandstone about one foot three inches thick. This was found in the shaft sinkings and observed in parts of the district after the explosion. There was also a 'rider' coal, some one foot six inches thick, about 25 feet above the Old Coal Seam.

W District

Lay-out

11. Plan No. 1 shows the W District in relation to active and disused workings from Nos. 4 and 5 Shafts of Six Bells Colliery and also to disused workings in the Old Coal Seam from Marine Colliery, where a disastrous explosion occurred in the Black Vein in 1927.

12. The working faces in the W District were identified by a number prefixed by the letter 'O'. There were three single-unit longwall conveyor faces situated between one mile and one mile and a quarter from the shafts; all three were advancing northwards towards the disused workings of Marine Colliery The O.10 unit had on its right side the gob of a series of previously worked faces; O.12 unit was beginning to skirt the left side of O.10 unit; O.18 unit had solid coal on both sides. The gradients of the intakes and faces are shown on Plan No. 1; roadways rose slightly towards the faces which, in turn, rose slightly from west to east. O.10 and O.18 were normal production units and O.12 a standby face; coal was filled for two weeks out of three on the morning shift and in the third week on the afternoon shift.

Methods of working coal

13. The O.10 face was 103 yards long and had been advanced at the rate of about 12 yards a month to within about 55 yards of the Marine Colliery old workings. The coal was cut near the floor to a depth of three and a quarter feet by a machine mounted on an armoured conveyor; both machines were compressed air driven. Hydraulic props and linked bars a metre long were used in a 'prop-free front' system of support. The roadside packs were eight yards wide and the waste between was completely caved. The intake loading gate was supported by steel arches backed with wood lagging, the necessary height being obtained by a roof ripping six feet thick. The arches, twelve feet wide and ten feet high, were commonly known as twelve feet arches. The road that had formerly been the intake for O.9 face had become the supply road for O.10 and was being reconditioned as the face advanced. Shots were fired in coal and in the stone of the intake face ripping.

14. The O.18 face was 96 yards long and had been advanced at the rate of about 27 yards a month. The coal was cut near the floor to a depth of four feet six inches and filled by hand onto a belt conveyor, both machines being driven by compressed air. The roof was supported by adjustable friction-type props and linked bars four feet six inches long. The waste had been completely caved until difficult roof conditions prompted a change in May, 1960, to strip packing; the packs were four yards wide and the wastes nine yards. The intake road was supported with twelve feet arches for the first 200 yards of its length and with eight feet arches, eight feet wide and seven feet high, for the last 40 yards. The return was supported with ten feet arches. The necessary height was made by ripping mainly in the roof. Shots were fired in coal and, except in the intake, in stone.

15. The O.12 standby face was 118 yards long. The coal was worked and filled by hand onto an electrically driven scraper chain conveyor. The face had been advanced a total distance of 20 yards, and only ten yards

in the six months before the explosion; it was last worked for one shift on 8th June, 1960.

Transport of coal and supplies

16. Coal from the face conveyors was transported by way of stage loaders and semi-troughed belt gate conveyors to

conveyors in tandem on the main intake; all were electrically driven. The tram-loading point was on the double parting near old O.1 intake.

17. Supplies for O.18 unit were distributed in trams by a system of compressed air driven haulages from the double parting through O.7 Crosscut to the main return and thence to the face of the supply gate. Those for O.10 and O.12 units were taken in trams through O.7 Crosscut to the main return, then back through O.2 Crosscut to the main intake and there off-loaded and manhandled; they were drawn up O.10 supply gate on a single tram hauled by a compressed air driven engine situated near the face.

Ventilation

18. The directions of the main ventilating currents are shown by coloured arrows on Plan No. 2. A little more than 5,000 cubic feet of air per minute entered O.10 face from its loading gate and about another 1,500 cubic feet per minute of controlled leakage air passed along the supply gate. The firedamp content at the statutory observing point, 30 feet on the return side of the face, averaged about 0·25 per cent. About 9,500 cubic feet of air per minute reach O.18 face and the percentage of firedamp 30 feet from the face averaged 0·8. There was no express provision made to deflect air into O.12 face, but some—measured after the explosion to be 3,300 cubic feet per minute at the lower end of the face—naturally took this course and, to this extent, the

with that of O.12.

General experience

19. The only major difficulty encountered in the working of O.10 unit arose from a large roof cavity which developed in the intake near two parallel faults some 170 yards from the main intake. The cavity apparently began at the roadhead and extended as the face advanced until it was at least 30 feet long and some 20 to 30 feet high from the roof of the seam, and certainly as high as the ‘rider’ coal. The arches set beneath the cavity were originally covered with lagging timber and some debris. This condition might have been altered by subsequent repair work, but it seems more than probable that by the time the explosion occurred there was a considerable thickness of fallen stone above the lagging. Firedamp apparently

face ripping until, but not after, 9th May, 1960; at the time of the explosion it was not considered necessary to maintain a brattice sheet at the face ripping. Small quantities of firedamp continued to be found quite frequently elsewhere in the unit.

20. Firedamp in small quantity was found occasionally at the O.12 loader gate face ripping.

21. The most serious trouble from the ventilation point of view was encountered in O.18 unit. Firedamp

roadhead face ripping and from time to time shots could not be fired there.

The area ventilation engineer, R. W. Simpson, investigated the problem in December, 1959, and on his recommendation a " Venturi " type air blower was installed at the ripping. This did not, however, altogether overcome the difficulty and in May, 1960, the thickness of the roof ripping was reduced from about six feet to three feet by taking up some of the floor and reducing the size of the roadway by using eight feet arches. The manager prohibited shotfiring at the ripping and arranged for methanometer surveys of the unit with daily reports of the results. Another " Venturi " was installed in the face ripping of the return roadhead.

THE SHIFTS IMMEDIATELY BEFORE THE EXPLOSION

The Afternoon Shift on 27th June

22. Coal filling proceeded normally throughout the afternoon shift of 27th June on O.10 unit under the supervision of W. Doel, an overman, and J. D. McDonald, a deputy. R. Hall, a deputy acting as a shotfirer, assisted by K. Baker, a collier, fired some 30 shots in the coal ; neither Hall nor the overman, who had tested the waste at the return end of the face before any shots were fired, found any indication of firedamp. McDonald, on his mid-shift inspection, found small feeders of firedamp in O.10 and O.9 returns and in O.12 loader gate. During his pre-night shift inspection, he found the same small issues.

23. T. G. Morgan, the overman in charge of O.18 said that, because of trouble with the conveyors, coal filling started late in the shift and the 'cut' was not cleared. The deputy for O.18 unit, D. E. Price, during both his mid-shift and his pre-night shift inspections, found firedamp at the face ripping in the return, at the face ripping of the intake, and at two places on the face. It was reported to him late in the shift that a coupling on the face conveyor motor had been sparking, but when he reached the place this had been attended to by a fitter and Price was satisfied that the trouble had been rectified.

The Night Shift on 27th-28th June

24. Only ripping and repair work was being done on the night shift of 27th-28th June in O.10 unit, where deputy R. H. Law was in charge. In his mid-shift inspection, he found small quantities of firedamp in the returns of O.9 and O.10. During his pre-day shift inspection, he found slight indications of firedamp in the return end of the waste and in the return of O.10 unit, in O.9 return rippings and in a cavity farther outbye. He did not find any firedamp in O.10 intake rippings during either of his inspections.

25. At about 3.00 a.m., E. Boots, a shotfirer, assisted by J. H. Evans, fired a round of four shots with a six-shot exploder in O.10 intake face rippings. Boots said that he tested for firedamp ; he examined the holes with a break detector and charged each of them with two four-ounce cartridges of Unigex explosive. Evans filled sufficient stemming bags with stone dust. Boots did not put a filled bag at the back of any hole before charging. He fired the round, examined the rippings for firedamp and pulled down some loose stone. Law was not present during the shotfiring but in his inspection later he noticed some bed separation at the face of the

ripping. The fore-poling supports had not been advanced, but he considered that this could safely be left for the day shift as nothing was likely to fall.

26. In O.18 unit, deputy W. C. Nash, during his pre-day shift inspection. detected some firedamp in the intake ripping and there replaced a brattice sheet. There was no shotfiring in this unit during the night.

27. W. V. Jenkins and A. Mathews, underground fitters, were putting a two-inch compressed air supply pipe through an existing hole in the brickwork of O.9 Undercast. They noticed that an arch girder on the face side of the undercast had shifted slightly and that a small quantity of debris had fallen, but they apparently considered that there was no immediate danger of further falls. The compressed air was twice cut off from the whole district as Jenkins also repaired a tapping gland on an eight inch compressed air supply pipe. The first period was from about 11.30 p.m. to 12.15 a.m. and the second from about 5.30 a.m. to 6.15 a.m. During these periods the "Venturi" appliances in O.18 unit could not function.

The Day Shift on 28th June

28. The day shift descended as usual between 6.00 a.m. and 6.30 a.m. on 28th June. Nobody can say what work the men were doing on that shift, but the manager said he would have expected the following distribution—five men, including the deputy, on O.10 face; three or four men on the face rippings of O.18 intake; two men working the coal cutting machine at the return end of O.18 face; a maximum of six supply men in O.18 return; and a borer and his assistant in the return just outbye of the crosscut near O.18 unit. The rest of the men, who normally would have been advancing packs, withdrawing supports and advancing the face conveyor, should on this shift have been along the main loader belts because the manager, having received a report that the conveyors were getting into a dirty state, had arranged that they should be thoroughly cleaned.

THE EXPLOSION AND RECOVERY

The Explosion

29. At about 10.45 a.m. on Monday, 28th June, M. Purnell, a linesman. was working with D. Lane putting up a signal line near the electric haulage engine some 25 yards inbye of the entrance of the old T intake. Lane was some ten yards inbye of Purnell when there was a noise and a lot of dust. Purnell fell on the engine and Lane was blown past him. Purnell had no idea what had happened but when he picked himself up he found Lane apparently dead. He began to make his way to the pit bottom, feeling along pipe ranges because the air was thick with dust.

30. Two fitters, H. J. Legge and C. J. Lewis, were eating food by the transformers in the mouth of the old T intake when they heard a sound like a compressed air pipe bursting. There was a great deal of dust in the air and they lost contact with each other but each made for the pit bottom as best he could. Legge thought that a transformer had blown up and on his way outbye he telephoned to the pit bottom. Shortly afterwards he met S. Holland, a deputy, and W. Coleman, an underground engineer, who were coming in to investigate, and told them of his experience.

Rescue and Recovery

31. S. Holland was the deputy responsible for the inspection of airways and thus had a good knowledge of the pit ; he and Coleman had been coming outbye from an old district when they met a cloud of dust. They thought that a compressed air supply pipe had broken and they hurried to the downcast pit bottom. The dust cloud had also been seen at both shafts and someone had telephoned the surface. Holland received from the manager at the surface a telephoned instruction to investigate, and he and Coleman went inbye along the main intake towards W District. They met a number of men going about their normal work and were told that a man nearby was feeling ill ; Holland gave instructions for him to be taken out of the pit. He did not speak to the man who, as he realised later, must have been Lewis.

32. Holland and Coleman later met Legge who told them of his experience at old T transformers. They went to these transformers but, finding them apparently undamaged, returned to the main intake and continued inbye. A few yards past the junction with old T intake they saw a body which must have been that of Lane. At the double parting they found the air so thick with dust that they concluded an explosion must have occurred. They were unable to make contact with the pit bottom by telephone so Holland sent Coleman out to report to the manager and went on alone. Just inbye of the airbridge at O.7 he found a fall of ground almost blocking the main intake and decided to retreat. On the way outbye he noticed that one of two separation doors in the mouth of old T return was damaged. The other was open ; he closed it and observed then a considerable increase in the quantity of air passing down the main intake.

33. Holland continued outbye and met the manager and the area general manager, who happened to be making a visit to the colliery ; he reported his findings to them and the manager issued instructions that all men were to be withdrawn from the pit and the emergency procedure put into operation. All three hastened to the surface to study the plans of the mine and to decide upon action necessary in the light of the knowledge that access to the W District by the main intake was blocked by the fall of roof.

34. The manager and Holland very shortly afterwards returned below ground with a canary and on their way inbye met H. Silverthorne, an overman ; these three went to the fall and there met P. J. McLaughlin, another overman, who was captain of the colliery rescue team. They also found there a number of other men among whom was B. Rees, a collier in No. 4 Pit, who was chairman of the colliery lodge of the National Union of Mineworkers. Some of these men had found two doors in O.7 Crosscut destroyed and had fixed up a temporary door to assist the restoration of ventilation.

35. The manager instructed everyone to leave the pit except Holland, Silverthorne and McLaughlin, who then accompanied him through O.7 Crosscut into the main return. There they tested for firedamp and found up to two per cent. in the general body of the air. Some 15 yards inbye of the junction of O.9 return, McLaughlin saw that the canary had died so the party had to retreat. They went back to the fall in the main intake and started to make a hole over it. They had just succeeded in doing so when rescue teams began to arrive.

36. Rescue brigade men from Porth Central Rescue Station and Six Bells Colliery went down the pit soon after 1.00 p.m. under the supervision of the Superintendent of the Crumlin Rescue Station. After setting up a fresh air base, these teams at once started exploratory work in which they were later supported by two other teams.

37. The hole over the fall was not at first large enough to allow the passage of men wearing self-contained breathing apparatus and the first explorations were made by way of O.7 Crosscut and the main return. One team got as far as half way along O.18 face before being forced to retire because the 'life' of their breathing apparatus was expiring; they found a number of bodies and observed that the doors on the crosscut near O.18 unit had been blown towards the return. Another team went into O.9 return but encountered a fall of roof just inbye of O.9 Undercast. By the time these two teams had returned and reported, the hole over the fall in the main intake had been enlarged sufficiently to allow the passage of men wearing rescue apparatus. Other rescue teams made systematic explorations of all roads and faces. They returned to report that the air was stagnant and that there were no survivors.

THE INVESTIGATION

Nature and Scale of Examination

38. Preliminary examination of the affected area failed to disclose any obvious igniting cause and indicated that it would be far from easy to determine the point of origin of the explosion. The task was, however, undertaken in close collaboration by all concerned. National Coal Board management officials and specialists, Inspectors of the National Union of Mineworkers and H.M. Inspectors of Mines and Quarries all played their part in a sustained effort, the scale of which was illustrated by evidence given that H.M. Inspectors alone spent over 250 shifts at the mine. Scientific staff of the Safety in Mines Research Establishment (S.M.R.E.) made a meticulous inspection for indications of flame and blast and collected numerous samples and specimens for scientific examination in their laboratories. All the electrical and mechanical equipment of the district was examined *in situ* by specialists and many items were sent for test to the S.M.R.E.

Extent of the Explosion

39. Microscopic examination of over 500 specimens of dust and fibrous material indicated that flame had swept, as shown on Plan No. 3, through some 3,000 yards of roadway and each of the faces with the exception of O.10. Flame had traversed the main intake road, both roads serving O.10, most of the old O.9 return, the intake of O.18 and its return for 30 yards outbye from the face. The main return was affected only locally by flame through the [illegible] There were signs of prolonged burning of firedamp in two lengths of roadway, for 70 yards outbye from O.10 intake roadhead and for about 25 yards outbye from O.18 return roadhead.

Directions of Propagation

40. The explosion was not a violent one and for this reason indications of blast were not very prominent. Those disclosed by painstaking investigation, when considered as a whole, gave the indications shown by the green arrows on Plan No. 3. On the main intake there were signs pointing in both directions from near the junction with O.10 intake. The inbye indications persisted to and along O.18 intake and continued along the face. Signs in O.10 intake, on the whole, pointed outbye from the face. In O.10 supply gate, although the doors at the entrance were blown inbye towards the face, there were signs of blast in both directions at the junction of face and roadway ; in the restricted area of old O.9 face there were strong signs of blast towards the return. The brickwork sides of the O.9 Undercast were blown in directions away from the main intake, the doors in O.2 Crosscut, in O.7 Crosscut and in the crosscut near O.18 unit were all blown towards the return airways.

41. Specimens of coked dust indicated the directions of flame to have been as shown by the red arrows on Plan No. 3. These indications of direction were generally consistent with the indications of blast. Minor and local contra-indications observed were not at all unusual. There were clear signs that flame entered both ends of O.12 face. Coked dust depositions found in O.10 supply road indicated that flame had travelled from the main intake to O.9 old face and along it to O.9 return where it died out at about 200 yards from the face.

Ventilation Tests

42. A number of tests were made with the object of determining whether any reductions in quantities of air or changes in ventilating pressure would lead to the accumulation of firedamp at any point where it was not normally found. The amount of ventilation in and near the faces was greatly reduced by short-circuiting the main intake and return airways and, in O.10 unit, by blocking the old O.9 return. The trials were searching and prolonged beyond any likelihood of their duration in practice ; some of them were deliberately made at a time when the barometric pressure was favourable to the appearance of firedamp. Nothing significant emerged. The firedamp ceiling in the cavity on O.10 intake lowered a little ; a very thin roof layer was detected by probe and methanometer for some distance inbye but this firedamp dispersed into the general body of the air long before it reached the face. A careful watch was maintained, especially at times when barometric pressure was falling, close to the inaccessible connection between the old O.9 main gate and the Marine gob ; but there was not at any time an indication of firedamp being given off.

Safety Lamps

43. The safety lamps found in the affected area, forty-eight electric cap lamps and eight flame lamps, were examined at the S.M.R.E. Twenty-nine of the electric lamps were found to be undamaged and it was concluded that damage sustained by others had resulted from the explosion. Of the eight flame lamps, four were undamaged and three were slightly damaged but shown by tests to be still safe. One was badly damaged but as this lamp had been found on the main intake the damage was considered to be consequential.

Contraband

44. A police constable who examined the clothing of the victims at the surface found an unsmoked cigarette. A. S. Jones, H.M. Inspector of Mines and Quarries, found two live matches in a haversack underground. J. T. Thirlaway, area scientist, during investigations in the district, examined a polythene bottle and found inside it a plastic bag tied to the stopper by a thread. L. G. Fear, H.M. Senior District Inspector of Mines and Quarries, and members of his staff made further extensive and intensive searches for contraband in the district but with negative results.

Roadway Dust Samples

45. An examination of colliery records showed that the procedure followed in taking and testing roadway dust samples before the explosion was in order except that samples were not taken during the months of December, 1959, and April, 1960. No explanation was given for the omission in December, but the man whose duty it was to take samples in April said that he was prevented from doing so by his daily preoccupation with the ventilation of O.18 unit.

46. Forty-four samples were collected on 21st June, one week before the explosion, and 41 of these were found to contain over 80 per cent. of incombustible matter. The other three, all taken in the vicinity of the main loading point, contained, respectively, 57, 70 and 75·6 per cent. of incombustible matter. The volatile matter of the coal worked was less than 25 per cent. so that the management could, had they notified H.M. Inspectorate to that effect, have established 60 as the minimum percentage of incombustible matter required to be maintained. They had not done so and thus, by regulation, a minimum percentage of 75 automatically applied.

47. C. A. Bilton, H.M. Inspector of Mines and Quarries, collected six samples on 17th May, 1960, from places where he considered the combustible content likely to be highest—two just inbye the main loading point, two just inbye the transfer point from O.18 gate belt to the trunk belt and two in O.18 return immediately outbye the roadhead. Analyses of these samples showed that four contained more than 75 per cent. of incombustible matter. The other two contained more than 70 per cent. but less than 75 per cent. and H.M. Senior District Inspector, in correspondence, drew the attention of the management to these results; he was assured that the zones concerned had been re-treated and that the results of re-sampling had been satisfactory.

48. The results of post-explosion roadway dust sampling and analysis are indicated on Plan No. 4. The majority of these samples contained less than 75 per cent. of incombustible matter: of the 64 samples taken in conveyor roads 29 contained more than 60 per cent. but less than 75 per cent., and 29 contained less than 60 per cent. The discrepancy between the results of pre-explosion and post-explosion samples will be commented upon later.

Mechanical Apparatus

49. K. S. Worthington, H.M. Inspector of Mechanical Engineering, made a critical examination of the mechanical apparatus in W District and of air compressing machinery on the surface. The standard of installation and

maintenance was generally satisfactory. There were some minor defects but none of them contributed to the explosion.

50. A hole in a compressed air pipe had been repaired by paper and hemp rope, a malpractice which could cause a fire. A wooden plug was found to have been driven into a hole in the compressed air supply main about 40 yards from the roadhead of O.10 intake; the plug showed very slight signs of heat but this had apparently been caused by the explosion. Three compressed air pipe joints made with rubber rings were found to be 'blowing' rather badly on O.12 face, but laboratory examination of the rubber showed no sign of frictional heating.

51. The O.10 stage-loader driving motor situated about 30 yards from the face of the intake was found to be fitted with an aluminium alloy fan and cowl. The cowl had been fractured but the cracks did not seem to have been freshly produced, nor were there any recently-made indentations or abrasions. Some of the steel wires of the mesh guard covering the air inlet in the cowl had at some time fouled the roots of the fan blades, but the rubbed surfaces were not new. The fan was found to be free-running and without end play on the motor shaft, which might have allowed the fan to rub against the wires or other surface.

52. The haulage engine in O.10 supply gate was found with the throttle valve partly open, the brake off and reverse gear engaged: the rope 'lead' was underneath the drum, instead of above as it normally was. An empty supply tram was found at its outbye terminus between the two doors in O.10 supply gate. The haulage rope connected to it was very slack and a "barhook" (backstay) was attached to and beneath the tram as though it had been over-ridden. It was suggested that the haulage engine might have been running in reverse gear at the time of the explosion and that it continued to do so until the pressure of air fell after a breakage of pipes caused by the explosion. Tests carried out after the explosion showed that when the engine was left running after the tram had reached the outbye end of the road the spare rope stayed slack on the drum until it was caught up and coiled in the opposite direction. Old indentations on a girder of the haulage framework indicated that at some time the rope had coiled beneath the drum. The evidence that the engine might have been running was tenuous as the throttle lever might easily have been moved either in the explosion or accidentally afterwards; in any event, I am satisfied that incendive sparks would not have been produced.

Electrical Apparatus

53. A. L. Alexander, H.M. Electrical Inspector of Mines and Quarries, and Chief Testing Officers of the S.M.R.E. inspected all electrical apparatus in position and 95 items were sent to the S.M.R.E. for further critical examinations and tests. The apparatus was found to comply with the certified designs and, apart from minor defects, to have been well maintained.

54. Every flameproof enclosure was twice subjected to test to find whether, under the most stringent conditions, an explosion of firedamp in air within it would ignite a surrounding inflammable mixture of firedamp in air. The external inflammable atmosphere was not ignited in any of the 124 tests made.

55. The telephone and signalling appliances were tested for intrinsic safety in methane-air mixtures. Some items had been damaged by the explosion but the tests showed that an adequate margin of safety had existed under working conditions.

56. The remote control circuits associated with eight of the gate-end switches controlling the conveyor motors were certified as intrinsically safe in 1939, but have since been found, when tested by a more modern method, to be capable of igniting methane. In seven of the circuits used, however, the remote control cables were found intact and the remote control enclosures were proved to be flameproof. In the remaining circuit, the remote control switch housings were flameproof but the connecting cable was damaged ; the damage, however, was such that sparking could not have occurred.

57. A single-shot exploder found in O.18 return was tested and found to conform to its approval specification. The wire-armoured roadway cables were examined underground and tested at a voltage considerably higher than the working voltage without disclosing any defect liable to cause open sparking. All the flexible cables in use were examined at the surface and tested at a voltage considerably in excess of the working voltage, again without disclosing any defect which could have given rise to open sparking.

58. Tests were carried out on the two "Venturi" tubes to determine whether or not they could have accumulated an electrostatic charge sufficient to cause an ignition. These tests were made in conditions far more conducive to the development of such a charge than those likely to have been present in the pit, but the maximum charges developed were not capable of igniting firedamp.

THE CAUSE OF THE EXPLOSION

Point of Origin and Spread of the Explosion

59. F. J. Hartwell, a Senior Principal Scientific Officer of the S.M.R.E., said that the indications of the directions of blast and flame suggested to him that the explosion started in the vicinity of O.10 intake roadhead ; at this roadhead there appeared to be a zone of small disturbance in which little dust was raised but relatively prolonged burning of rich firedamp had occurred. The heavy burning observed on timber close to the ripping lip indicated slow burning at that point ; because of the gradient of the road, any accumulation of firedamp would have been thickest at the face of the ripping and this view was consistent with the degree of scorching of timber seen at floor level there. Had the explosion originated anywhere but at the O.10 intake roadhead, the flame would certainly have been forced on to O.10 face and this had not occurred. Taking into account the probable concentration of the firedamp and the fact that the flame reached the floor, he estimated that the amount of pure methane present at the time of the explosion was between 150 and 200 cubic feet. This quantity would have been enough to produce the violence necessary to raise coal dust farther outbye in O.10 intake. He considered that the explosion subsequently was one mainly of coal dust, principally that raised from conveyors for it

died out on the tram haulage section of the main intake and on the main return. The prolonged burning at O.18 return roadhead could only have been due to the inflammation of firedamp from open breaks, together with some from the adjacent waste. The signs of extra violence found near O.10 supply roadhead might have been due to firedamp forced out of the waste by the explosion in the intake.

60. Hartwell had carefully considered, and put forward tentatively, a possible alternative theory visualising that a preliminary ignition might have occurred at O.10 supply roadhead, that flame then passed through the waste to ignite gas in O.10 intake roadhead, and that this in turn caused the coal dust explosion. In a number of cases flame has been proved to have travelled long distances in open breaks across wastes. But to satisfy the theory in this case it was necessary to postulate either that the ignition at the supply roadhead coincided with the accumulation of firedamp at the intake roadhead, or that the ignition in the supply roadhead forced firedamp, not on to the face, but by some means into the intake roadhead, where it was virtually unmixed with air when reached by the flame. Neither of these hypotheses seemed likely. He, therefore, adhered to the opinion that the explosion started in O.10 intake roadhead.

61. With one exception, to which I shall refer later, mining experts of the National Coal Board, the National Union of Mineworkers and H.M. Inspectorate all agreed with this view.

62. There was not immediately apparent in this location the necessary coincidence of an incendive agency and a source of firedamp in quantity sufficient upon ignition to raise and ignite coal dust. Even so, careful consideration of the possibilities leads me to accept O.10 intake roadhead as the most likely place of origin of the explosion.

Source of Firedamp

63. The fact that firedamp had not been found in the O.10 intake ripping since 9th May---some seven weeks before the explosion---suggested that something unusual must have happened to cause the accumulation there of about 150 cubic feet of firedamp in a period not longer than the five hours or so which elapsed between the night shift deputy's examination at about 5.30 a.m. and the explosion. Firedamp persisted after the explosion. For example, two days later H. L. S. Johnston, Under-manager of the No. 4 Pit, observed one and a half per cent. midway up both O.10 intake and O.10 supply gate. The ventilation had not then been restored and so a large emission of firedamp is not necessary to account for Johnston's observation. The possibility arose of firedamp having migrated to the roadhead by layering along the roof of the roadway from the large cavity some 100 yards outbye on this road but, in the light of the ventilation tests made afterwards, I conclude that it was unlikely to have happened. Tests in boreholes later drilled into the roof between the cavity and the ripping did not indicate any substantial flow along breaks or bed separation channels.

64. Another possibility was that the firedamp reached the roadhead as a consequence of displacement of firedamp by a large fall of roof in the waste. In all probability any firedamp in the waste would normally be confined to the upper and return end of it and, even if there had been such a fall, firedamp would not have been forced out to the roadhead.

65. More likely than the displacement of already released firedamp is the opening of new channels for firedamp emission, perhaps from the 'rider' coal, by ground movement. There are many recorded cases of large feeders of firedamp having issued quickly, but such feeders have usually been associated with obviously abnormal ground movement and have not been short-lived. The investigations after the explosion discovered neither such ground movements nor a substantial feeder. There could, however, have been enough extra roof movement to create new channels for a slow issue of firedamp close to the roadhead itself. J. Grindle, a repairer, spoke of the appearance of bed separation at the roadhead the day before the explosion and R. H. Law observed it after the shotfiring on the night shift. A possible reason for a change in conditions at the roadhead was put forward by L. G. Fear, who drew attention to the existence of a small fault in the Marine workings the line of which, if continued, would have passed through the roadhead, and to a change of strata inclination near the roadhead. Another possibility is that the pillar of coal between O.10 face and the Marine workings, having been reduced to about 55 yards in width, must have been heavily loaded and so in a condition conducive to extra roof movement at its edges.

66. I think it probable that the firedamp accumulated slowly from small feeders close to the roadhead. With an airflow of 5,000 cubic feet per minute in this twelve feet arched roadway, the velocity near the roof would have been very low and it is unlikely that, in the absence of a sheet, the air would have swept away any such accumulation. There is no reason, however, to suppose that it had reached proportions detectable on a flame lamp when the pre-shift inspection was made at 5.30 a.m. I was impressed at the Inquiry by the fact that, although firedamp appeared quite frequently, it was not suggested that the deputies had ever failed to make proper examinations or to take appropriate steps when they found it. V. Harding, the deputy for O.10 unit, who was killed, may well have examined the place, probably in the beginning of his shift, and I feel sure that had he found an appreciable quantity of firedamp in the ripping he would at least have erected a brattice sheet. Even so, and allowing for slight dispersion, an issue into the ripping of little more than one cubic foot of firedamp per minute from 7.30 a.m. onwards would have been sufficient to produce the minimum of 150 cubic feet that Hartwell estimated to have been involved in the beginning of the explosion.

Means of Ignition

67. The results of the investigation discount as possible causes of ignition the safety lamps and the electrical and mechanical plant used. Of the known possible causes of ignition there remain for consideration the illegal use of a naked flame for smoking, shotfiring and frictional sparking.

Contraband

68. I have considered carefully the possibility implied by the finding of an unsmoked cigarette, two live matches and a plastic bag, but I am satisfied that the explosion was not caused by the striking of a match either accidentally or by someone trying to smoke. The point of ignition was at O.10 intake roadhead and the nearest body was found over 100 yards away.

Shotfiring

69. Preliminary consideration of an igniting agent pointed to the possibility of a 'hanging flame' from shotfiring and L. R. James, Head of the Safety Department, National Union of Mineworkers, South Wales Area, remained of the opinion that this was the most likely cause of the ignition. The round of four shots fired in the roof ripping near the face of O.10 intake roadhead at about 3.00 a.m. on the previous night shift could conceivably have ignited a continuous feeder of gas in a bed separation or other break. Such a 'hanging flame' sometimes—fortunately only rarely—continues to burn and could cause an explosion should a mixture of air and firedamp move upon it. The omission of stemming from the back of the shotholes in O.10 intake face rippings would have increased the risk of ignition in a roof break a little beyond the end of the hole and therefore undetectable. It seems probable that bed separation evident after the explosion was present to some extent before the shots were fired and that there would have been some firedamp in the overlying beds. Plate I and Plan No. 5 both relate to this ripping as it appeared some time after the explosion when the investigation focussed attention on that place; by that time the fore-poling had been advanced.

70. A search of British records of 'hanging flame' incidents disclosed reports of 24 cases since 1934. Six of these arose from shots fired in coal. In ripping shots, which are fewer in number but far more dangerous, there were seventeen recorded instances of 'hanging flame' in the 26 years. Three of these could not be closely located from the information given, but it seemed that thirteen others occurred after the firing of shots in return roadheads. The only ignition which led to a disaster was also the only one which occurred in an intake road. This was at North Gawber Colliery in 1935[1].* In this case the intake road was, however, at the rise end of a face and near a partly-closed airway leading to a face in advance of it.

71. In none of these cases did ignition occur in conditions similar to those which obtained in O.10 intake roadhead. It is difficult to visualise circumstances in which firedamp in quantity sufficient to account for the explosion could, over a period of seven hours or so, have accumulated in the ripping without reaching a flame left from shotfiring, unless the flame was in a bed separation break in the lower part of the ripping. That was perhaps possible but I do not think it at all probable.

Frictional Ignition

72. Many witnesses described sparks which were sometimes produced either when the wedges were knocked out of the clamps of friction props or roof bar joints, or when released props, in falling, struck supports still in position. It is well known that sparks may result in this way or from operations such as the striking of the edge of a prop with a hammer. A great deal of investigation, however, has failed to show that sparks liable to cause ignition of firedamp are produced by this kind of steel-to-steel contact. There is no history of any such ignition.

73. Sparks, or more properly frictional heatings, resulting from impact involving certain kinds of rock, however, are dangerous. Firedamp can be ignited when, in machine cutting, the picks strike quartzitic rock or

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* The numbers in square brackets refer to the Bibliography at Appendix IV.

pyrites. Nothing of the sort could have happened in this explosion, however, as the machines had not been cutting for some time before.

74. Firedamp may be ignited by a particular type of blow from a steel hand-pick on some kinds of rock. Seven such cases were recorded in 1930 in a Safety in Mines Research Board Paper by M. J. Burgess and R. B. Wheeler[2], who were able to obtain ignitions in the laboratory. More recently, the S.M.R.E. has designed an apparatus to simulate mechanically the type of blow that causes ignition with a hand-pick. Tests were made in an explosive atmosphere with samples of quartzitic sandstone that had been exposed in the roof of O.10 intake roadhead, as indicated in Plan No. 5. Four ignitions were obtained in six tests, during which the rock surfaces were struck a total of 130 blows. A specimen of rock from the roof of O.10 supply roadhead containing an intrusion comparable to that of the rock in O.10 intake roadhead was also tested and an ignition was obtained after about 200 impacts. At the time of the explosion, the only place where the quartzitic rock might have been struck with a hand-pick was at O.10 supply roadhead. Hartwell, in evidence, discussed the possibility that firedamp was ignited there but, for reasons already given, this seems highly unlikely.

75. The S.M.R.E. has also examined the possibility of ignition of firedamp by friction between rock and rock. The results of tests by Burgess and Wheeler were reported on in 1928[3]. Other tests of this kind have been made recently and reported on in S.M.R.E. Annual Report for 1959[4]. The apparatus used consists of a rock 'slider' which is pressed with known force against the periphery of a rotating rock wheel in an explosive atmosphere; the pressure between the surfaces is measured and the time between the application of the load and any ignition of firedamp is taken. Ignition has been obtained with quartzitic rock. The greater the speed of the wheel and the longer the duration of the friction, the more likely it is to occur.

76. From the experiments it is deduced that, to produce an incendive condition, a suitable rock would first have to fall a distance sufficient to gain the necessary speed and then slide some distance on another rock; the shorter the fall of the rock, the longer would have to be the slide.

77. I have carefully examined the available records of ignitions believed to be due either to the impact of rock on rock or of rock on steel; the latter must, in the nature of things, include the possibility that the incendive impact may have been between rocks. The subject is of such importance that I have summarised the records in Appendix III. Four of the explosions referred to occurred in Canada. So far as this country is concerned, six of the seven instances mentioned were in South Wales. Sir Henry Walker, then Chief Inspector of Mines, in his report on the Marine Colliery disaster in 1927[5], considered that the explosion may have been due to a stone falling on stone. He cited as supporting evidence for this view possible similar incidents which had occurred between 1896 and 1927 at Maindy, Ferndale and Lletty Shenkin Collieries. In more recent years, other incidents have occurred at Cwm Colliery in 1949[6] and at Lewis Merthyr Colliery in 1956[7].

78. It seems clear that, if quartzitic rock falls and strikes either a steel object or possibly pieces of similar rock with sufficient impact, an incendive

PLATE I. INTAKE (LOADER GATE) ROADHEAD OF O.10 UNIT

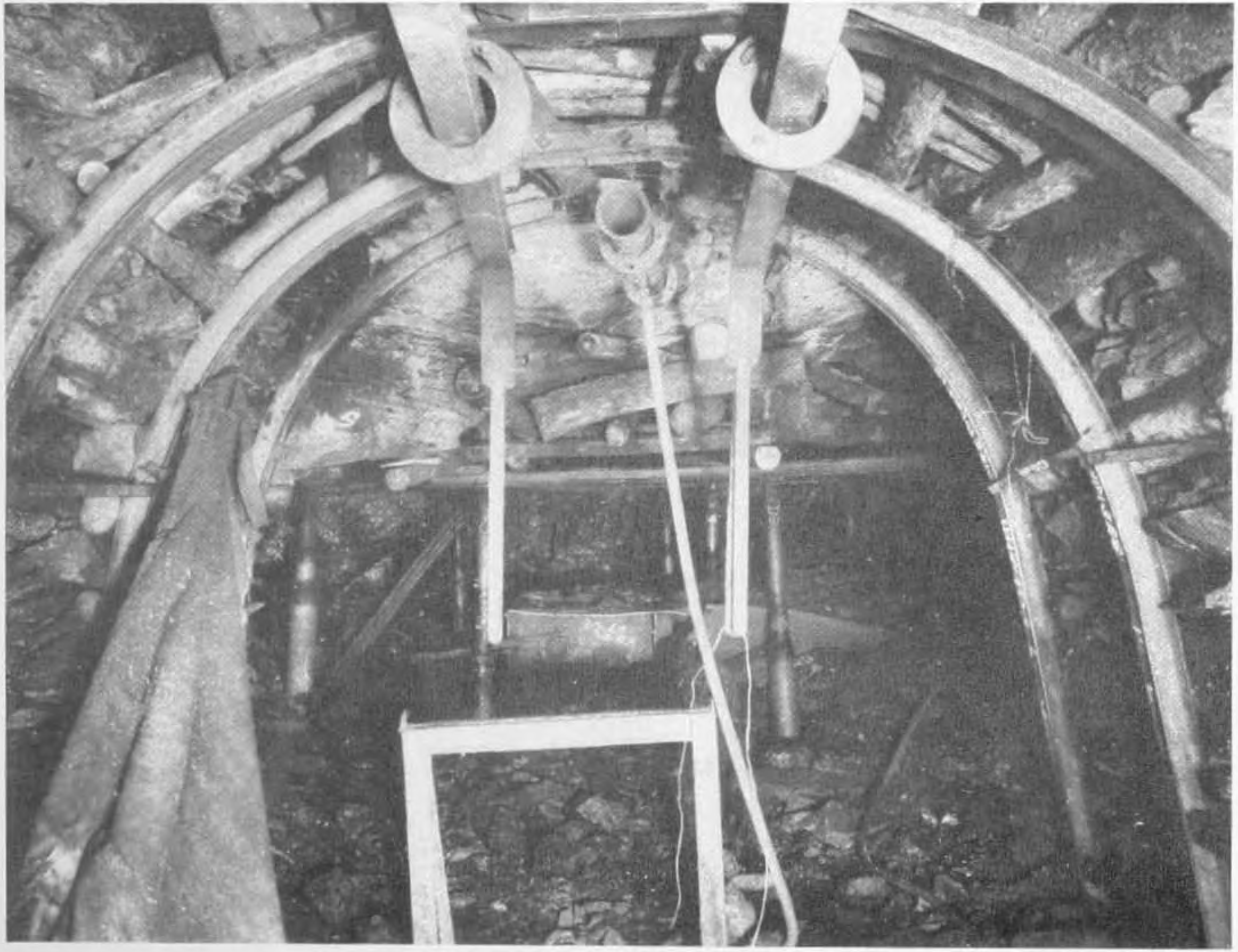

PLATE II. RETURN ROADHEAD OF O.18 UNIT

condition may result. Hartwell suggested that the impact of the mechanised pick used in the experiments he described would have been about equivalent to that of rock weighing 260 lbs. falling for a distance of three and a half feet onto a steel object. He thought that the most probable cause of the explosion was that there was a fall of rock bringing down with it firedamp that had accumulated at the ripping and that one of the larger pieces of rock struck the canopy in such a way as to produce an incendive condition and so cause inflammation of the surrounding atmosphere. Pieces of quartzitic rock, the largest being estimated to weigh about 240 lbs. were, in fact, found on the ground and on the canopy under O.10 intake ripping (Plate I). Some of it could have fallen a distance of six feet.

79. The mechanics of firedamp being brought down from near the roof by falling stone and then mixing with air have been demonstrated with perspex models, made at the Buxton Station of the S.M.R.E., of the road-heads at which the explosions occurred at Lewis Merthyr Colliery and at Sutton Colliery in 1957[8]. I commend to all mining engineers the film which has been made to illustrate these demonstrations.

80. The evidence was not completely satisfying, but I incline to the view that firedamp was brought down by a fall of roof and was ignited by frictional heat at the point of impact between a quartzitic stone and the steel girder forming the top of one side of the canopy. I refer later to methods of minimising the risks associated with falls of hard rock from a high cavity and from near the face of high rippings.

81. If a fall of stone of a not uncommon nature for a distance of six feet or so may be dangerous, the question immediately raised is the degree of risk involved in the routine collapse of roof in wastes. There is, however, no recorded experience of ignition of firedamp from this cause in longwall wastes in this country. This may well be because, for ignition to occur, there must be the remote coincidence of a number of conditions including the fall of a certain kind of rock, the right type and strength of impact and the presence at or about the point of impact of a firedamp-air mixture within a relatively narrow range.

82. The following questions seem to require particular attention : whether the conditions of the tests, with frequent pick blows in the same place, resemble what can occur in practice ; to what extent such impacts can be related to the impact of falling stone ; whether the revolving wheel test provides reliable data upon which to found conclusions regarding falling stone ; to what extent the ignition hazard is affected by the mass of the falling stone and its velocity ; whether there is some peculiarity in the mines in South Wales, such as the nature of stone, which may account for the preponderance there of these ignitions. All these problems, together with others relating to frictional ignition, are the subject of research at the S.M.R.E. and there can be no doubt as to the importance of this work.

A Minority View

83. A. Davies, a National Union of Mineworkers' Inspector, advanced the theory that the explosion started as a result of the firing of a ripping shot in O.18 return roadhead, which is illustrated in Plate II. The well-kept records of explosive issued and returned showed that a detonator and a pound of explosive, issued to the deputy of O.18 unit on the morning

of the explosion, were not recovered afterwards. Davies thought that a shot may have been fired in the right hand side of the ripping just before the explosion, that this may have ignited firedamp which had continued to burn and that the deputy and others were at the time of the explosion fetching stone dust in order to put out the flame. I saw nothing in this place to lead me to think that a shot containing as much as one pound of explosive might have been fired in the ripping. It seemed to me far more probable that the missing explosive had been used in the coal near the ribside for there were large lumps which had apparently been 'turned back' a sufficient distance from the face to make a track for the coal cutting machine. It would have been a very reasonable thing for the cutterman, who had only to square out the end of the face on this shift, first to cut enough coal at the corner for such a shot and then cut again. There was a supply of stone dust very near the ripping. But the conclusive evidence against the theory advanced was that, if an ignition had taken place in O.18 roadhead, the direction of flame would have been completely contrary to the indications found.

GENERAL DISCUSSION

Contraband and Searching

84. The statutory requirements relating to the systematic search of underground workers for smoking materials had not been carried out at the No. 5 Pit since February, 1959, when the workmen who had been carrying out the searching ceased to do so because of a matter of payment. The manager said that he had then arranged for under-officials to search instead. It came to his notice a fortnight before the explosion that his arrangements had broken down. He thereupon confirmed his earlier instructions to the under-officials but there was no evidence of any follow-up action to see that these were observed; after the explosion, it was discovered that they had not been. The manager is, of course, responsible for ensuring the observance of the arrangements for searching and for securing that when these arrangements are not in operation no person goes below ground. But I think that others, upon reflection, may not feel satisfied that they did all they might have done in the matter.

85. Searching is very necessary as a constant reminder against carelessness and, where it is done efficiently, it can be a deterrent to those who might otherwise wilfully attempt to take smoking materials below ground. I was particularly disturbed by the evidence that smoking materials had been taken below ground at Six Bells Colliery and was shocked to find no dissent from the implication that the plastic bag found in the water bottle was a provision intended by someone at some time to defeat a searcher with the object of smoking below ground.

Roof Support

86. The general standard of roof control on O.10 face was good. The seam roof at the intake roadhead was not insecure but the system of support at this place, and the implementation of it, left something to be desired. The system of support could with advantage have incorporated the use of chocks. The hydraulic props used were eminently suitable for use at

roadheads but the prop density there was less than on the remainder of the face ; additional supports should have been set at the margins of ground to be brought down by shotfiring. Long experience has shown a need for more than average density of supports at roadheads, especially where, as in this case, there is a machine stable which increases the distance from pack to face. The enlarged view on Plan No. 2 shows that the packs were not completed as close to the face as they should have been, a matter of prime importance at roadheads. Similar criticisms apply to the support of O.18 return roadhead.

87. Intensive support of the roadhead is particularly necessary when, as in O.10 intake, the road is along a coal rib. Roof settlement over the coal rib may not be arrested but it is delayed and the higher rate of settlement over the packs must result in sharp deflection of the roof at the ribside, with the risk of extensive fracturing there. Because the higher beds are better supported at the ribside, the lowering of the immediate roof above the roadway tends to the formation of bed separation there. The advantages and disadvantages of the practice of forming roads along the ribside, and the necessary precautions if roads are so situated, are fully considered and well documented in a report issued in 1952 by the National Coal Board's South Western Divisional Committee on Strata Control[9].

88. Some months before the explosion the roadway had met the faults. The roof had not then been held and the consequence had been the large cavity. A proper standard of roof control and support at roadheads should ordinarily prevent the development of cavities. Where they do occur, perhap in association with a seam abnormality, their extent can be limited by improved support at and ahead of the rippings. Many cavities develop between the last-set arch and the ripping face where the usual method of initial support of the newly exposed roof is by fore-poling. Even where this is carried out well its effectiveness depends upon the resistance of the supports, usually steel arches, which carry the straight girder 'poles'. Recently-set arches, especially those incorporating means of accommodating the inevitable height loss, are often lightly loaded and a comparatively small load on the advancing end of a fore-pole can cause the inbye supporting arch to lower and thus produce a magnified drop at the end of the pole. There is need for the development of better practice in fore-poling and of means whereby road supports, though capable of accommodating height loss, offer greater resistance when newly set, at the time when support from them is most valuable.

89. In roof conditions which predispose cavity formation at roadheads, the original excavation may be made smaller, and thus easier to control, by the adoption of the pilot method of roadway formation. In this method, which is not uncommon in South Wales, a small roadway is taken near the face and a larger one made a short distance outbye. Alternatively, where the floor is not liable to excessive heave, unduly thick roof rippings may be avoided by floor ripping or by a combination of roof and floor ripping, as was adopted in O.18 intake. The development of mechanical, perhaps pneumatic, means of conveying stone from the excavation to the pack spaces in either of these systems would be very helpful ; much more difficult problems in mining engineering have been successfully overcome. The desirability or otherwise of adopting either of these alternatives would fall to be determined in the light of all the circumstances.

90. Most cavities are small to begin with and special measures taken in good time may halt their extension. If, however, a roadhead cavity is allowed to extend as the roadway advances, it may become virtually unmanageable. A stage must arise in the development of such a cavity when it is necessary to stop the face so that proper measures may be taken to prevent its further development. The identification of such a stage is the concern of all officials; the decision, except in emergency, may be a function of the senior management of the colliery.

91. Another problem which requires consideration is whether, once a large cavity has formed, it should either be filled or otherwise supported and kept ventilated. This again is a matter of judgment in each case, but generally speaking, filling is to be preferred. The means of filling large cavities have been much improved recently. In his report for 1958[10], H.M. Inspector of Mines and Quarries for the South Western Division referred to the filling of roof cavities by pneumatic stowing with material fed into a crusher-stower situated beneath the cavity. More recently, H. Wright, in a Paper[11] has described how cavities may be filled by pumping into them a light-weight compressible material. I hope that managements will, in appropriate circumstances, give careful consideration to the adoption of such methods of filling cavities. In weak ground, falls of stone will generally continue in any cavity not completely supported until, in time, the void is largely filled. But it must be borne well in mind that before then there is some risk of firedamp being expelled from the cavity or even ignited therein by a large fall of stone.

Firedamp Determinations

92. The firedamp content of the general body of the air at the statutory point of determination had on occasions exceeded one per cent., but the manager had failed to give notice of these results to H.M. Inspectorate. There were also a number of irregularities in connection with the making and recording of determinations. Some of the results had not been entered in the book provided at the colliery for the purpose and some of those recorded referred to determinations made at times other than the latter part of a cutting shift. There was no record for O.12 unit.

93. The person responsible to the manager for making firedamp determinations and taking air measurements was not solely concerned with ventilation. He was responsible also for the collection of roadway dust samples and for monthly examinations of fire-fighting equipment. When difficulties with firedamp were encountered in O.18 unit, he had insufficient time to give proper attention to all his duties. Nevertheless, the deficiencies and irregularities should have been avoided. Careful consideration of these and related matters led me to the conclusion that the manager might have been greatly assisted by the employment at the colliery of a ventilation specialist who could, if necessary, have devoted all his time to this work. The "Bryan" Report recommended that "local management, when confronted with difficult ventilation problems, should take advantage of the expert advice which should always be available within the National Coal Board". Something more now seems to be necessary in the direction of providing such continuous expert attention to the ventilation of each mine as may be necessary to prevent difficulties arising. Consideration of this

suggestion could well form part of a wider concept which Sir Andrew Bryan had in mind when, in his closing address on behalf of the National Association of Colliery Managers and the British Association of Colliery Management, he suggested that there was a need for operational research to discover ways and means of improving the effectiveness of the large manpower now employed in the field of safety.

Firedamp Detection

94. A number of the persons carrying flame safety lamps had not been trained and certified in their use. Unsuccessful attempts have been made at many mines to persuade workmen to become qualified and to carry and use firedamp detectors. I understand that a payment for carrying and using them has now been arranged and I hope that the last has been heard of these difficulties.

95. It was suggested at the Inquiry that deputies should be provided with methanometers and probes for examining places otherwise inaccessible to them. I feel sure that there is a case for the wider use of these aids by ventilation officers in special investigation work—one aspect of which I shall refer to later—but not, for the time being at any rate, by deputies in routine inspections. I would, however, agree entirely with a suggestion that deputies should be provided, as soon as possible, with a better means of examining for firedamp in high places, not only because it is difficult for them to reach the roof of such places with their lamps, but because it is known that present types of lamps may not give accurate indications of thin roof layers. Flame safety lamps so equipped that a sample may be brought down from the roof to the lamp by an aspirator and a tube are becoming available, and the National Coal Board is carrying out complementary development work with a view to producing a flame lamp detector which will give direct and improved performance in the detection of very thin layers.

Emission of Firedamp

96. The O.18 face was advancing into an area not likely to have been drained of firedamp to any appreciable extent by previous workings ; the nearest seam extracted was the upper leaf of the Black Vein, some 60 yards above. A fairly substantial firedamp emission was therefore to be expected and did in fact occur. When last measured before the explosion, the quantity of air in the return airway was 9,450 cubic feet per minute, and it contained one per cent. of firedamp at a point 30 feet from the face. The 'make' of firedamp was thus about 94 cubic feet per minute. Firedamp appearances were quite frequent, mainly in the intake rippings, the highest point in the unit, until the thickness of the roof ripping was reduced from six feet to three feet by the substitution of eight feet arches for the twelve feet arches previously used and by taking some floor ripping.

97. The 'make' of firedamp in O.10 unit was small—less than 17 cubic feet per minute when last calculated before the explosion ; the percentage of firedamp at the return end of the face was only one-quarter of one per cent. Nevertheless, firedamp was quite frequently reported by the deputies mainly at or near the return end of the face.

Firedamp Drainage

98. It was suggested at the Inquiry that had a system of firedamp drainage by boreholes over the gob been practised this accident might have been averted. I do not find the evidence strong enough for me to subscribe to this view, but I consider it very likely that had such a system been adopted in O.18 unit it would have saved many people a great deal of trouble and anxiety. The National Union of Mineworkers' lodge chairman was apparently concerned, because of shotfiring, about the appearances of firedamp in O.18 unit and he discussed this with the manager on at least one occasion just before the explosion. Long before this, however, the manager and, indeed, the group manager, had demonstrated their concern by taking part in special methanometer surveys.

99. The adoption of firedamp drainage was considered by the management. I think that this unit was one in which firedamp drainage might well have been adopted. It could conceivably have been much more effective than the local air deflection measures taken, by assisting the naturally buoyant firedamp to rise to the drainage holes and so away from the edges of the working. One of the objections advanced by the area ventilation engineer was that, for successful drainage, holes would have had to be bored from the intake road as well as from the return. This would not necessarily have been the case. There are many examples of firedamp drainage from the return side only and on faces longer than in O.18 unit. An ascentional ventilation lay-out, although not called for by other considerations, might have simplified the problem here but there are instances of successful drainage, with proper precautions, from intakes.

100. Firedamp drainage could well be, in some conditions, one of the best ways of minimising dangerous emissions from the waste. The very important Section 56 (2) (*b*) of the Mines and Quarries Act, 1954, imposes upon managers the duty of securing that appropriate steps are taken for this purpose. The waste conditions can only be ascertained by investigation such as is made, for instance, in the gassier seams of North Staffordshire where ventilation officers regularly observe the firedamp content near roof level in the accessible wastes by means of methanometers and probes. I strongly recommend procedures which have been set out in papers by R. H. Clough and J. Carver[13] and by E. Steele and D. C. Yates[14].

Air Velocities

101. The O.10 unit made less than one-fifth of the amount of firedamp given off in O.18 unit but the air quantity was also less by about one-half. The velocity of air on O.10 face was of the order of 100 feet per minute and thus substantially below the figure of 150 feet per minute recommended originally as a dust preventive measure in the Third Report of the Research Committee of the Monmouthshire and South Wales Coal Owners' Association[12], and subsequently quoted by the National Coal Board as desirable for faces in new and reconstructed collieries. The air velocity on the face is, of course, generally related to the velocity in the roadways serving the face: in thin seams a face velocity of 150 feet per minute might mean a low velocity in the roadway, which would be conducive to roof-layering of firedamp. Where the air has a fairly high velocity, it does to some extent sweep places just out of the general airflow and it can be

directed with some force to such places as ripping edges. Many explosions in recent years have occurred in seams which are not very gassy and have been attributed to the unexpected emission of firedamp, often in no great quantity and probably at a moderate rate. As the emission of firedamp can rarely be predicted accurately, the possibility, or indeed probability, of occasional abnormal emissions should be catered for by producing enough air to deal with such a situation. Had there been available on O.10 unit the quantity of air that there was on O.18 unit, and a means provided of deflecting a substantial part of this air into the ripping, I do not think that firedamp would have accumulated in quantity sufficient to have started a coal dust explosion.

Air Ejectors

102. These air-moving appliances are referred to in mining terminology as " Venturis ". It was suggested at the Inquiry that the two in O.18 unit were objectionable. Neither contributed to the explosion but attention was, quite properly, drawn to the hazard inherent in inefficient earthing—one of them was open to criticism in this respect—and the risk of recirculation. It was pointed out that in some European countries there are requirements fixing minimum lengths of tubing to prevent recirculation[15], and it was suggested that in this country the use of any such device was, by virtue of the provisions of Section 58 (4) of the Mines and Quarries Act, 1954, subject to the consent of an Inspector. In ventilation legislation, provisions governing earthing, siting and recirculation are laid down only in respect of auxiliary fans. In view of recent developments in the use of air ejectors the time has arrived when the safety aspects should be discussed by the Ministry of Power with other interested parties.

Air Separation Doors

103. The prolonged opening of any separation door may adversely affect face ventilation and I heard evidence which suggested that this had happened from time to time in W District. Materials for O.10 unit had to pass through three sets of doors and be man-handled part of the way, a process not satisfactory either from the aspect of ventilation or of transport. The wider adoption of long trunk conveyors in places where it is not possible to keep a separate track for materials alongside the conveyor has added to the difficulty of supplying material to faces and calls for careful consideration in planning the working of such a district.

Aluminium Alloys

104. I had no difficulty in excluding as a possible source of ignition the aluminium alloy component of the stage loader motor situated some 30 yards from the face of O.10 intake. It is well known, however, that incendive sparks can readily be produced by friction between aluminium alloy and rusty steel. Following the explosion at Glyncorrwg Colliery in 1954[16], restrictions on the use of equipment consisting partly or wholly of aluminium alloy were imposed upon managements by instructions from the Headquarters of the National Coal Board, after discussion with the Ministry of Power, but these restrictions applied only at the coal face. I think that the subject should now be re-examined with a view to extending the area of restriction to all parts of a mine where firedamp may be a hazard.

Shotfiring Practice

105. Some very conflicting evidence was given on shotfiring practice. Many of the workmen witnesses said that they had never seen a break detector used; witnesses who fired shots maintained that they had always used one. Only one was found after the explosion and there was no evidence to suggest the existence of any other in W District. The regulations require the owner of a mine to provide one break detector for each shotfirer on duty. It was contended by those concerned that one shotfirer normally fired all the shots on his shift but that if, as happened occasionally, a deputy also fired shots, the shotfirer and the deputy arranged not to fire at the same time so that each could in turn have the use of the detector. This expedient could have been avoided by the proper provision of a detector for each shotfirer and for each deputy who fired shots. The break detector produced had clearly been very much used at some time. The point of the prong had become worn to such an extent that it did not satisfy the requirement of the official approval and, with the prong in this condition, a shotfirer could well fail to detect a completely longitudinal break wide enough to be dangerous.

106. Another serious irregularity alleged by many witnesses was that the specially provided stemming bags of fireproofed paper were sometimes partly, or even wholly, filled with fine coal instead of with suitable inert material. Twenty-two bags filled with fine coal were found on O.10 unit after the explosion. It is possible that the Inquiry disclosed an isolated instance, but managements generally will be well advised forthwith to check the position at their collieries. The proper provision of suitable stemming material at any place where a shot is to be fired is a very important safety matter and it seems to me that from all points of view there must be a method better than one involving the use of paper bags, especially those intended to be filled by hand below ground. One way might be to prepare stemming material only on the surface and in a form readily recognisable by those who are to use it below ground.

107. The round of four shots in O.10 intake ripping on the night shift before the explosion were fired when the only persons in the unit, other than the deputy, were the shotfirer and his assistant; they did not advance the horsehead supports to the ground exposed by shotfiring. It was apparently not unusual to fire shots towards the end of one shift and leave the setting of support to the newly-exposed ground for a following shift. The practice of shotfiring at times when as few persons as possible are at risk is commendable, and there is much to support the view that shotfiring should be carried out between shifts. It is, however, essential that the operations associated with shotfiring—the preparatory setting of additional supports around the margins, the withdrawal of the supports from beneath the roof to be brought down and the supporting of the newly exposed ground—should be carried out in sequence with the minimum of delay between stages after supports have been withdrawn. This is important in mines generally as a contribution to good roof control and as a safeguard against accidents caused by falling stones.

108. There was no evidence at the Inquiry to support a suggestion made there that shots had been fired in the presence of firedamp, but A. Davies and L. R. James both expressed the view that it is potentially dangerous

to fire a shot in a ripping where a hurdle sheet is in use to remove firedamp, and three published reports made by H.M. Inspectors about 30 years ago were referred to in support of this view. The matter is not relevant to this explosion if it originated, as I believe, in O.10 intake roadhead, but the question raised is one which merits further thought in the light of present-day conditions and related considerations. Any step likely to militate against the use of hurdle sheets as precautionary measures might be a retrogression ; many more might well be so used, preferably of a type such as was suggested in Safety Pamphlet No. 26[17]. The shotfiring danger to be guarded against could perhaps be effectively lessened by an appropriate increase in the amount of general ventilation provided or the adoption of firedamp drainage, possibly localised, or both.

109. My observations in O.18 return roadhead led me to think that shotholes were perhaps not being positioned as well as they might have been ; too many of them were bored at an inclination steeper than the strata and therefore were the more likely to intersect any bed separation breaks present. So far as practicable, shotholes should be drilled parallel with the bedding planes.

110. Every advantage should be taken of the new methods and materials that are continually becoming available for use in shotfiring. A much safer explosive than the present 'equivalent sheathed' has recently been developed. Under regulations soon to be made, approved types may be used, without exemption, to fire delay action rounds with approved detonators and exploders in any place where explosives may be used. This new explosive is certainly weaker than others now in use but the great advantages to be derived from short-delay blasting may well make it worth while to use heavier charges, or even to bore more holes. Mining engineers aided, I think, by more specialist advice should carefully examine the possibility of using this less incendive type more extensively.

111. Following a report by the National Coal Board's North Eastern Divisional Shotfiring Committee[18], trials have been carried out on the injection of foam into ripping shotholes before blasting, as a means of reducing the risk of ignitions in breaks. H.M. Inspector for the North Eastern Division described the progress of these trials in his report for 1959[19]. I understand that the trials are continuing satisfactorily and that similar trials, but on a smaller scale, are being carried out in South Wales. These trials should be encouraged because, in principle, the method provides a valuable safeguard against an ignition of firedamp by the potentially dangerous ripping shot.

Coal Dust Dangers

112. I have already recorded the results of the pre-explosion and post-explosion roadway dust samples at Six Bells Colliery and pointed out that, although the pre-explosion samples were generally satisfactory, a widespread explosion occurred.

113. Many attempts have been made to correlate results of pre-explosion and post-explosion dust samples and the position was well summarised by F. V. Tideswell in a Paper published in 1952[20]. This paper cites examples which tend to show that in rope haulage roads and walking returns the results of post-explosion samples give a fair guide to

the composition of dust in those roads at the time of an explosion. In other roads, notably those where coal is carried by belt conveyor, wide differences may be expected ; before an explosion there may be imperfect mixing of coal and stone dust, a situation particularly likely to arise on conveyor roads where rich deposits of coal dust can easily collect under the conveyors and on the conveyor structures. The deposits of coal dust under the conveyors are by no means easy to sample and this, together with dust from any coal being conveyed, may account for considerable discrepancies in the results of samples collected before and after the explosion.

114. There was evidence that the roadway conveyors were not kept clean ; but cleaning and stone-dusting even to standards which would be regarded as very good practice are, unfortunately, not a complete safeguard against a coal dust explosion.

115. Published work by Godbert, Bradshaw and Leach[21] [22] gave results of observations they made at several collieries on the rate of deposition of coal dust on roadways inbye of loading or transfer points and in returns. They showed, among other findings, that during a coal filling shift the quantity of dust in the coal actually on a conveyor may be, of itself, quite sufficient to propagate a coal dust explosion.

116. An ignition of firedamp alone in the relatively small quantity and in the conditions visualised near the face of O.10 loading gate could conceivably have occurred without anybody knowing much about it. The propagation of the explosion by coal dust again emphasises what I consider to be the biggest single problem of safety in modern coal mines—that of keeping in a safe condition those roadways in which coal is transported by conveyors.

117. The limitations of general stone-dusting on conveyor roads led some years ago to the conclusion that an additional safeguard was necessary and then to the suggestion that stone dust barriers should be used for this purpose. They cannot prevent an ignition of coal dust but they can limit the extent of an explosion. Although for some years barriers had been used abroad, notably in Germany, it was not until 1952 that a decision was taken to use them in this country. It may well be that some mining engineers are still not convinced of the vital need for barriers. This may stem either from reluctance to accept that general stone-dusting cannot provide complete protection or from a fear that the very presence of barriers will lead to the neglect of general stone-dusting. I am convinced that stone dust barriers are necessary, but I must emphasise that general stone-dusting is an equally essential part of the protection ; the absence of general stone-dusting could permit a coal dust explosion to develop a speed which barriers could not arrest.

118. A National Coal Board's Production Department Instruction was issued on 1st September, 1953, requiring managements to provide stone dust barriers on conveyor roads and setting out very clearly the reason for the provision. Regulations, which were not made earlier because it was considered that insufficient was known on the subject, came into force on 1st October, 1960. These regulations require managers to prepare schemes specifying the position and type of each barrier, and it is thus of the greatest importance that they should be convinced that the proper

provision of stone dust barriers is a vital requirement which, if neglected, might have disastrous consequences.

119. The National Coal Board's Production Department Instruction in force at the time of the explosion at Six Bells Colliery may not have been altogether free from ambiguity but, on my reading, it seems to have required ' primary ' barriers in the W District at the following places :—

(1) O.18 loader gate—not more than 100 yards inbye of the transfer point onto the conveyor in the main intake ;

(2) O.10 loader gate—not more than 100 yards inbye of the transfer point onto the conveyor in the main intake ; and possibly.

(3) the main intake—at a point not more than 100 yards inbye or outbye of the transfer point of O.12 gate belt.

The extent of the explosion might possibly have been much less had barriers been provided at these places. In the present state of knowledge I cannot dissent from the views expressed in evidence that barriers might have prevented the spread of the explosion from O.10 unit to O.18 unit.

120. As a coal dust explosion is, fortunately, a comparatively rare occurrence, the period of seven years since barriers were first introduced into this country has provided only three instances of their operation in practice. W. Brown, in his special report on the explosion at Horden Colliery, Co. Durham, in 1953[23] referred to the destruction of a stone dust barrier in the following words :—

> " Therefore, while it is uncertain how far the explosion would have propagated had there been no stone dust barrier, it is worthy of record that the explosion did, in fact, stop at, or very near the barrier and that despite the very mild explosion the barrier was satisfactorily destroyed and a substantial amount of its stone dust was dispersed."

Two recent incidents seem to indicate satisfactory functioning of barriers. In the first, an explosion occurred during the re-opening of a mine which had been temporarily closed as a result of a fire ; investigation after the explosion showed that it had been confined to the intake roadway leading to the affected face ; a stone dust barrier at the outbye end of this roadway had been discharged, but a second barrier in the main roadway outbye had not been disturbed. The second relates to a district of a mine which was sealed-off to smother an underground fire ; when the district was re-opened some five months later, it was found that an explosion had occurred, but that it had been confined to a 300 yard length of roadway between the face and the site of a stone dust barrier, which had been discharged ; a detailed examination was not possible because the district had immediately to be re-sealed following a second explosion.

121. The S.M.R.E., who have been working on the problem of dust explosions for many years, are to construct a large experimental gallery, which will be most valuable in the further research work quite clearly needed.

122. The Safety and Health Committee of the Coal Industry National Consultative Council has devoted much time and energy to the problems of coal dust explosion risks and continues to do so. A Sub-Committee of the Safety and Health Committee is considering the siting and construction of

stone dust barriers. The report of the Sub-Committee on Mining Explosions[24] referred briefly to the danger from wet coal dust, to which attention had been directed by the report on the explosion at Kames Colliery in 1957[25] and recommended that a Working Party of experts on coal dust explosions should be set up. This Working Party, having considered the results of experiments carried out by Dr. Cybulski in Poland and other evidence, has recently completed its report on wet coal dust and is to consider a review of the whole problem of coal dust explosions, which is now being prepared by the S.M.R.E. This consideration should include, as a matter of urgency, the adoption of precautionary measures in the zone of the greatest risk of firedamp ignition—that is within, say, 100 yards of the face.

CONCLUSIONS

123. In view of the scale and the exhaustive nature of the Inquiry, it was not surprising that some evidence dealt, quite properly, with alleged irregularities. I have referred to such of the matters raised as seemed to me to have sufficient bearing on the circumstances of the explosion to warrant inclusion in this report. In commenting upon some facets of the evidence, I have considered it necessary to be critical. Despite this, I accept the opinion of L. R. James in his most helpful evidence that the district was 'a good average district'. It is for this very reason that I find the circumstances of this disaster so disturbing.

124. During the earlier years of the century up to 1927 when the Marine Colliery explosion occurred, this part of the South Wales coalfield suffered an unfortunate series of disastrous explosions. Since then, until the explosion at Six Bells Colliery, there was relative immunity. During the same period, experience in the country as a whole was that the incidence and average severity of major explosions remained substantially unchanged, apart from a welcome reduction in exceptionally serious disasters following the introduction of general stone-dusting in 1921[26]. New methods of work, in themselves advantageous from nearly all points of view, may increase the risk of firedamp ignition and it is necessary to ensure that the changes are matched by the adoption of appropriate precautionary measures against new or increased hazards. This explosion has emphasised that the ignition of a comparatively small accumulation of firedamp, such as is liable to occur in almost any seam, may in some circumstances cause a disastrous coal dust explosion.

125. No one can say with certainty where or by what means the explosion at Six Bells Colliery started. But after careful consideration I think that:

(1) The explosion started as an ignition of firedamp in the roadhead roof ripping of O.10 intake.

(2) The accumulation of the firedamp might have been prevented had there been a hurdle sheet near the face ripping.

(3) The cause of ignition was frictional heat produced by the impact of a piece of quartzitic rock falling for a distance of about six feet,

from roof exposed by shotfiring, onto a steel girder forming part of a conveyor canopy.

(4) The fall of this rock might have been prevented had the roof between the last-set steel arch and the new ripping face been supported immediately after the firing of a round of shots there about seven hours before.

(5) An explosion of firedamp alone might not have caused any casualties as there was nobody in the vicinity at the time.

(6) The explosion which spread throughout most of the district was one mainly of coal dust raised on the conveyor roads.

(7) The coal dust explosion might possibly have been confined to O.10 unit had there been sufficient stone dust barriers suitably placed.

RECOMMENDATIONS

126. The possibilities that the explosion may not have originated in O.10 intake roadhead and may have been caused otherwise than by a fall of stone widen the field of recommendation of action designed to reduce the explosion risk. Implementation of some of these suggestions might well necessitate an increase in specialised staff, but I am convinced that in some fields much more specialised work should be done to help the manager in the discharge of his very onerous responsibility for safety.

127. I recommend that:—

(1) The Working Party of the Safety and Health Committee of the Coal Industry National Consultative Council which is to review the general problem of coal dust explosion hazards should consider, as a matter of urgency, what additional precautionary measures could be taken on lengths of conveyor roadways nearest the face and most likely to be affected by a firedamp explosion.

(2) The potential danger of firedamp ignition associated with the fall of certain kinds of rock should be recognised by managements as an additional reason for perfecting measures designed to prevent falls at roadheads and for the maintenance at all times of effective ventilation of roof rippings, cavities and waste edges.

(3) The ventilation engineering service of the National Coal Board should provide managers with the greatest possible specialist advice and assistance on firedamp drainage by boreholes and on all aspects of ventilation.

(4) The National Coal Board's efforts designed to provide deputies with the best means of examining for firedamp in places out of easy reach should, if possible, be intensified.

(5) All persons engaged in shotfiring should bear in mind that the safe performance of their duties demands meticulous care and managements should lose no opportunity of satisfying themselves that it is being exercised. The nature and form of stemming material best suited to general use and least likely to lead to malpractice

should be investigated. Trials of foam injection into ripping shotholes should be encouraged. A wider use of explosives specialists could have many advantages.

(6) Mining engineers of the National Coal Board and other interested parties in South Wales should give fresh consideration to ways and means of reducing the incidence of large cavities on roadheads and of dealing safely with any which occur.

(7) The Ministry of Power should review with interested parties the use below ground of air ejectors.

ACKNOWLEDGMENTS

128. I gladly place on record my appreciation of all the help afforded me in this investigation. The Mayor and Corporation of Newport County Borough placed at my disposal a Court Room eminently suitable for my purpose and many persons helped towards the smooth working of the arrangements there. In this connection I am greatly indebted to the surveying and other staff of the National Coal Board who prepared and displayed the excellent plans. I thank those who appeared at the Inquiry as representatives of the various parties concerned for their very able and courteous assistance. The Area General Manager and his officials at the colliery spared no effort to facilitate the investigation. I would underline here my appreciation of the help given by Inspectors of the Safety Department of the National Union of Mineworkers. The officers of the Safety in Mines Research Establishment did invaluable work both in their meticulous investigation at the colliery and in their Sheffield and Buxton laboratories and testing station. Finally, I appreciate the assistance received from H.M. Inspectors of Mines and Quarries and other colleagues in the Ministry of Power in the investigation at the colliery, at the Inquiry proceedings and in the preparation of this report.

I have the honour to be, Sir,

Your obedient Servant,

T. A. Rogers.

APPENDIX I

Names of Men Killed

Name	*Age*	*Occupation*	*Reference No. on Plan No. 2*
Ivor James Baiton	48	Cutterman	45
Daniel James Bancroft	46	Collier on Panzer	36
Robert Charles Brown	35	Roof Control Officer	20
Frank Cooper	44	Supplies Man	29
Joseph Corbett	50	Haulier	43
Thomas George Crandon	46	Repairer	33
Walter Thomas Davies	34	Borer	28
Royden James Edwards	27	Repairer	8
Percy Gordon Elsey	52	Repairer	30
Albert John Evans	34	Packer	23
Leonard Keith Frampton	29	Collier	17
Albert Gardner	59	Assistant Cutterman	44
George Goldspink	37	Repairer	14
Clive Alan Griffiths	18	Prop Checker	13
Vernon Alexander Griffiths	33	Deputy Grade I	11
Ernest Victor Harding	51	Deputy Grade I	41
Idris Jones	57	Packer	15
John Percival Jones	56	Repairer	38
Joseph John King	56	Packer	37
Dennis Edmund Lane	19	Wireman	1
George Henry Luffman	55	General Worker	7
Telford Cecil Mapp	42	General Worker	32
Herbert Amos Mayberry	55	Dumper	5
William John Morden	52	Engine Driver	4
Sidney Moore	54	Repairer	3
Colin Malcolm Donald Morgan	26	Repairer	16
Colin Reginald Morgan	22	Assistant Repairer	26
Ray Martin Morgan	44	Repairer	27
Islwyn Morris	44	Deputy Grade II	31
Anthony Verdun Partridge	20	Assistant Borer	12
William Henry Partridge	45	Borer	19
Trevor Paul	25	Assistant Repairer	10
Wilfred Alfred Charles Phipps	60	Cutterman	6
Albert George Pinkett	45	Collier	18
Frederick Rees	37	Fitter Grade II	25
Mansel Reynolds	21	Measurer	21
William Glyn Reynolds	21	Assistant Repairer	24
Wilfred Hughes Thomas	57	Repairer	40
Arthur Waters	37	General Worker	34
Phillip John Watkins	53	Engine Driver	2
Wilfred Weston	47	Water Infuser on Panzer	42
Frederick White	58	Under-manager	35
William Burdon Whittingham	55	Assistant Repairer	39
Richard John Williams	51	General Worker	9
John Woosnam	24	Fitter Grade I	22

APPENDIX II

Names of Witnesses

Name of Witness	Occupation
Allen, A. J.	Timberman's Assistant
Alexander, A. L....	H.M. Electrical Inspector of Mines and Quarries
Assirati, C.	Colliery Fire Officer
Aylesbury, A. T. G.	Collier
Baker, K.	Collier
Beech, E. J.	Timberman's Assistant
Bilton, C. A.	H.M. Inspector of Mines and Quarries
Boots, E. D.	Shotsman
Coleman, W.	Underground Engineer
Cook, R. S.	Fitter
Davies, A.	Workmen's Inspector
Davies, W. H.	Rescue Brigade Man
Doel, W.	Overman
Dowden, W. H.	Assistant Repairer
Edwards, D. E.	Superintendent, Crumlin Rescue Station
Evans, J. H.	Labourer
Fear, L. G.	H.M. Senior District Inspector of Mines and Quarries.
Grindle, J.	Repairer
Gwilliam, S.	Collier
Hall, R. J. G.	Deputy
Hartwell, F. J.	Senior Principal Scientific Officer, S.M.R.E.
Hewitt, S. J.	Colliery Safety Officer
Hillman, H. I.	Foreman Fitter
Hillman, G. E.	Crasher
Holland, S.	Deputy
Holt, A. H.	Repairer
Holt, T. J.	Collier's Helper
Hooking, J. H.	Captain, Llanhilleth Rescue Team
James, L. R.	Workmen's Inspector
Jenkins, W.	Collier
Jenkins, W. V.	Fitter
Johnston, H. L. S.	Under-manager
Jones, A. S.	H.M. Inspector of Mines and Quarries
Law, R. H.	Deputy
Legge, H. J.	Fitter
Lewis, C. J.	Fitter
Lewis, T. J.	Collier
Luther, V.	Manager
Macdonald, J. D.	Deputy
Mathews, A.	Fitter
Morgan, Raymond	Repairer
Morgan, Reginald	Repairer
Morgan, T. G.	Overman

Name of Witness	Occupation
Nash, W. C.	Deputy
Owen, I.	Area Surveyor
Parsons, J. S.	Timberman
Powell, W. B.	H.M. District Inspector of Mines and Quarries
Price, D. E.	Deputy
Purnell, D.	Assistant Borer
Purnell, M.	Linesman
Rees, B.	Collier
Rees, L.	H.M. District Inspector of Mines and Quarries
Richards, E. H.	Collier
Richings, R. W.	Collier's Helper
Rideout, C. F.	Collier
Shore, J.	Crasher
Simpson, R. W.	Area Ventilation Engineer
Small, J.	Collier
Smith, Albert	Assistant Hitcher
Smith, Alexander	Police Constable
Stokes, J. C.	Deputy
Sutton, J. E. M.	Repairer
Thirlaway, J. T.	Area Scientist
Thomas, E. V.	Overman
Thomas, W. E.	Underground Mason
Triger, K....	Doctor
Vagg, S. I.	Collier
Walters, E.	Scientific Technical Officer
Williams, C. H.	Repairer
Williams, R.	Group Manager
Winters, J.	Repairer
Worthington, K. S.	H.M. Inspector of Mechanical Engineering
Yeandle, W. C.	Assistant Timberman

APPENDIX III

Ignitions by Impacts between Rocks and between Rock and Steel

Maindy Colliery, 1896: In the clearing of a fall, a cavity 18 feet high was created; a fall in the cavity is believed to have been responsible for an explosion occurring whilst no one was in the mine. (Explosion at Marine Colliery, Monmouthshire: Report by Sir Henry Walker, C.B.E.: Cmd. 3048.)

Ferndale Colliery, 1907: A small quantity of gas was believed to have been ignited by a fall of strong siliceous rock from a place about 12 feet above floor level during the clearing of debris brought down in repair work. (Report on Marine Colliery explosion.)

Belle Vue Colliery, Alberta, Canada, 1910–1911: Three separate explosions occurred during the extraction of pillars in a 13 feet thick seam inclined at an angle of 45 degrees; it is believed that the ignitions were due to collisions between pieces of bituminous sandstone as they fell down the steeply inclined roads. (Stirling and Cadman, Transactions of the Institution of Mining Engineers, Volume XLIV, page 740.)

Lletty Shenkin Colliery, Cwmbach, 1913: Repairers were working at a fall when another large fall of stone occurred; they saw flame rising when the stone fell on some iron bars. (Report on Marine Colliery explosion.)

Minnie Pit, 1918: The fall of a siliceous stone from a place about 12 feet above the floor of a thick coal seam worked by pillar and stall was given as a possible cause of the explosion. (Explosion at Minnie Pit of the Podmore Hall Colliery, North Staffordshire: Report by W. Walker, C.B.E.: Cmd. 810.)

Mine in Germany, 1922: An explosion was produced by the impact of a large piece of sandstone on a steel roof support arch. (U.S. Bureau of Mines Information Circular 7727 (Hartmann).)

Hillcrest Mine, Alberta, Canada, 1926: Mr. G. S. Rice, Chief Mining Engineer of the U.S. Bureau of Mines, came to the conclusion that frictional sparks or heating due to falling and sliding rock were possible causes of the ignition of firedamp. (Safety in Mines Research Board Paper No. 46, 1928.)

Marine Colliery, Monmouthshire, 1927: Sir Henry Walker considered that the explosion may have been due to stone falling on other stone which had already fallen. The probable place of ignition was on a working face, where a fall involving a bed of siliceous sandstone, was being cleared. (Report on Marine Colliery explosion.)

Cwm Colliery, 1949: A fall occurred in a cavity at a roadhead; stone collapsed about eight feet on to an arch girder and produced an ignition. (Reports of H.M. Inspectors of Mines for 1949: South Western Division: Report by T. A. Rogers.)

Lewis Merthyr Colliery, 1957: Hard 'clift' fell from a roadhead cavity for a distance of 20 feet on to arch girders and produced an ignition. (Explosion at Lewis Merthyr Colliery, Glamorganshire: Report by T. A. Jones, O.B.E., Cmnd. 316.)

Mine in Virginia, 1958: Supports had been withdrawn from a section; an explosion associated with a fall occurred. Miners 50 to 75 feet from the fall saw sparks and a flash of fire just before the explosion. (U.S. Bureau of Mines Report of Investigations 5548 (Nagy and Kawenski).)

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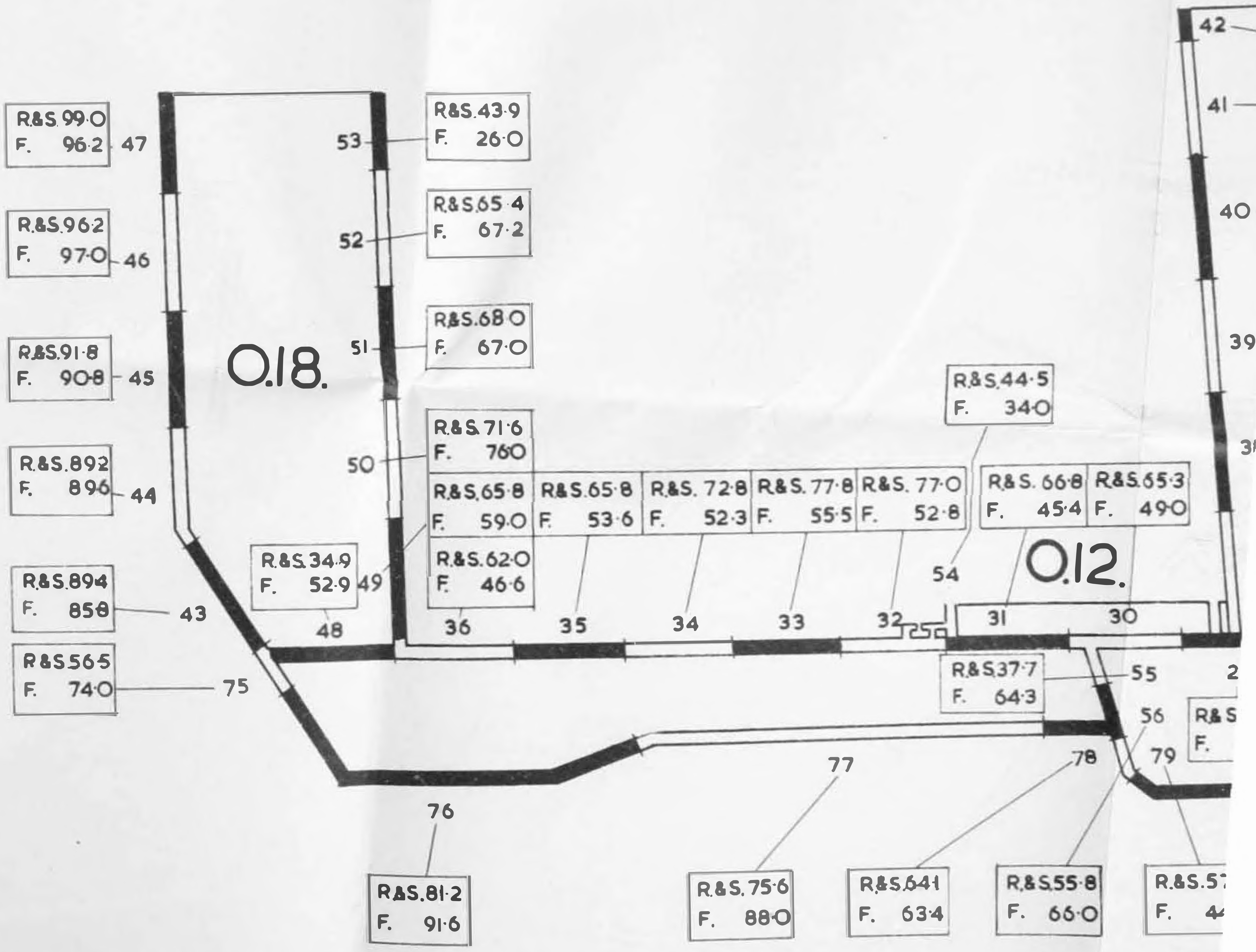
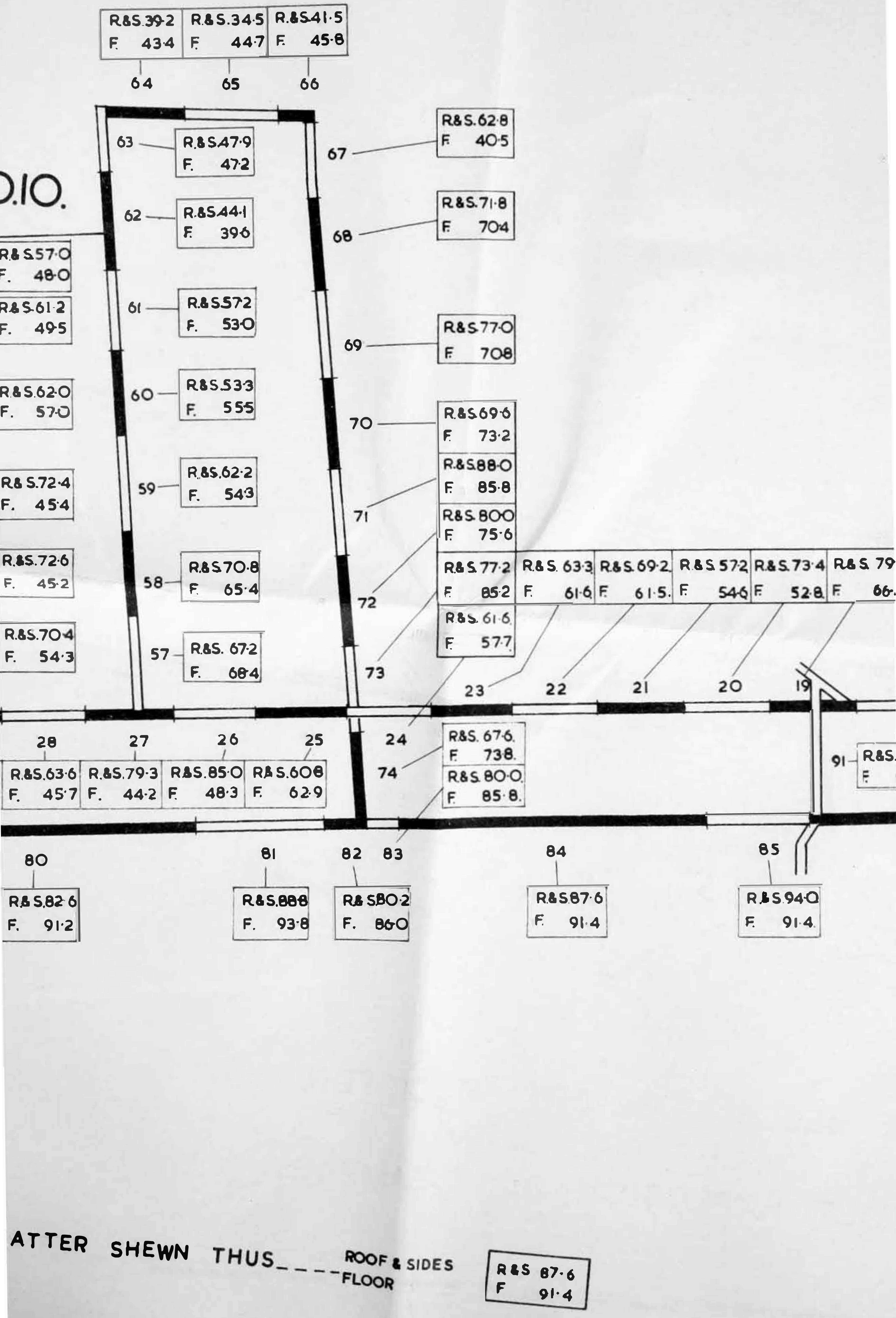
(30846) Wt. 811—1616 K37 2/61 D.L.

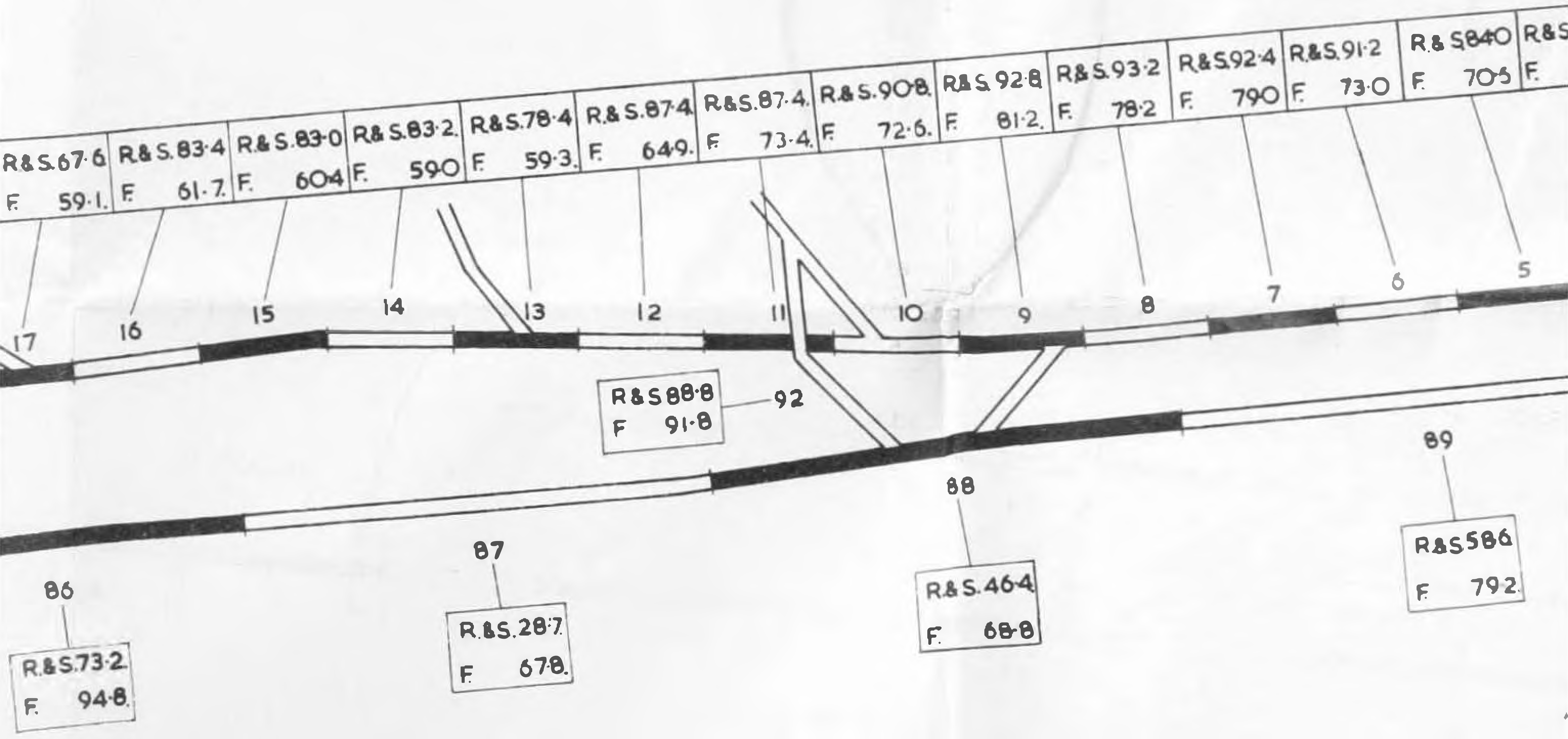


PERCENTAGE OF INCOMBUSTIB

35844 - Wt. 811 - Od. 1616 - SM - 1/61



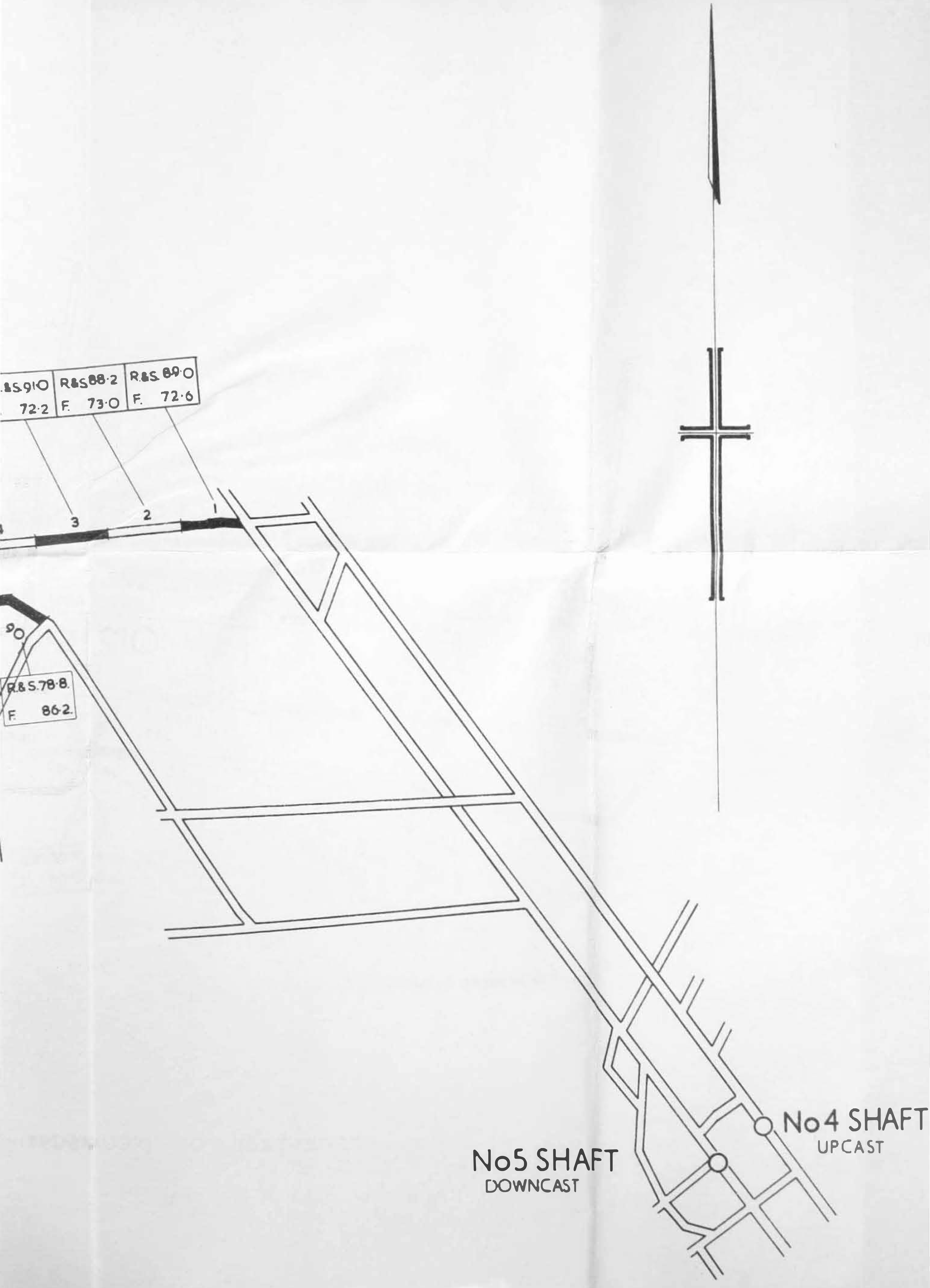
D.10.
R.&S.39·2 F. 43·4
64
R.&S.34·5 F. 44·7
65
R.&S.41·5 F. 45·8
66
63
R.&S.47·9 F. 47·2
62
R.&S.44·1 F. 39·6
61
R.&S.57·2 F. 53·0
60
R.&S.53·3 F. 55·5
59
R.&S.62·2 F. 54·3
58
R.&S.70·8 F. 65·4
57
R.&S.67·2 F. 68·4
67
R.&S.62·8 F. 40·5
68
R.&S.71·8 F. 70·4
69
R.&S.77·0 F. 70·8
70
R.&S.69·6 F. 73·2
71
R.&S.88·0 F. 85·8
72
R.&S.80·0 F. 75·6
73
R.&S.77·2 F. 85·2
R.&S.61·6 F. 57·7
R.&S.57·0 F. 48·0
R.&S.61·2 F. 49·5
R.&S.62·0 F. 57·0
R.&S.72·4 F. 45·4
R.&S.72·6 F. 45·2
R.&S.70·4 F. 54·3
R.&S.63·3 F. 61·6
R.&S.69·2 F. 61·5
R.&S.57·2 F. 54·6
R.&S.73·4 F. 52·8
R.&S.79 F. 66·
23
22
21
20
19
24
28
27
26
25
R.&S.63·6 F. 45·7
R.&S.79·3 F. 44·2
R.&S.85·0 F. 48·3
R.&S.60·8 F. 62·9
74
R.&S.67·6 F. 73·8
R.&S.80·0 F. 85·8
91
R.&S. F
80
R.&S.82·6 F. 91·2
81
R.&S.88·8 F. 93·8
82
83
R.&S.80·2 F. 86·0
84
R.&S.87·6 F. 91·4
85
R.&S.94·0 F. 91·4
ATTER SHEWN THUS - - - - ROOF & SIDES
FLOOR
R&S 87·6
F 91·4

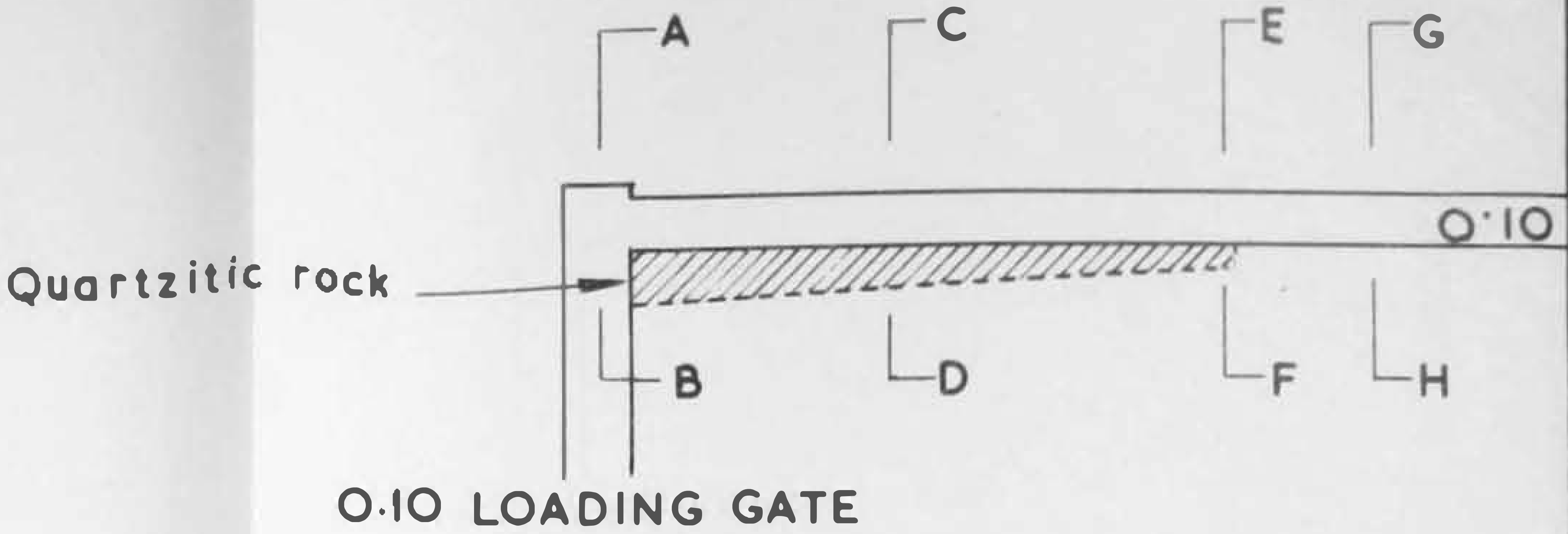


PLAN No. 4

SIX BELLS COLLIERY, W DISTRICT
OLD COAL SEAM
POST EXPLOSION DUST SAMPLES

SCALE OF YARDS

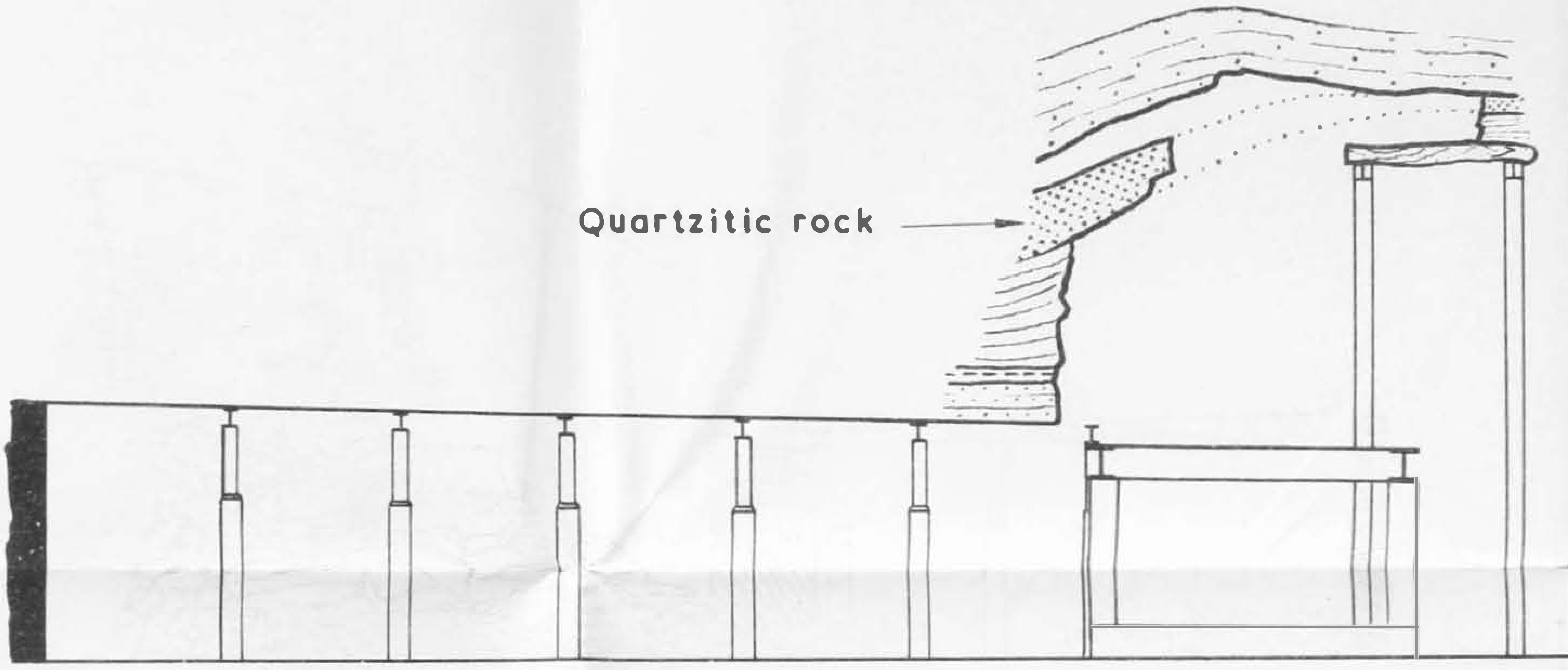

&S 91·0
72·2
R&S 88·2
F. 73·0
R&S. 89·0
F. 72·6
3
2
1
90
R&S. 78·8.
F 86·2.
No 4 SHAFT
UPCAST
No 5 SHAFT
DOWNCAST



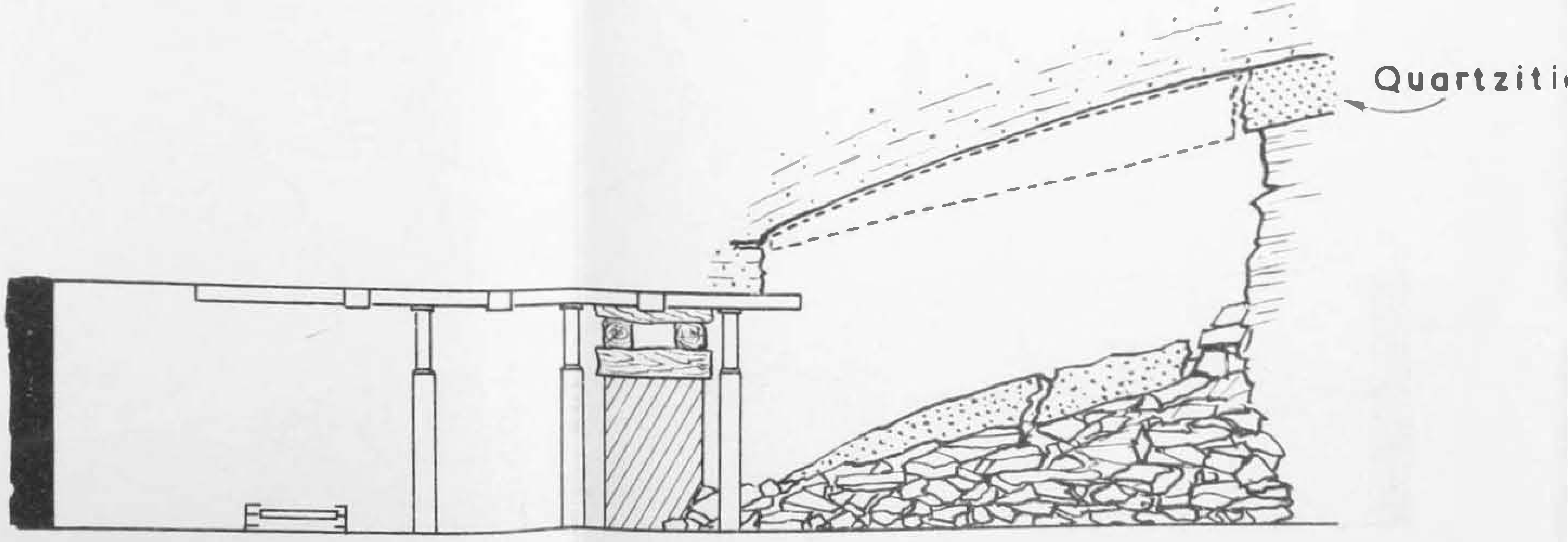
Plan of O·10 face showing

40 20

Scale



Cross section A – B at loading gate.



Cross section E–F 95 feet from loading gate.

PLA

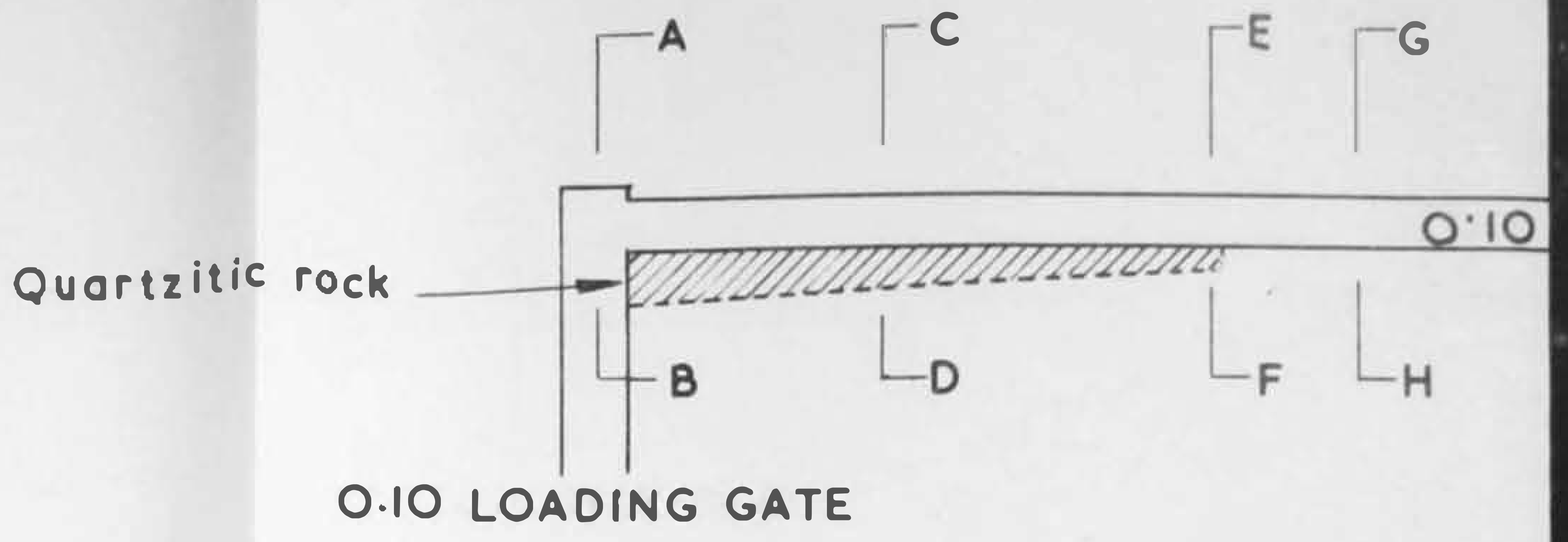
SIX BELLS COL
O·10 UNIT, C

CROSS SECTIONS SHOWING EXPOSURE AND EXTEN

0 5

SCALE O

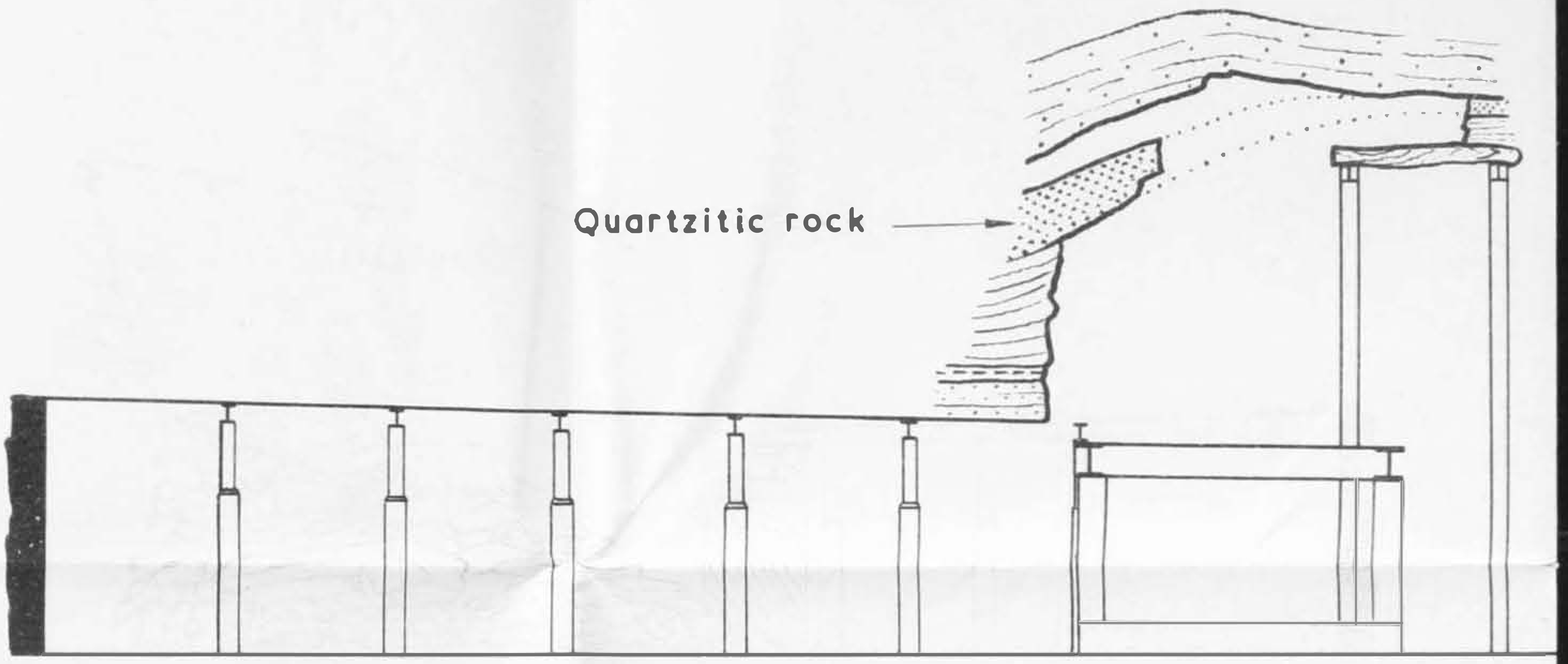
C.B.H. 35844-Wt. B11 - Dd. 1616- 5M -1/61



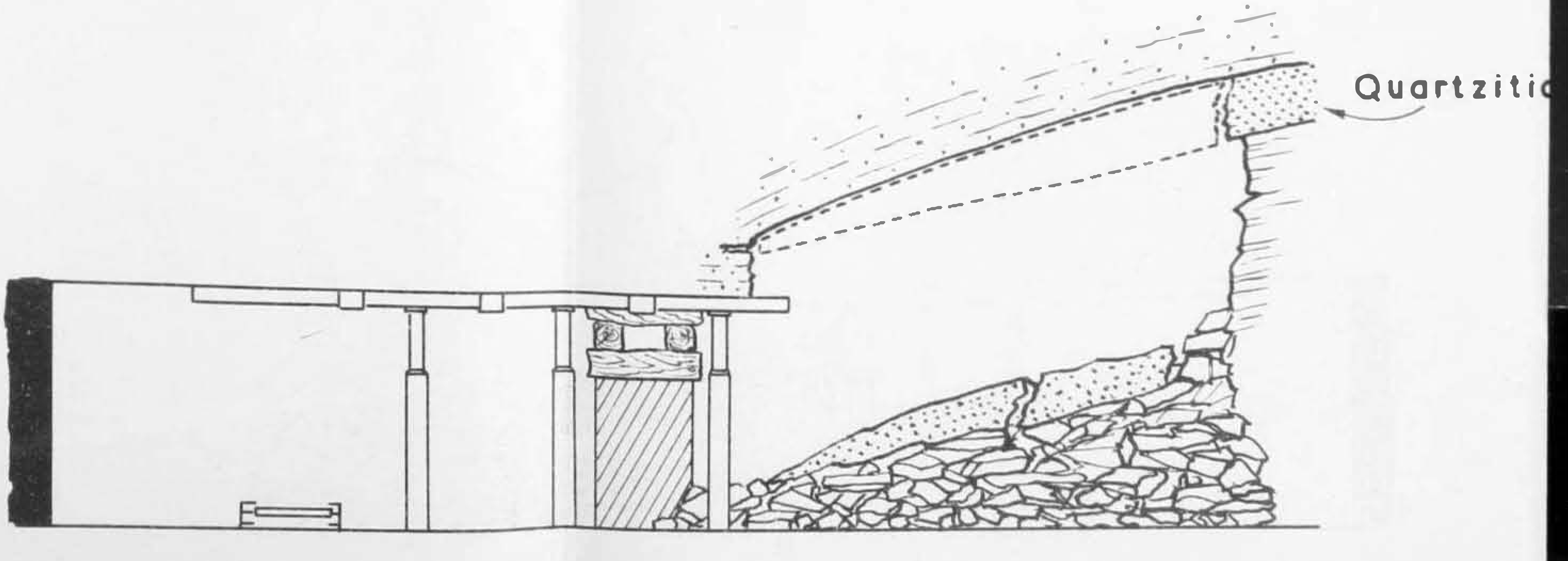
Plan of O·10 face showing

40 20

Scale



Cross section A – B at loading gate.



Cross section E – F 95 feet from loading gate.

PLA

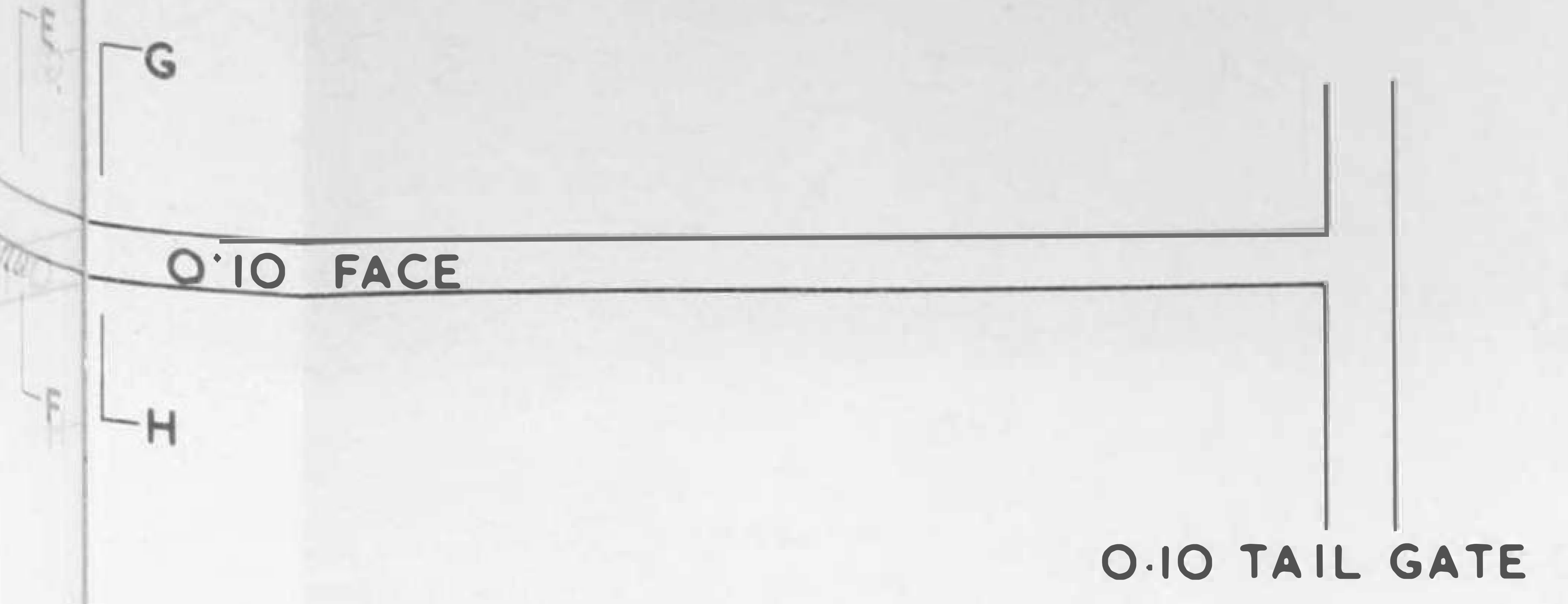
SIX BELLS COL
O·10 UNIT, O

CROSS SECTIONS SHOWING EXPOSURE AND EXTEN

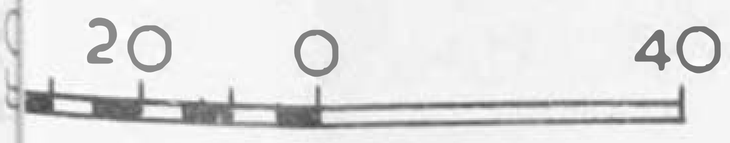
O 5

SCALE O

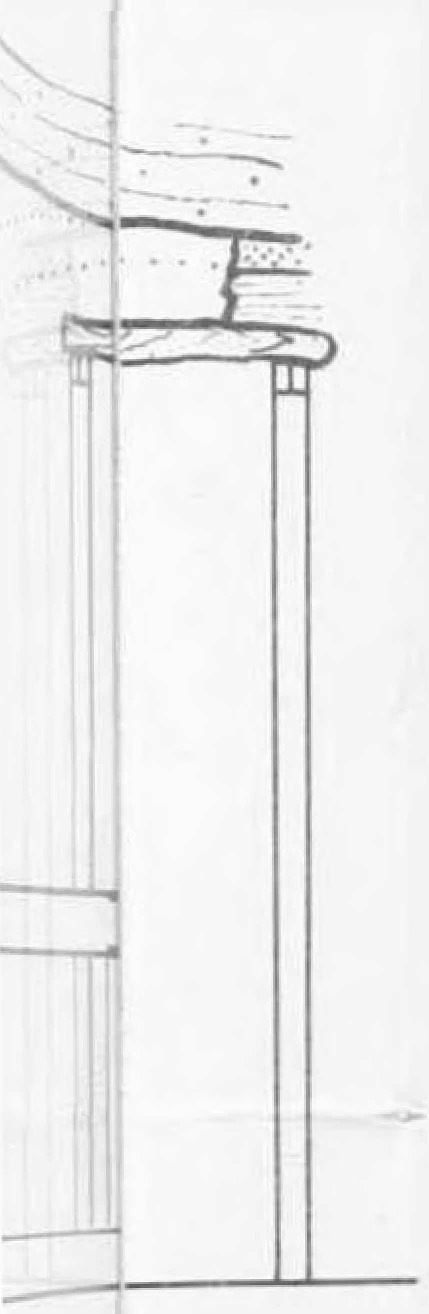
C.8H. 35844 - Wt. 811 - Dd. 1616 - 5M - 1/61

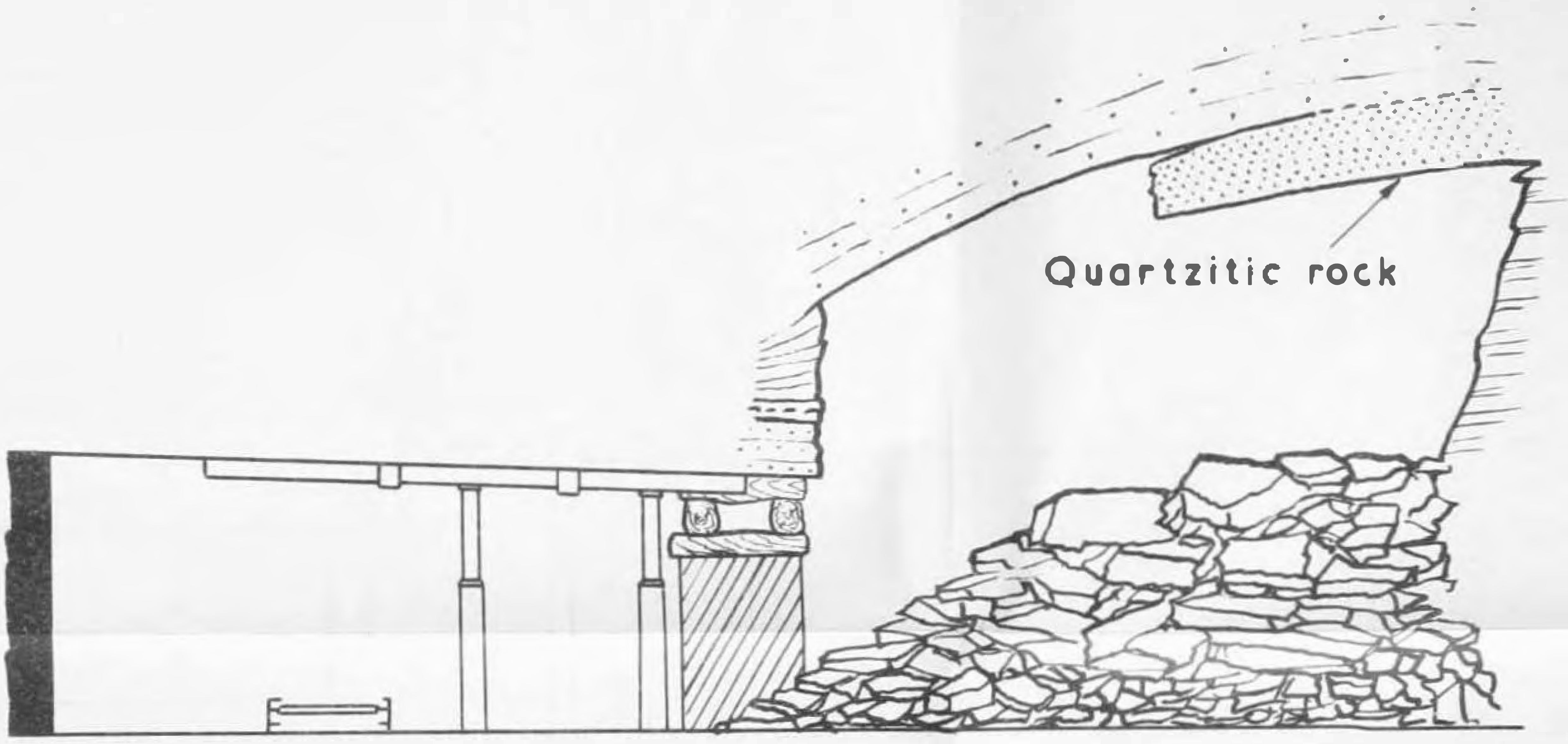


showing position of cross sections.

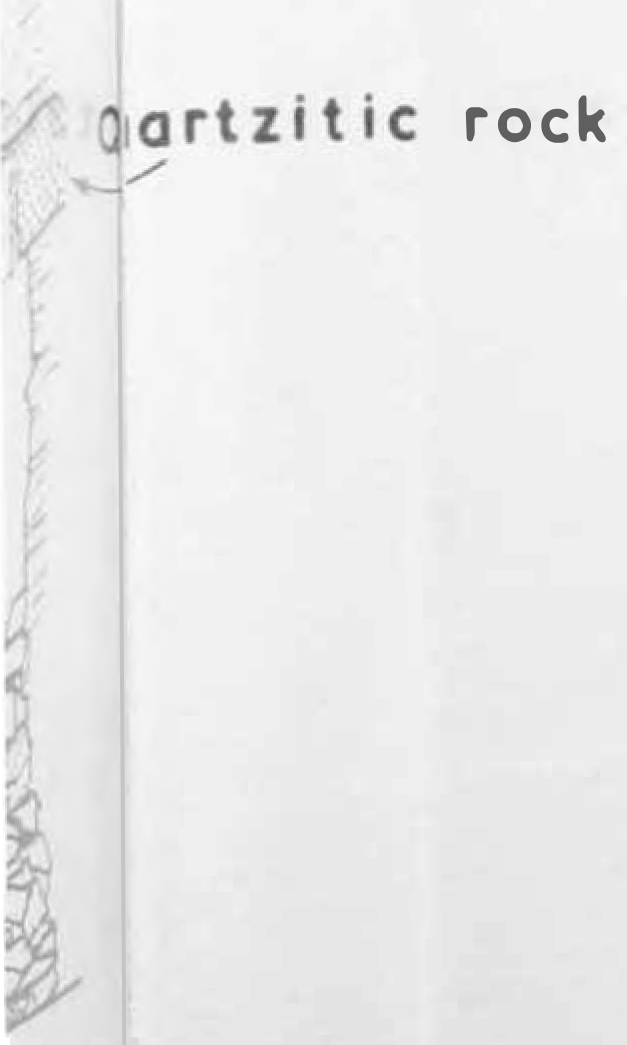


Scale of feet.





Cross section C – D 44 feet from loading gate.



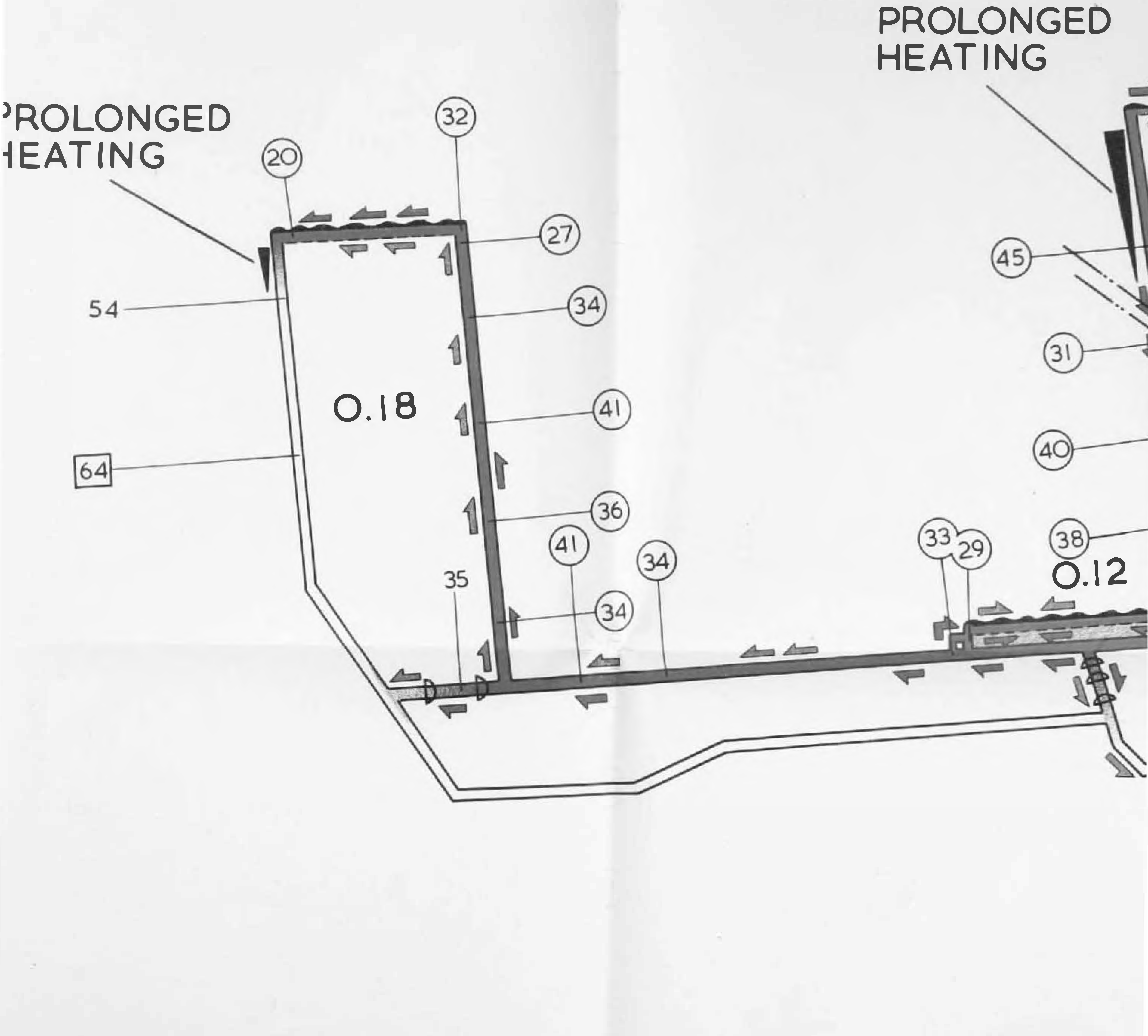
Cross section G – H 118 feet from loading gate.

PLAN No. 5

COLLIERY, W DISTRICT.
IT, OLD COAL SEAM.

EXTENT OF AN INTRUSION OF A HARD QUARTZITIC TYPE ROCK.

CALE OF FEET



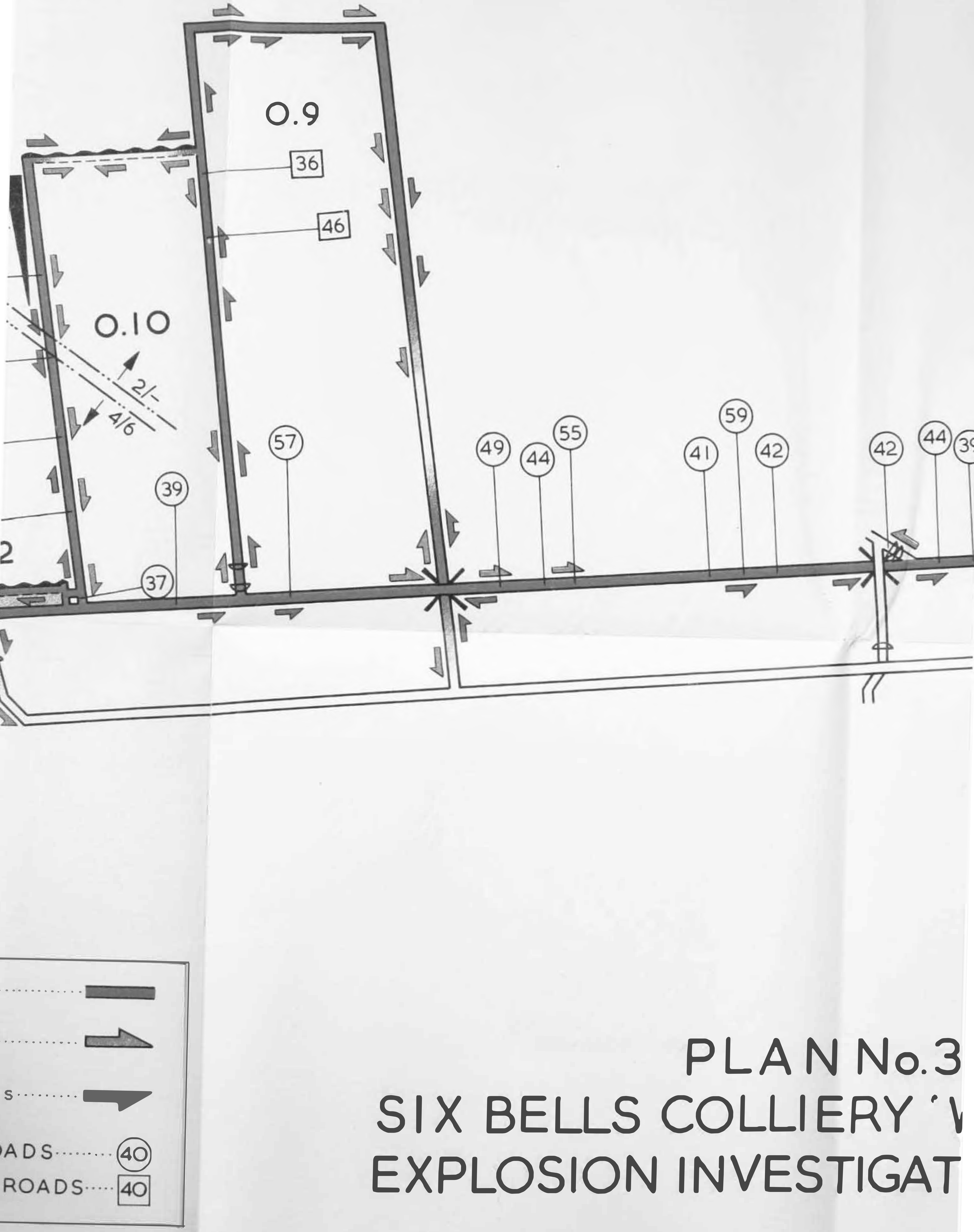
EXTENT OF EXPLOSION FLAME ....

DIRECTION OF BLAST ....

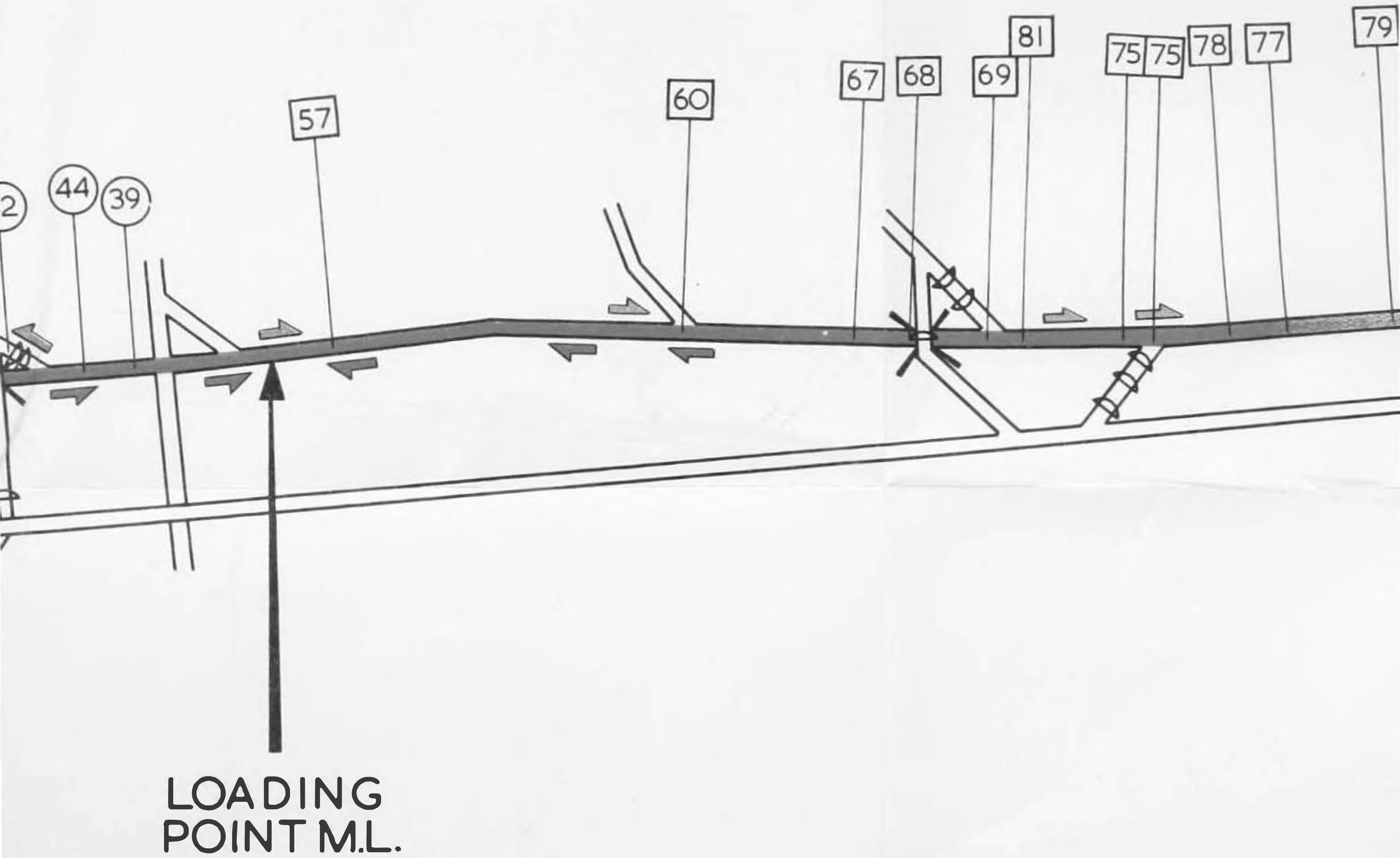
DIRECTION OF FLAME suggested by coked dust deposits

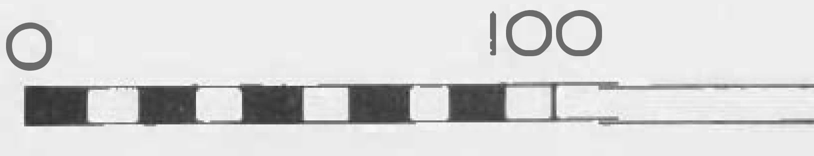
INCOMBUSTIBLE MATERIAL IN EXPLOSION DUST SPECIMENS PER CENT } ON CONVEYOR ROA
ON TUB HAULAGE R

C.B.H. 35851 - Wt. 811 - Dd. 1616- 5M - 1/61

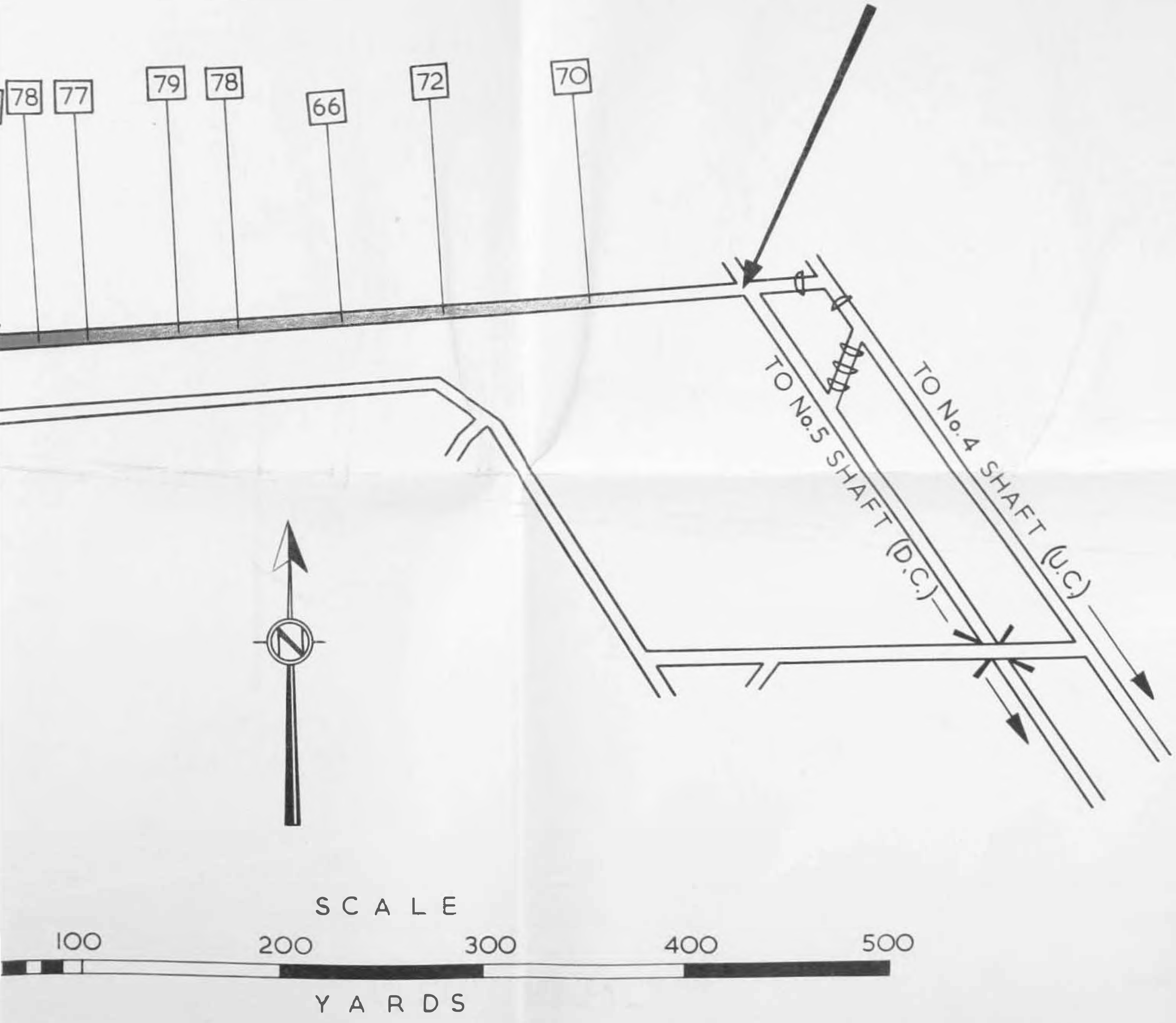


PLAN No.3
SIX BELLS COLLIERY 'W
EXPLOSION INVESTIGAT



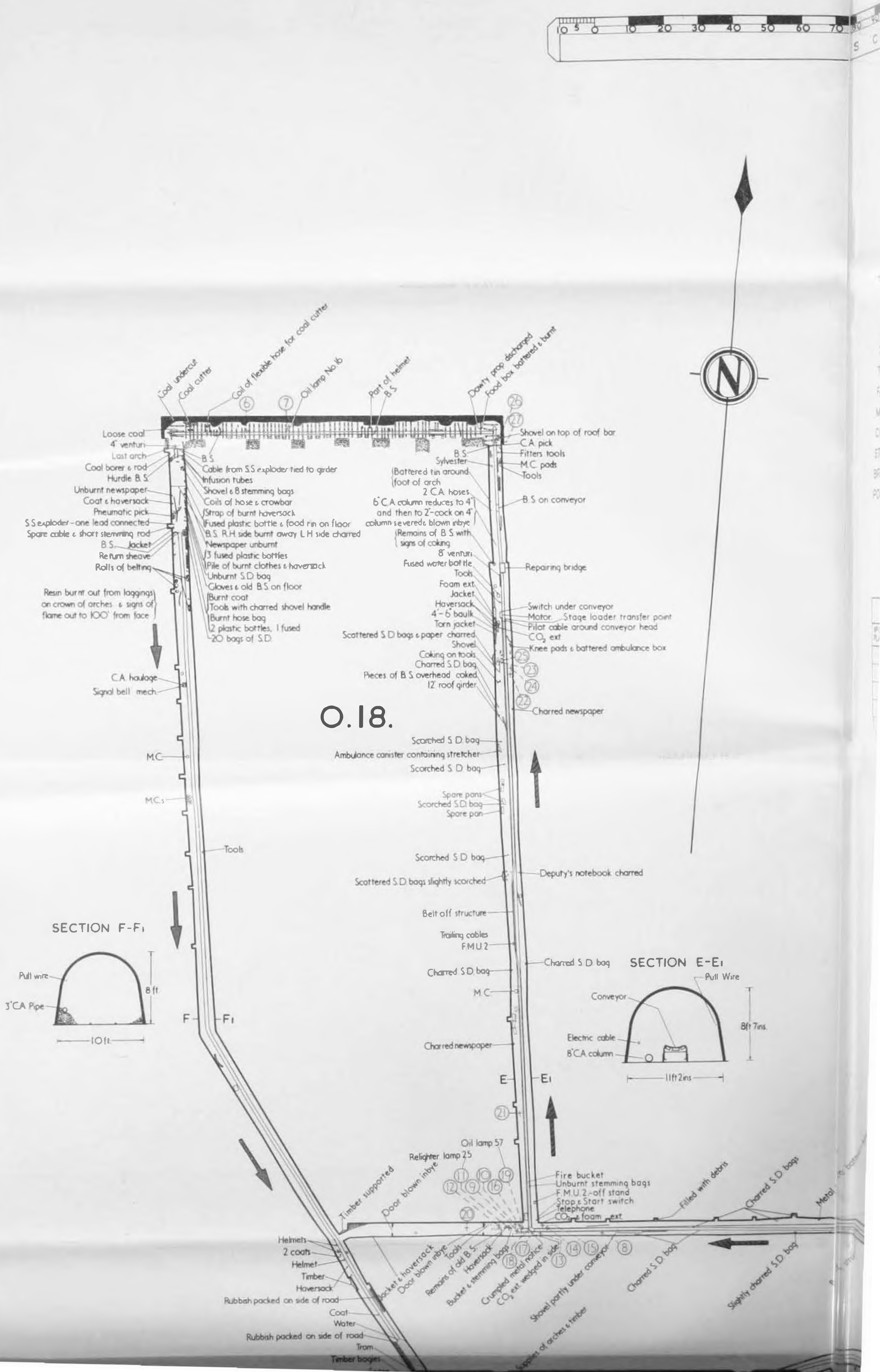


No.3
RY 'W' DISTRICT
GATION RESULTS

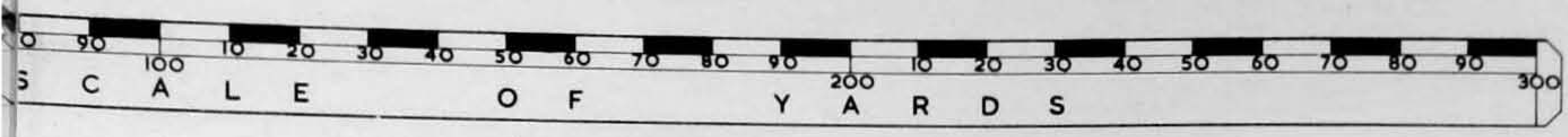


TURN 500 YDS FROM DOWNCAST SHAFT

SIX BELLS COLLIER



RY Nº 5 PIT – 'W' DIST

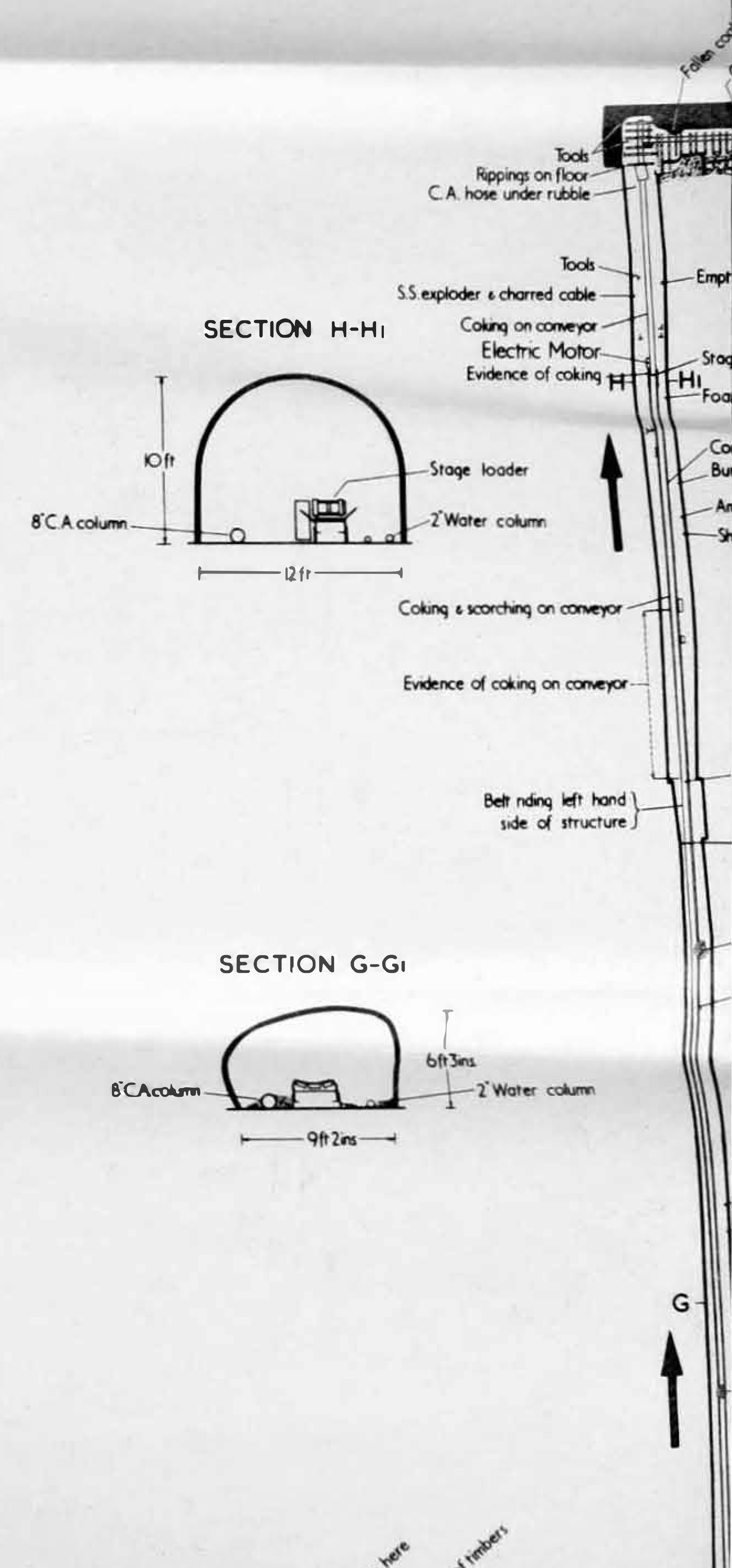


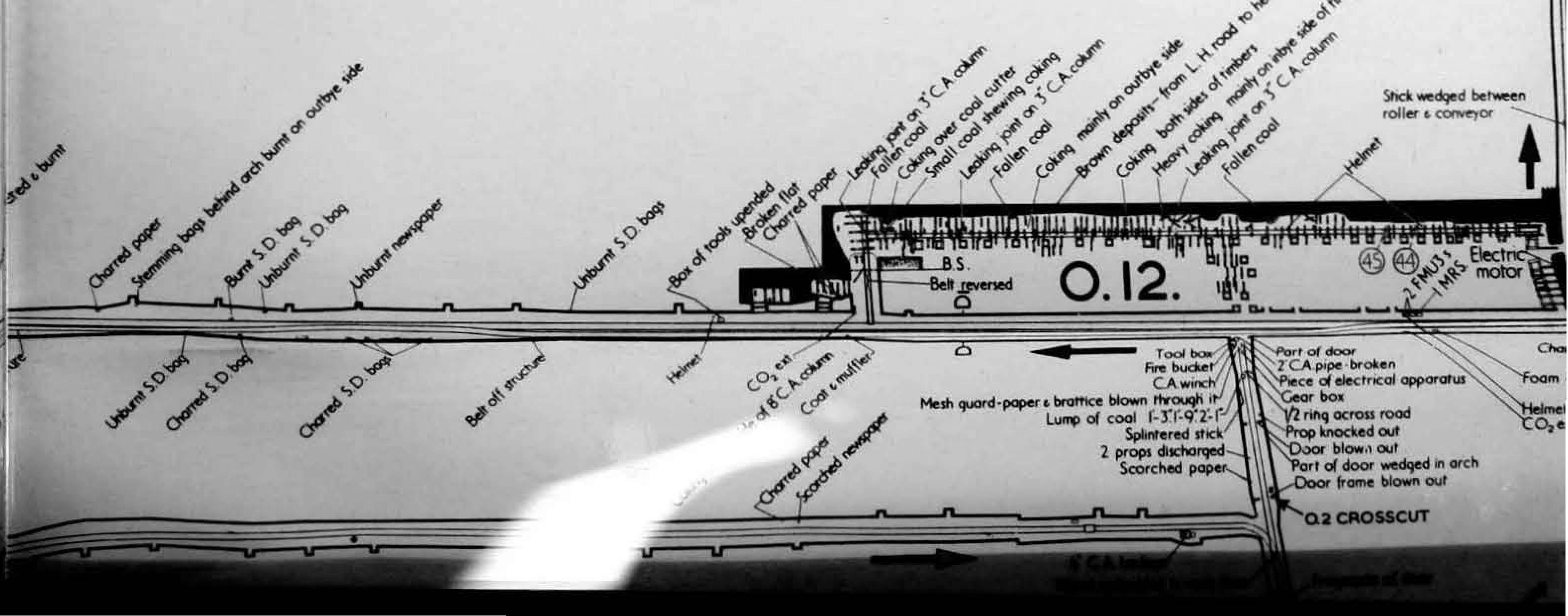
REFERENCE

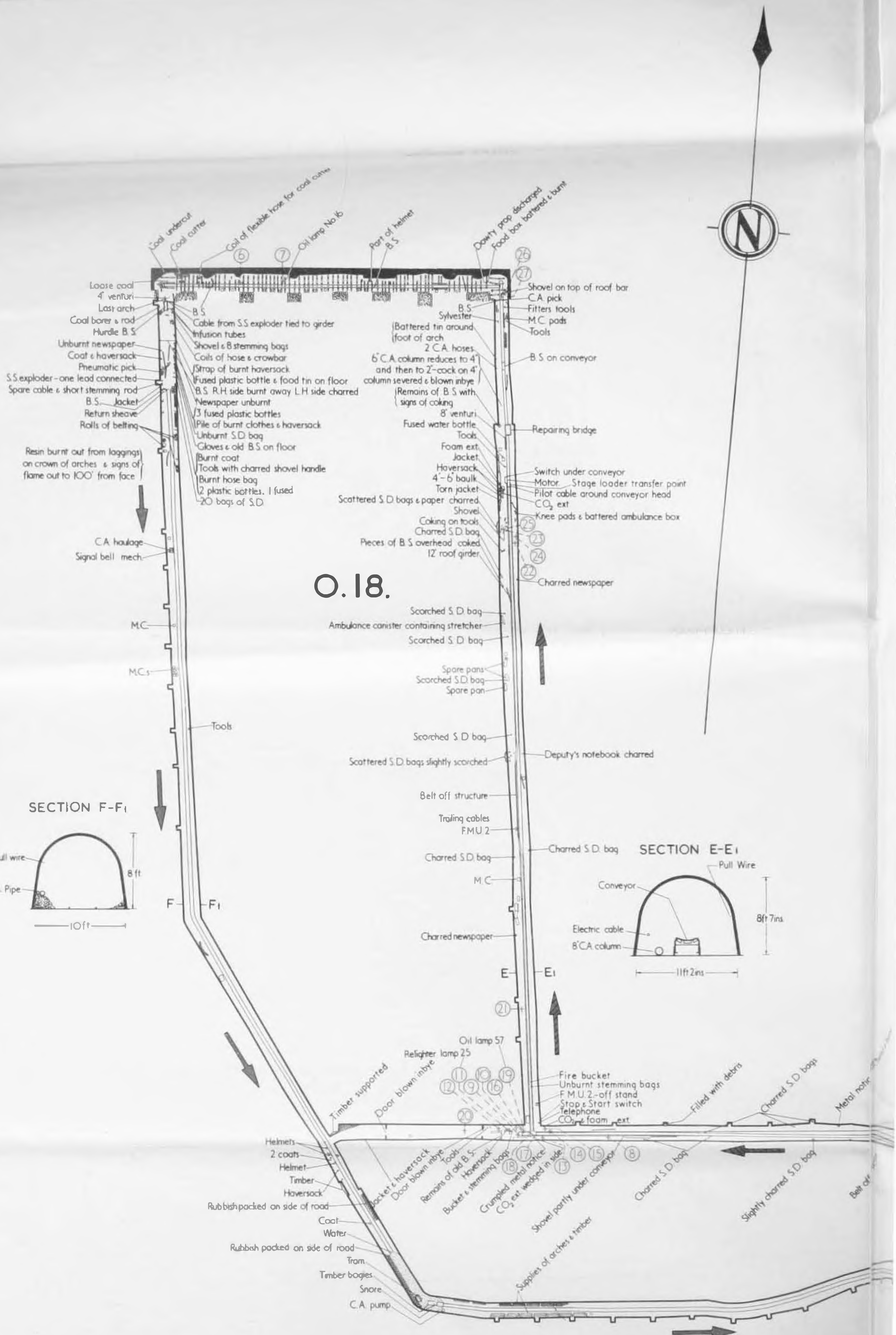
DIRECTION OF AIR CURRENT	INTAKE	➡
	RETURN	➡
EMPTY TRAMS		▭
TRAMS OF COAL		■
TRAMS OF RUBBISH		▩
TROLLEYS		⊡
FALLS		▒
MUSCHAMP CHOCKS		MC.
COMPRESSED AIR		C.A.
STONE DUST		S. D
BRATTICE SHEET		B. S.
POSITIONS OF BODIES		㉔✝

LIST OF KILLED

Nº on PLAN	NAME	Nº on PLAN	NAME
1	D.E. LANE	24	W.G. REYNOLDS
2	P.J. WATKINS	25	F. REES
3	S. MOORE	26	C.R. MORGAN
4	W.J. MORDEN	27	R.M. MORGAN
5	H.A. MAYBERRY	28	W.T. DAVIES
6	W.A.C. PHIPPS	29	F. COOPER
7	G.H. LUFFMAN	30	P.G. ELSEY
8	R.J. EDWARDS	31	I. MORRIS
9	R.J. WILLIAMS	32	T.C. MAPP
10	T. PAUL	33	T.G. CRANDON
11	V.A. GRIFFITHS	34	A. WATERS
12	A.V. PARTRIDGE	35	F. WHITE
13	C.A. GRIFFITHS	36	D.J. BANCROFT
14	G. GOLDSPINK	37	J.J. KING
15	I. JONES	38	J.P. JONES
16	C.M.D. MORGAN	39	W.B. WHITTINGHAM
17	L.K. FRAMPTON	40	W.H. THOMAS
18	A.G. PINKETT	41	E.V. HARDING
19	W.H. PARTRIDGE	42	W. WESTON
20	R.C. BROWN	43	J. CORBETT
21	M. REYNOLDS	44	A. GARDNER
22	J. WOOSNAM	45	I.J. BAITON
23	A.J. EVANS		



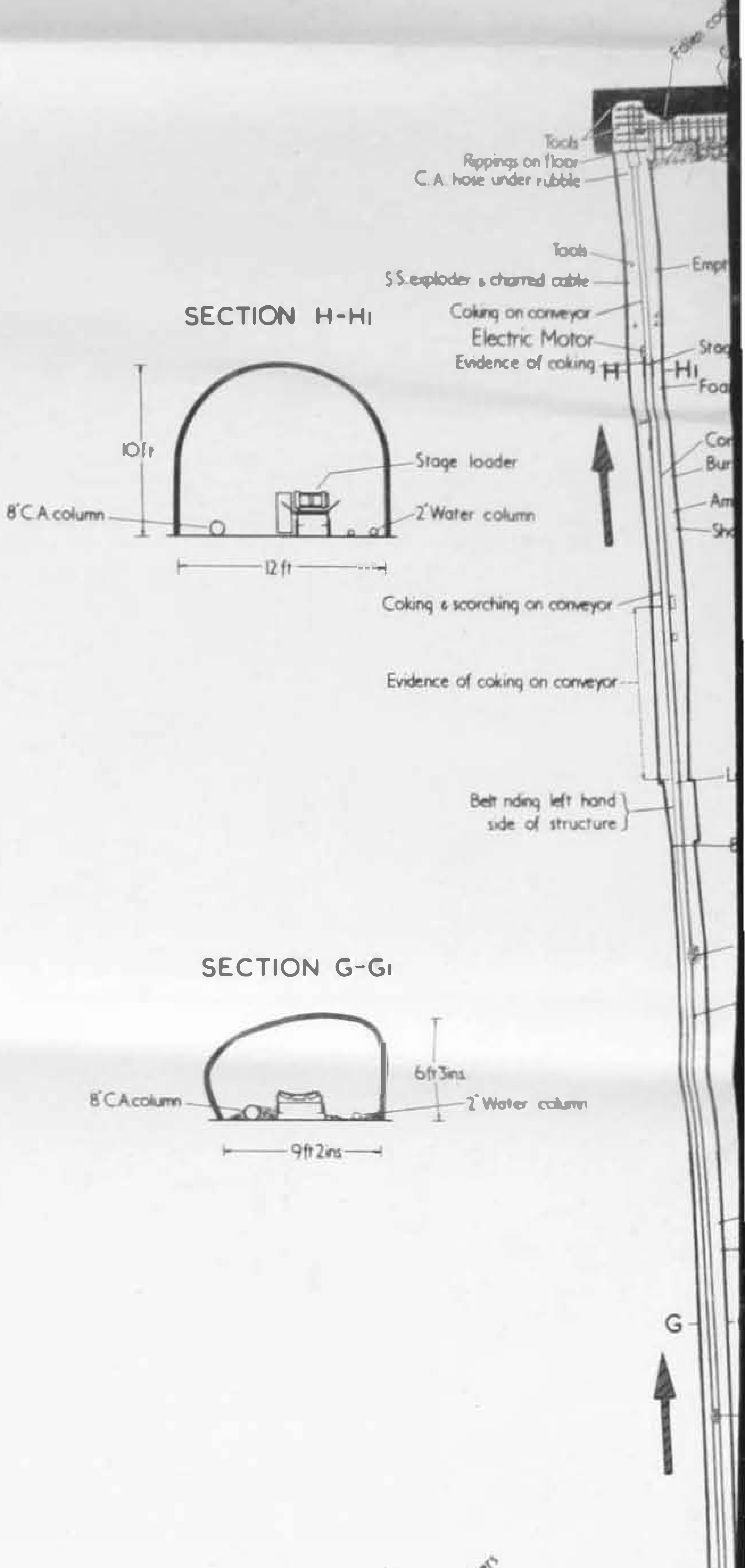




C.B.H. 35843-Wt. 811-Dd. 1616- 5M - 1/61

REFERENCE

DIRECTION OF AIR CURRENT INTAKE ➡
RETURN ➡
EMPTY TRAMS ☐
TRAMS OF COAL ■
TRAMS OF RUBBISH ▨
TROLLEYS ⊡
FALLS
MUSCHAMP CHOCKS MC.
COMPRESSED AIR C.A.
STONE DUST S.D.
BRATTICE SHEET B.S.
POSITIONS OF BODIES ㉔†



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Nº on PLAN	NAME	Nº on PLAN	NAME
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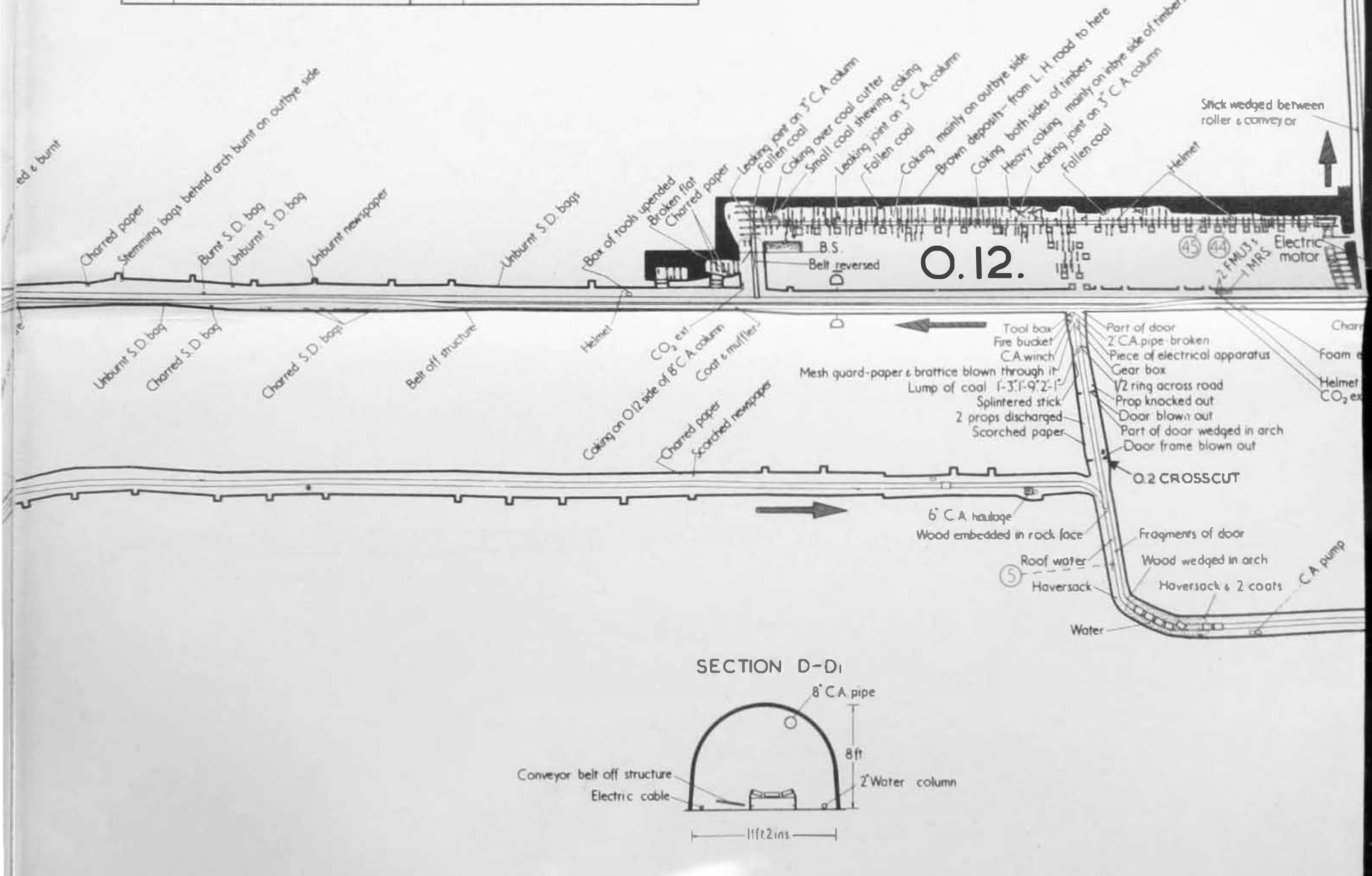
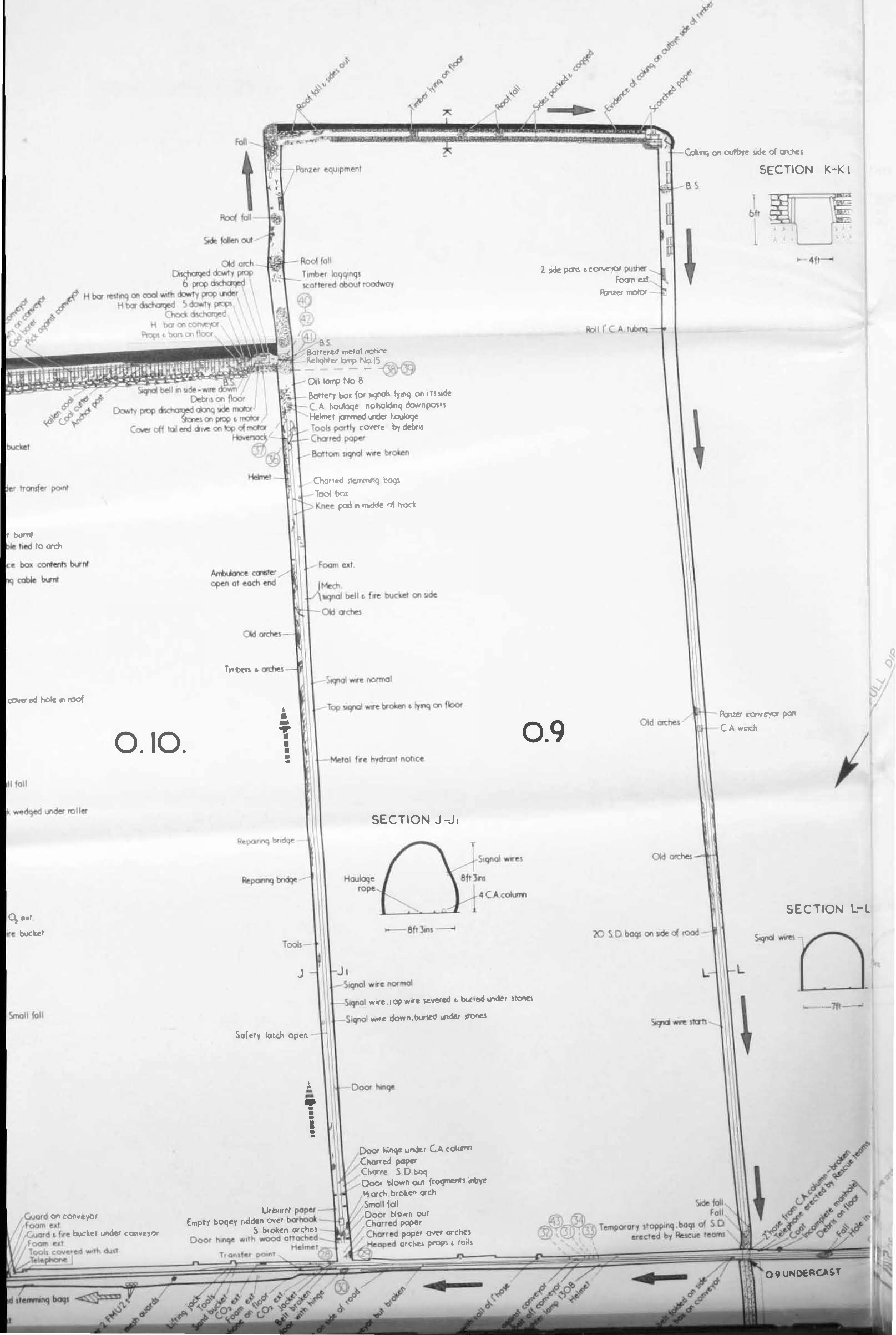
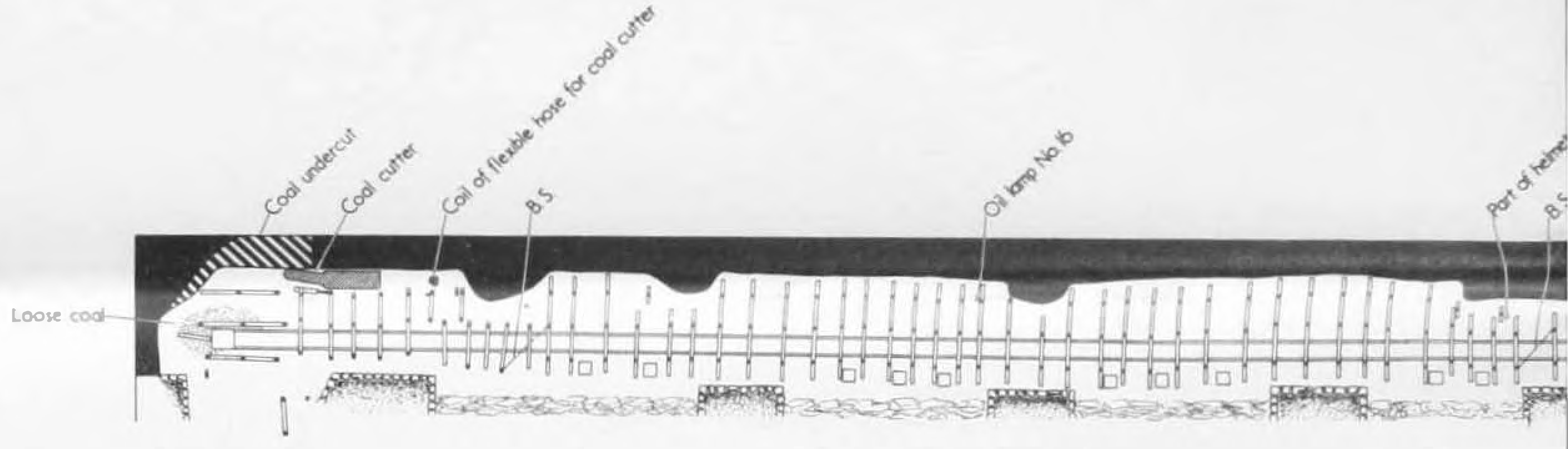
17	L.K. FRAMPTON	40	W.H. THOMAS
18	A.G. PINKETT	41	E.V. HARDING
19	W.H. PARTRIDGE	42	W. WESTON
20	R.C. BROWN	43	J. CORBETT
21	M. REYNOLDS	44	A. GARDNER
22	J. WOOSNAM	45	I.J. BAITON
23	A.J. EVANS		



ICT OLD COAL SEAM



M-PLAN SHEWING SC



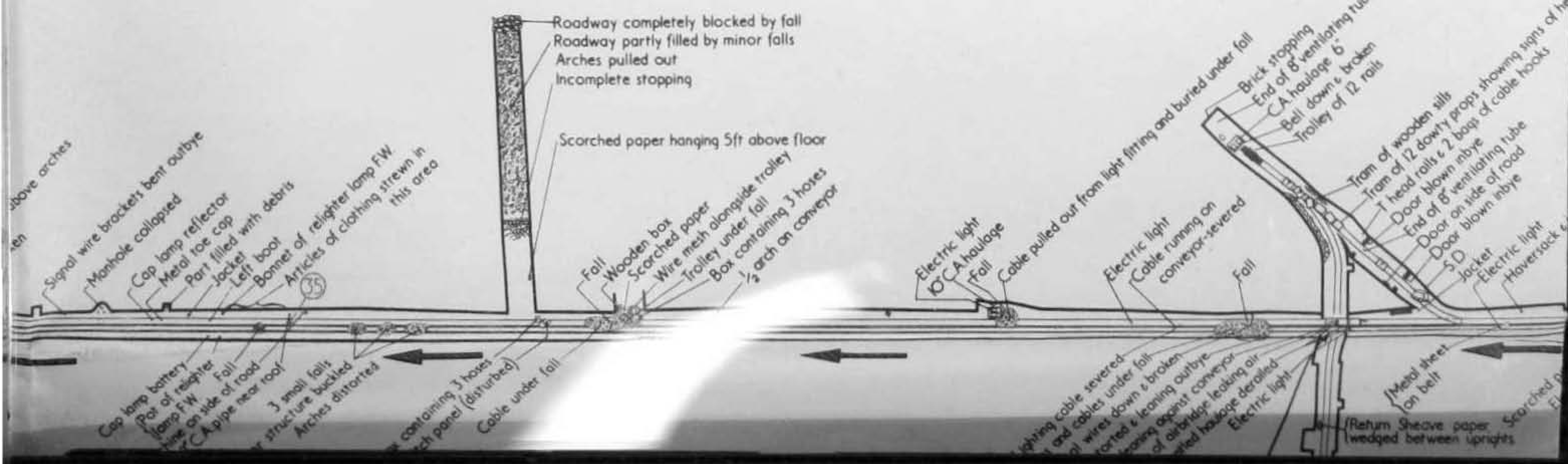
All muschamp chocks unless otherwise indicated

O.18.

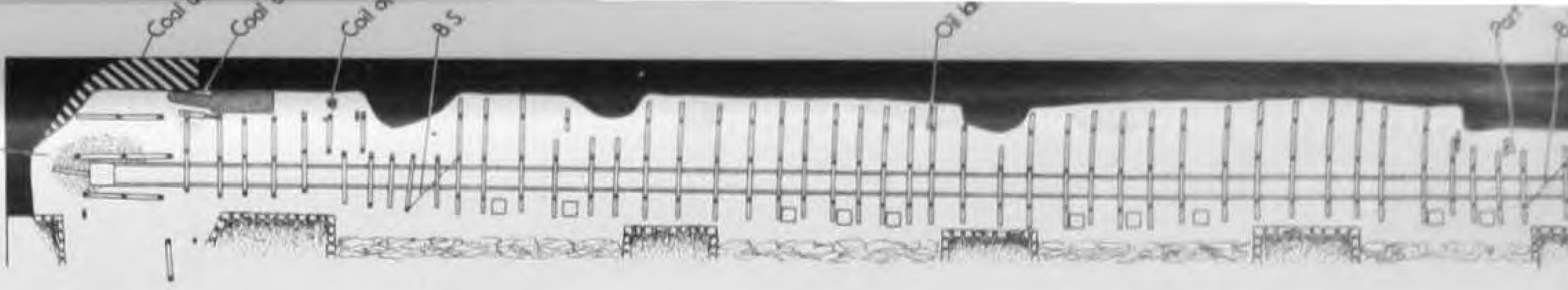
AVERAGE SECTION

OLD COAL SEAM

ins

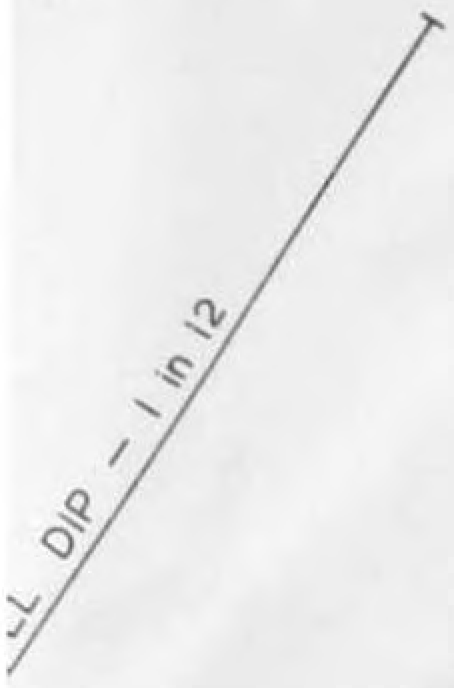



Old arch
Discharged dowty prop
6 prop discharged
H bar resting on coal with dowty prop under
H bar discharged 5 dowty props
Chock discharged
H bar on conveyor
Props & bars on floor
ard on conveyor
Dowty on conveyor
Coal borer
Pick against conveyor
Signal bell in side - wire down
Debris on floor
Dowty prop discharged along side motor
Stones on prop & motor
Cover off tail end drive on top of motor
Haversack
Fallen coal
Coal cutter
Anchor post
Roof fall
Timber laggings
scattered about roadway
40
42
41
Relighter lamp No 15
38
39
Oil lamp No 8
Battery box for signals lying on its side
C A haulage no holding downposts
Helmet jammed under haulage
Tools partly covered by debris
Charred paper
Bottom signal wire broken
37
36
Helmet
Charred slemming bags
Tool box
Knee pad in middle of track
fire bucket
loader transfer point
n ext.
veyor burnt
t cable tied to arch
bulance box contents burnt
t firing cable burnt
Ambulance canister
open at each end
Foam ext.
Mech.
signal bell & fire bucket on side
Old arches
Old arches
Timbers & arches
Signal wire normal
rge covered hole in roof
Top signal wire broken & lying on floor
O.10.
O.9
Metal fire hydrant notice
mall fall
tick wedged under roller
SECTION J-J1
Haulage rope
Signal wires
8ft 3ins
4 C.A. column
8ft 3ins
Repairing bridge
Repairing bridge
CO2 ext.
Fire bucket
Tools
J
J1
Signal wire normal
Signal wire, top wire severed & buried under stones
Signal wire down, buried under stones
Small fall
Safety latch open
Door hinge
Door hinge under C A column
Charred paper
Charred S.D. bag
Door blown out fragments inbye
½ arch broken arch
Small fall
Door blown out
Charred paper
Charred paper over arches
Heaped arches props & rails
Unburnt paper
Empty bogey ridden over barhook
5 broken arches
Door hinge with wood attached
Helmet
Transfer point
28
29
30
Guard on conveyor
Foam ext.
Guard & fire bucket under conveyor
Foam ext.
Tools covered with dust
Telephone
stemming bags
lighting transformer 2 FMU2's
2 wire mesh guards
Lifting jack
Tools
Sand bucket
CO2 ext.
Foam ext.
Telephone on floor
CO2 ext.
Jacket
Belt broken
Part of door with hinge
Part of belt on side of road
Belt on conveyor but broken
Box with 3 hoses & 1 nozzle
4
C
C1
3
2
43
34
32
31
33
Boring machine with roll of 1" hose
4ft diam haulage drum resting against conveyor
Belt off conveyor
Relighter lamp 1308
Helmet
Broken conveyor belt folded on side
Empty fire box on conveyor
6" CA haulage
Oil lamp 20
2 side pans & conveyor pusher
Foam ext.
Panzer motor
Roll 1" C.A. tubing
Old arches
Panzer conveyor pan
C A winch
FULL
Old arches
SECTION L-L1
Signal wires
7ft
20 S.D. bags on side of road
L
L
Signal wire starts
Side fall
Fall
Temporary stopping, bags of S.D.
erected by Rescue teams
2" hose from CA column - broken
Telephone erected by Rescue team
Coat
Incomplete manhole
Debris on floor
Fall
Hole in
O.9 UNDERCAST
Bricks from airbridge scattered on road
Old conveyor belt
Battered bucket
scattered paper & timber
Flexible hose across road
papers blown outbye against
Small quantity of
SECTION C-C1
Signal wires
6" CA column
8ft 3ins
10 ft

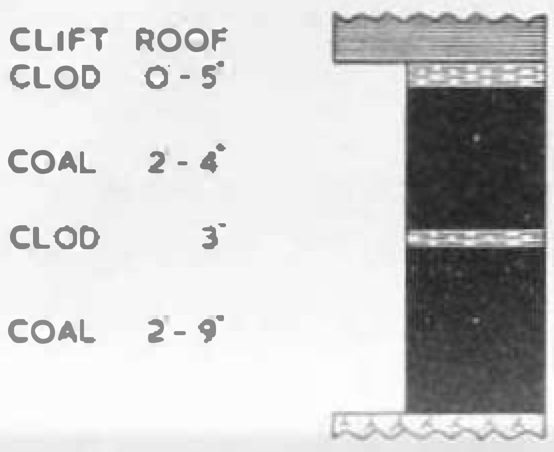


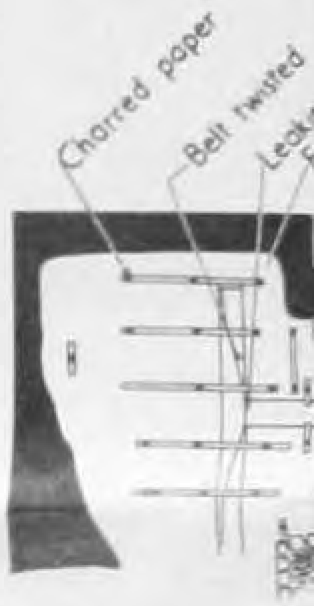
All muschamp chocks unless otherwise indicated

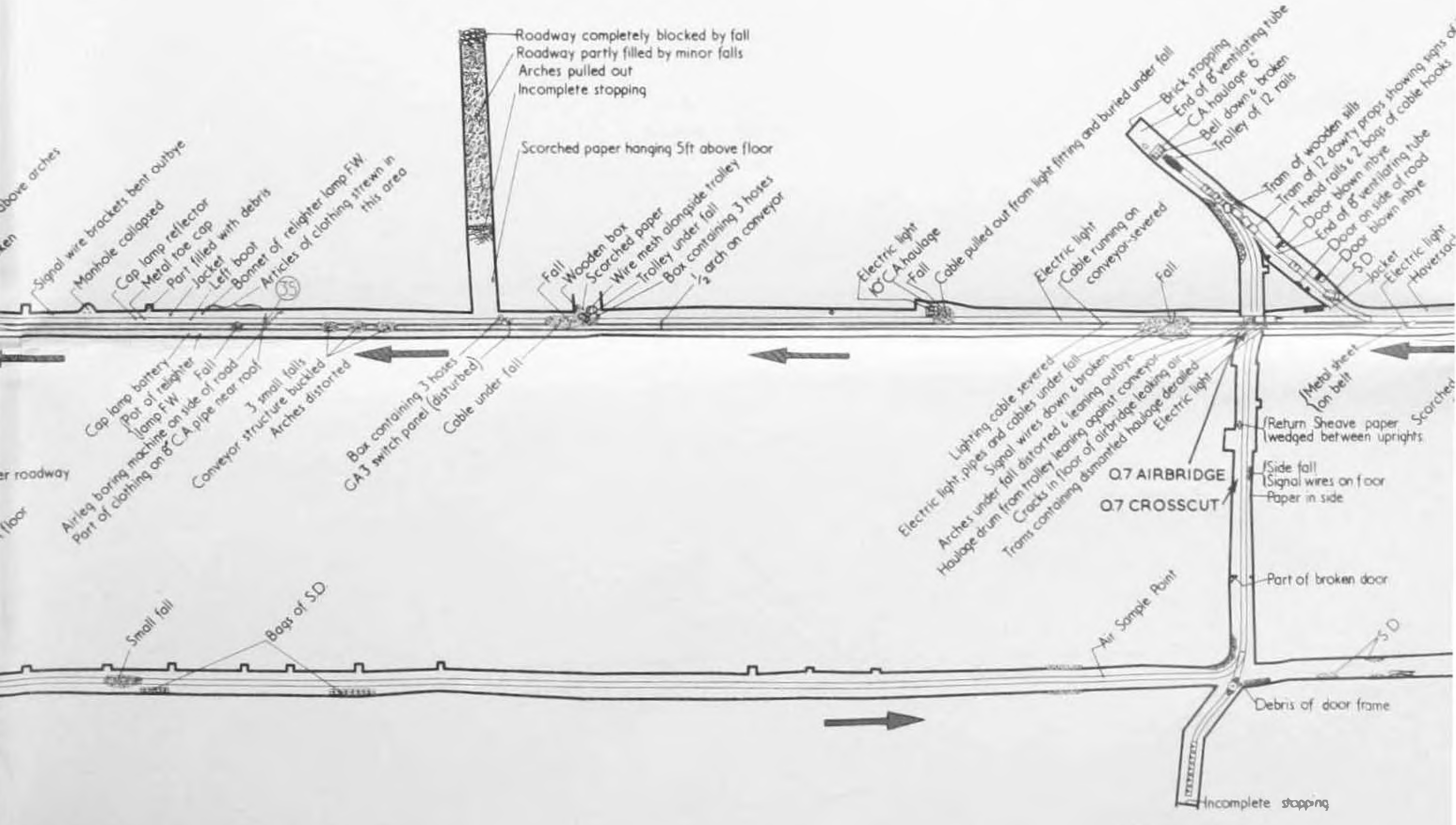
O.18.



AVERAGE SECTION
OLD COAL SEAM



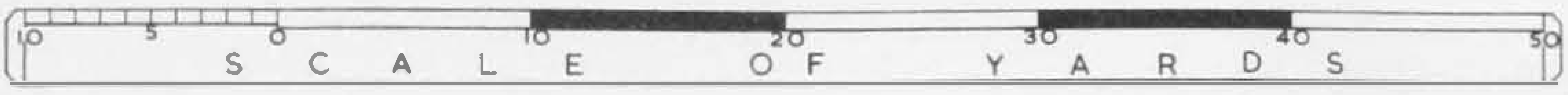


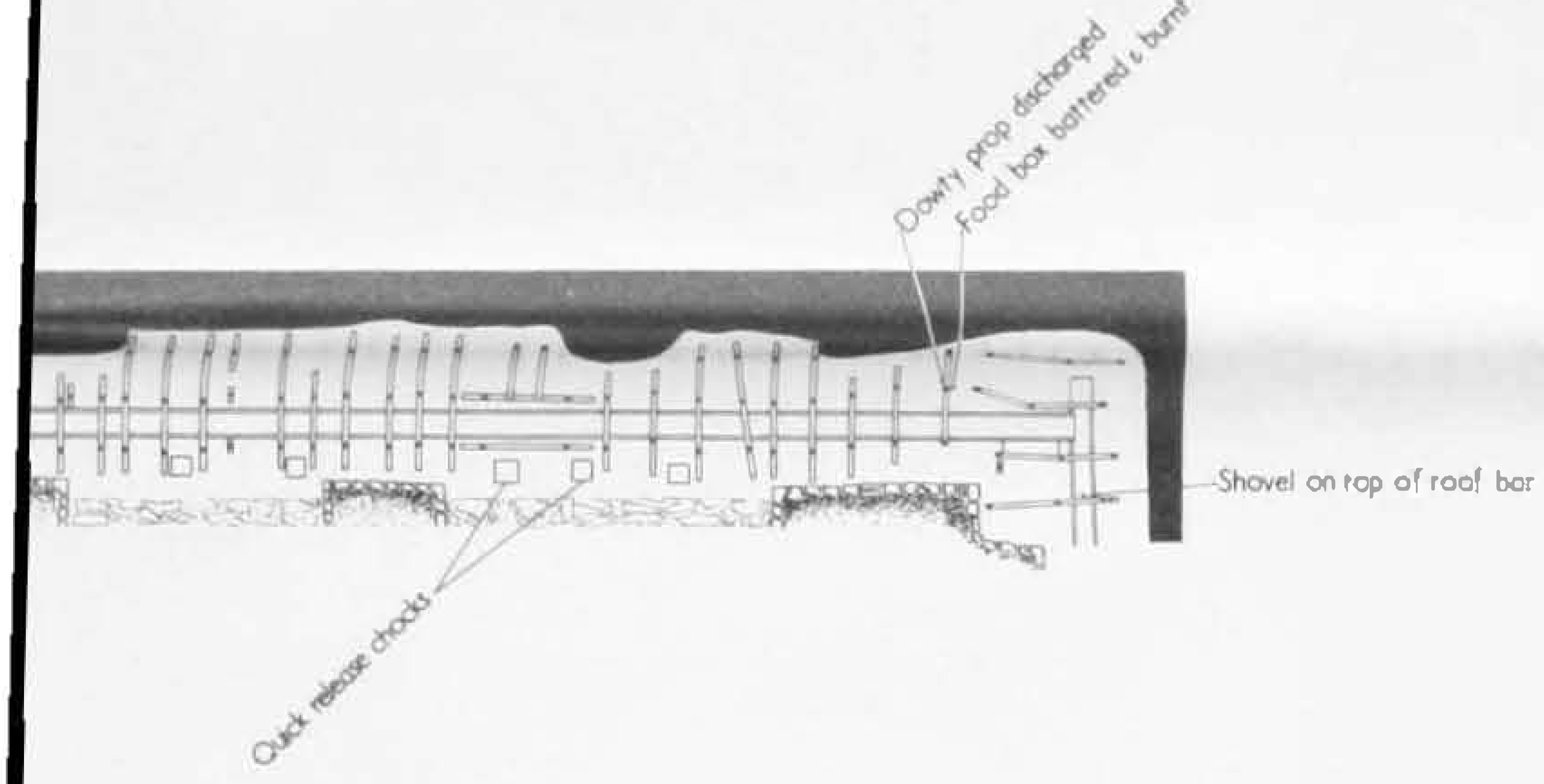


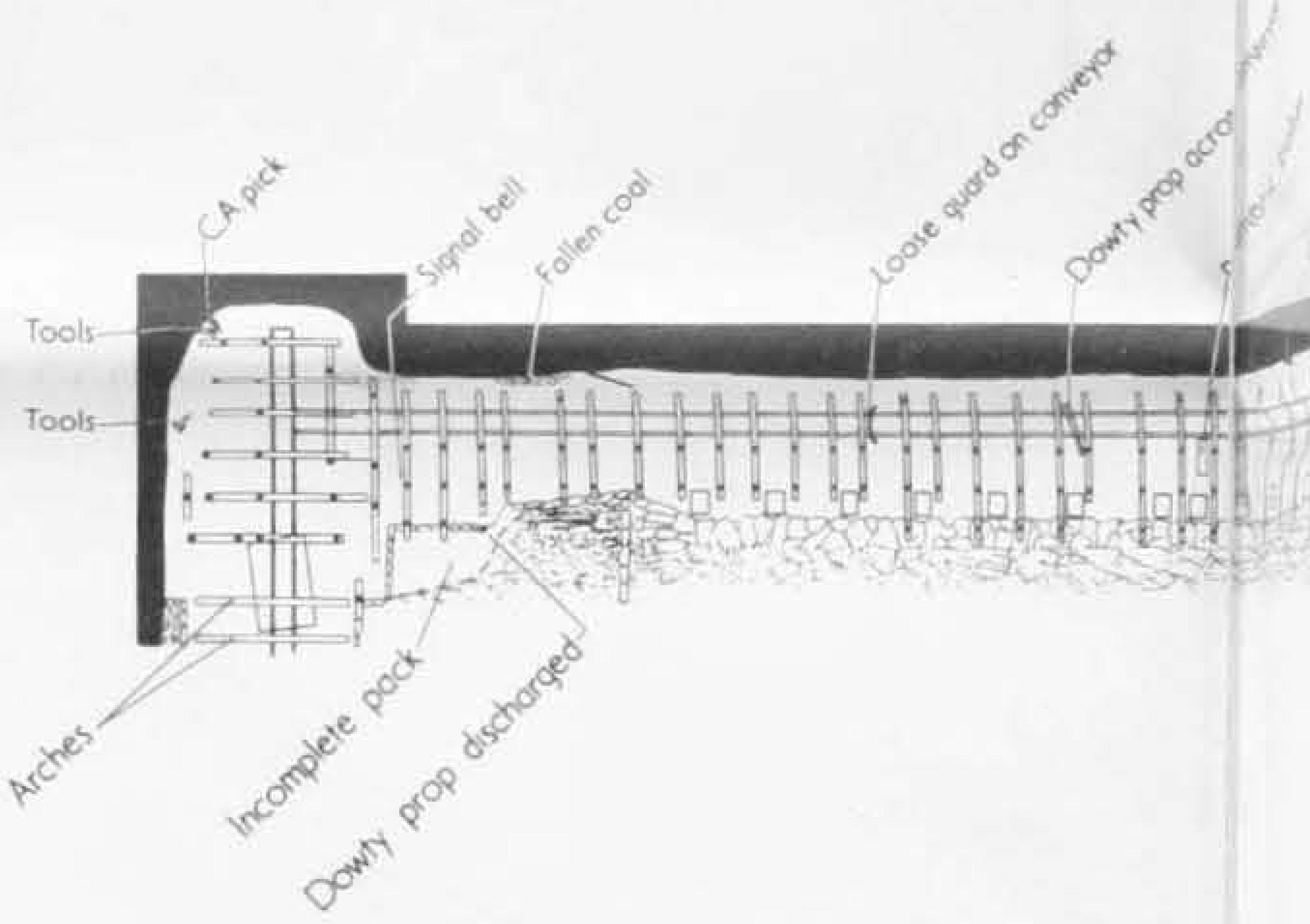
PLAN No.2

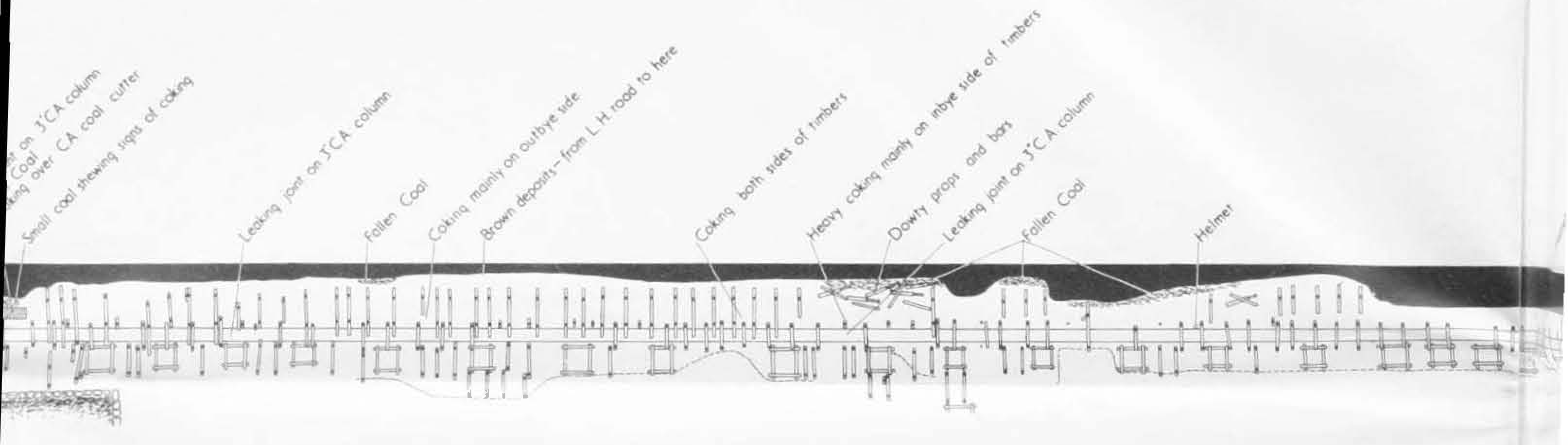
ENE OF EXPLOSION

ENLARGED PLAN OF COAL FACES









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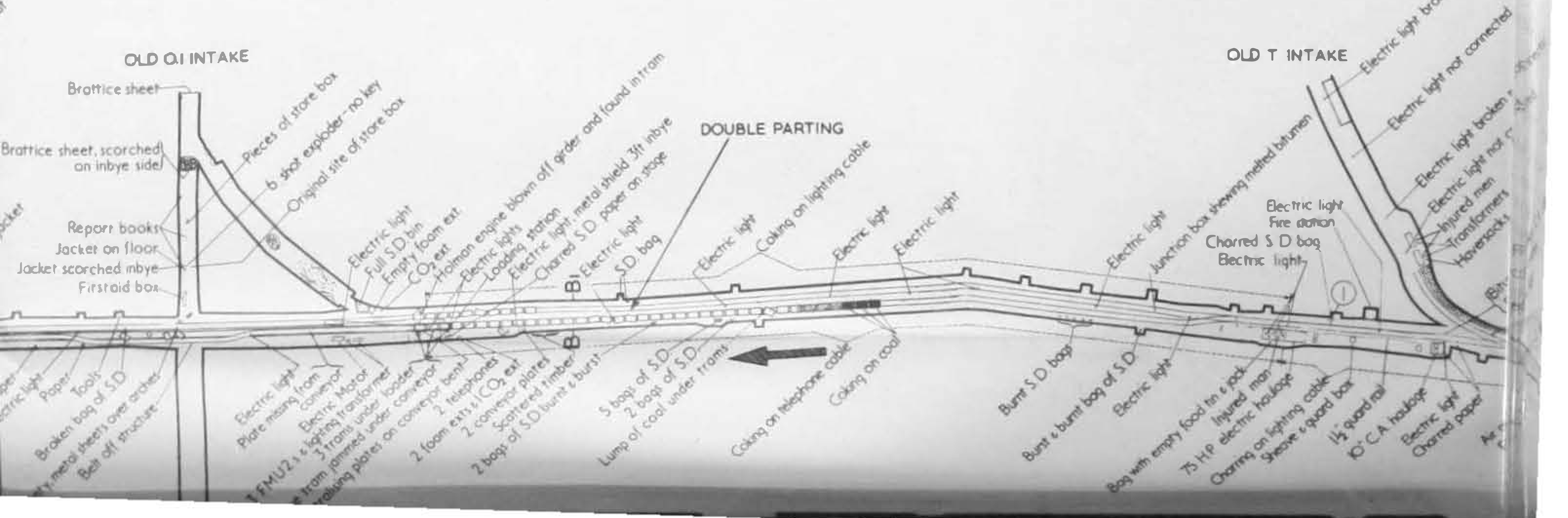
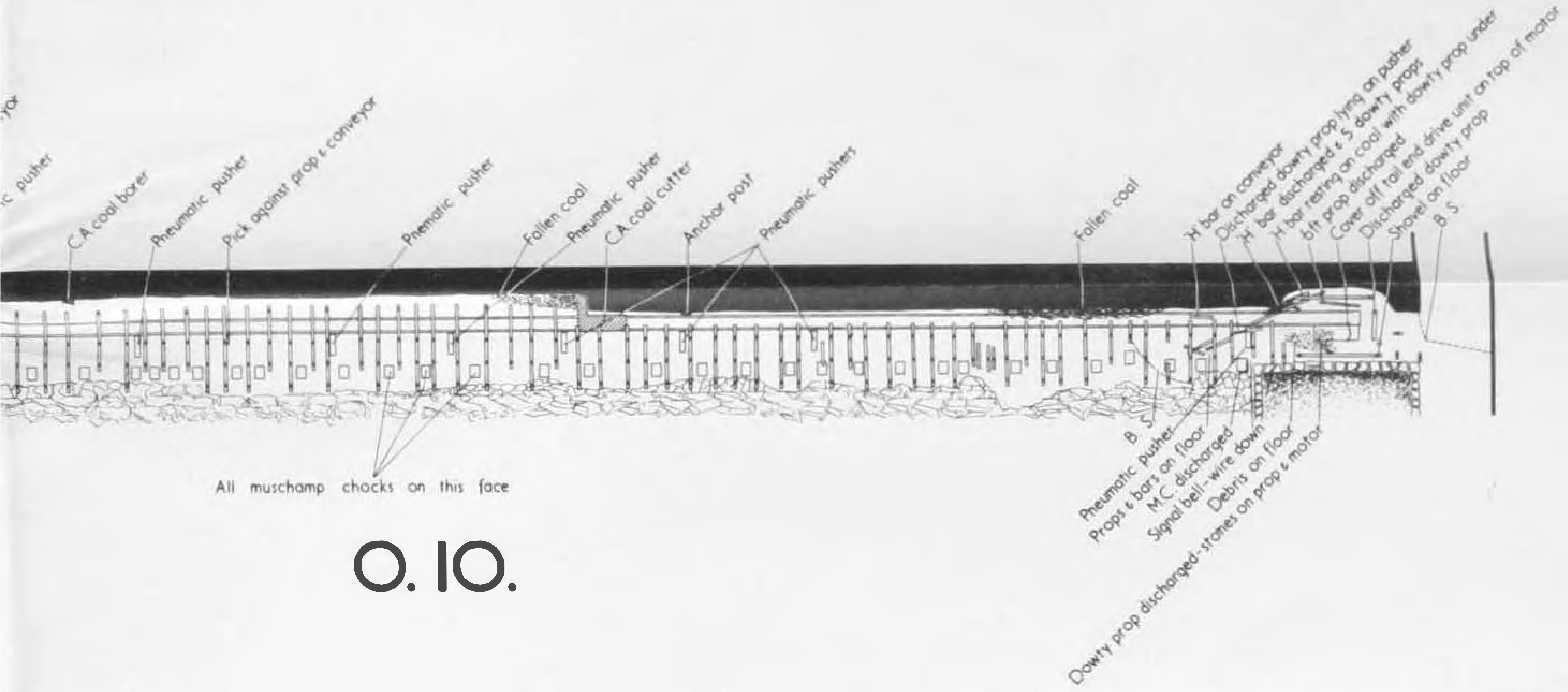


– 28TH JUNE 1960

S



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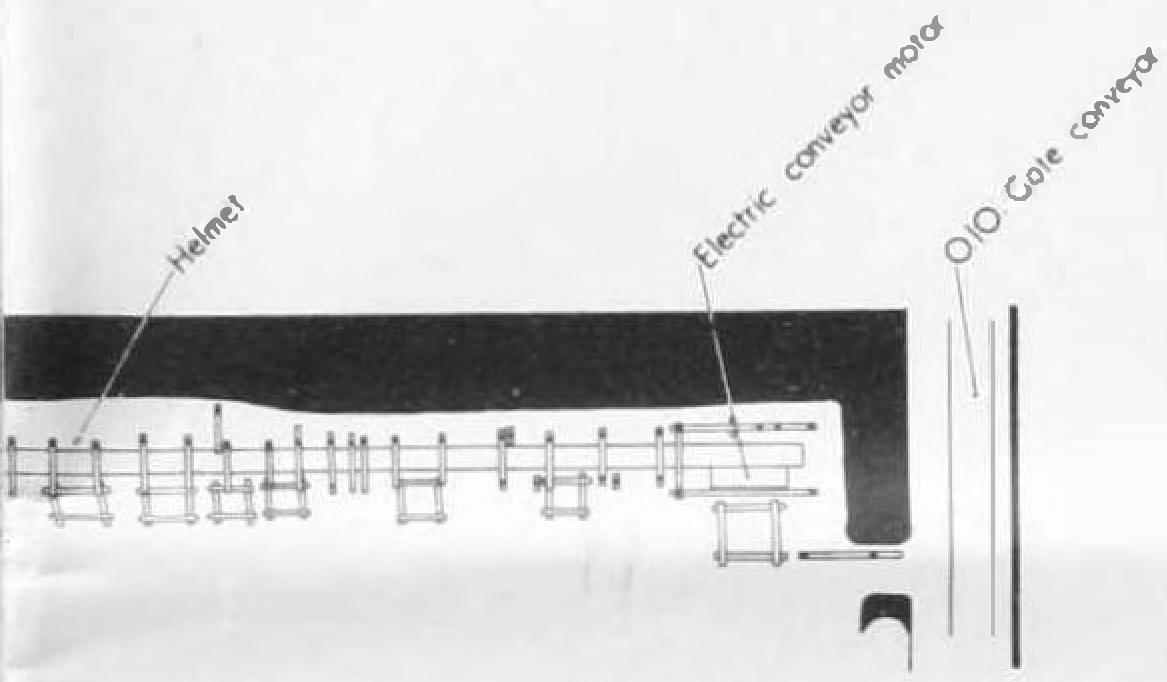

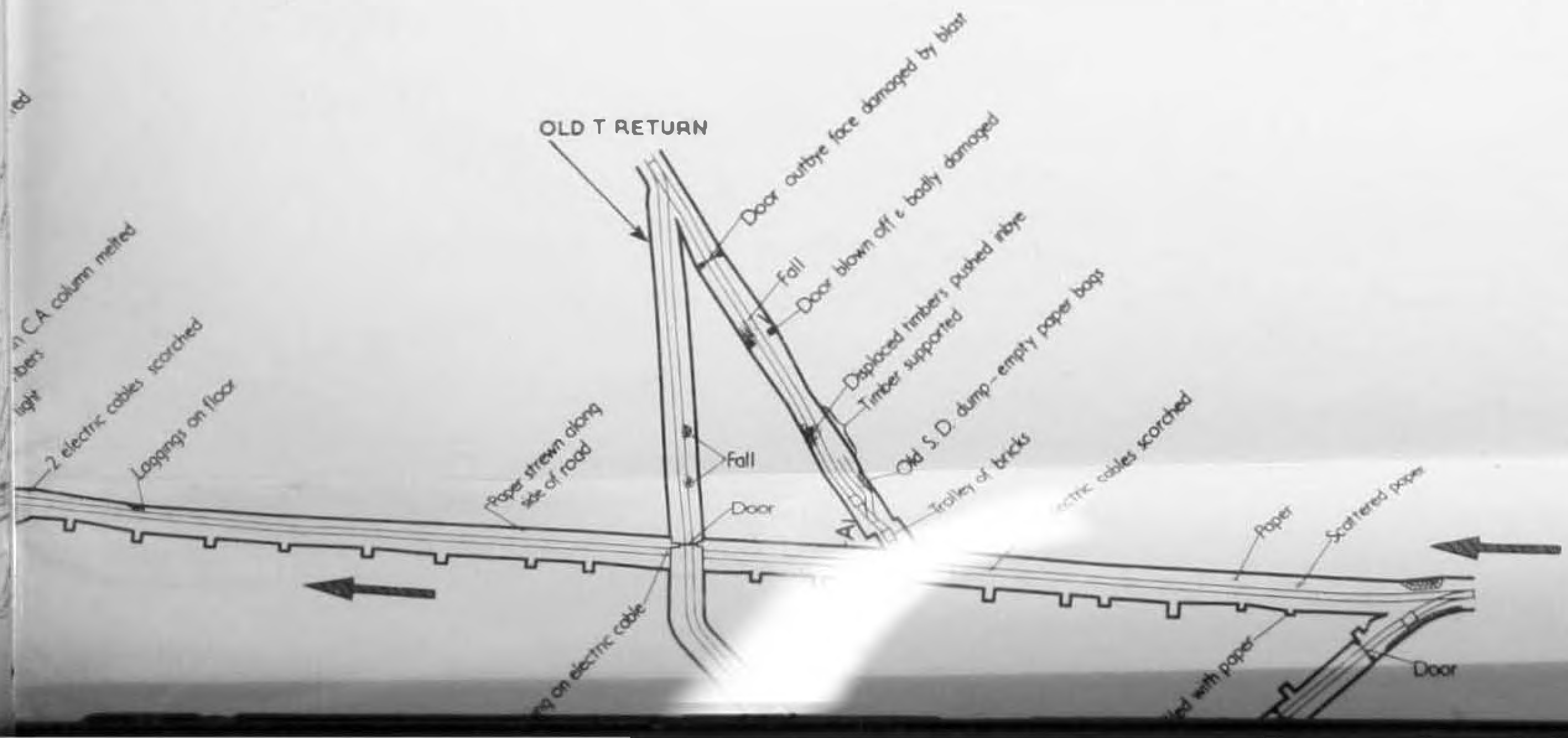

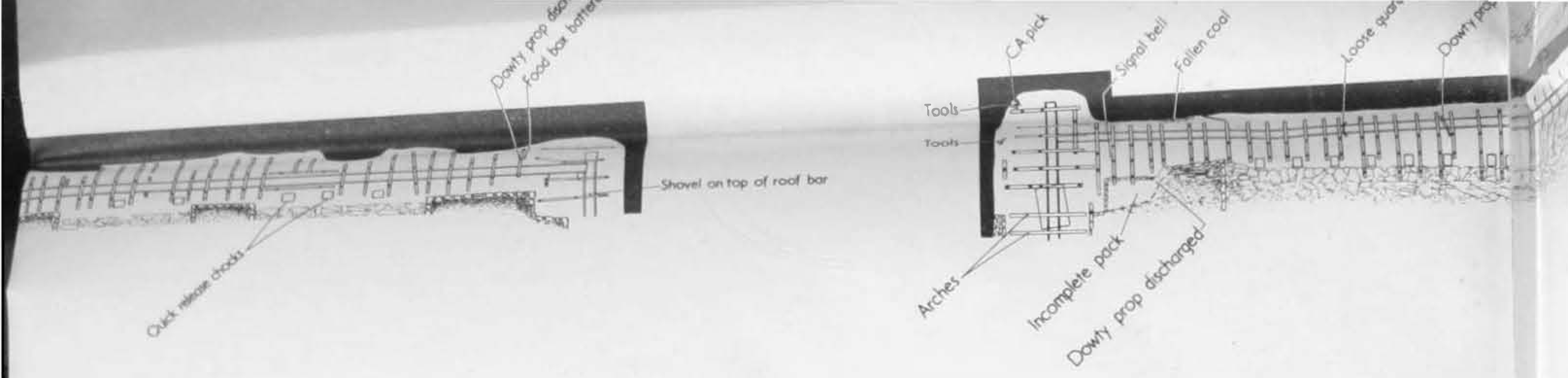

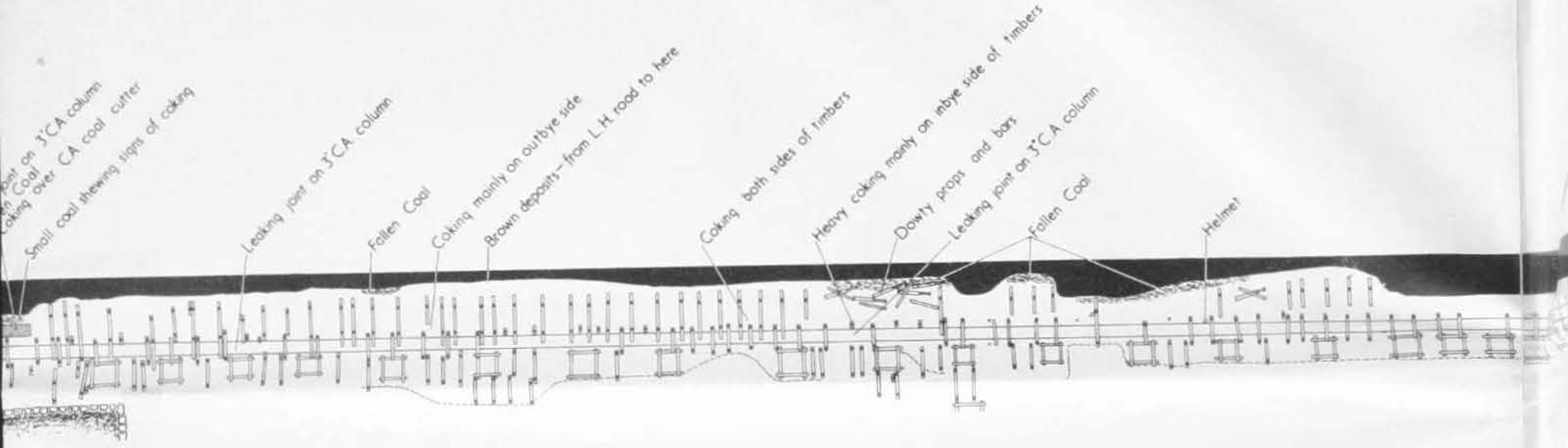

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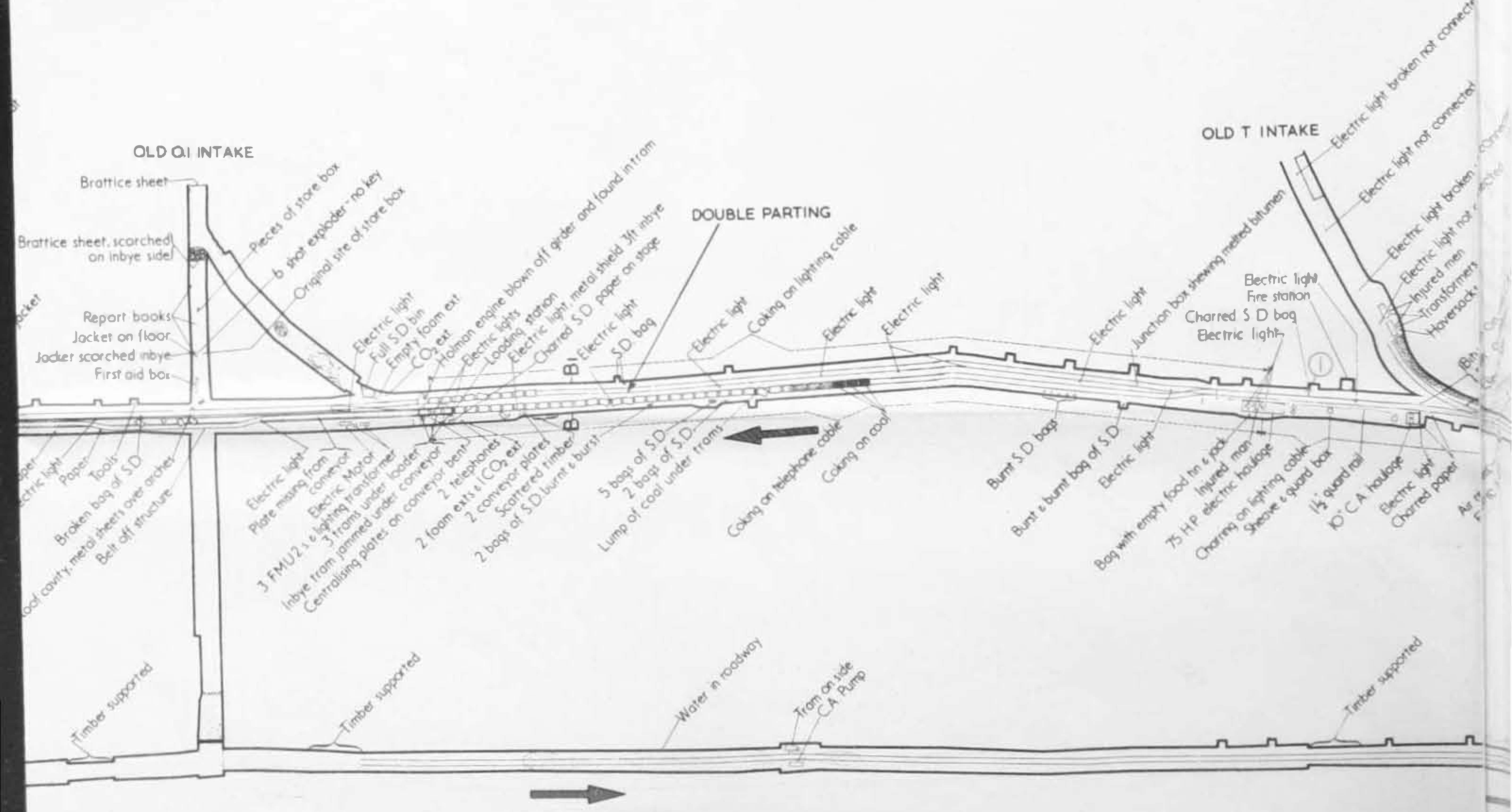
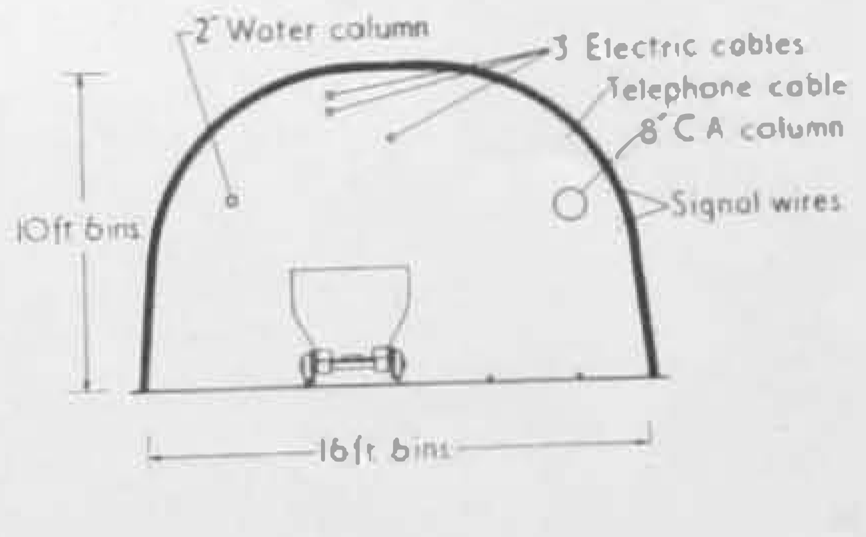
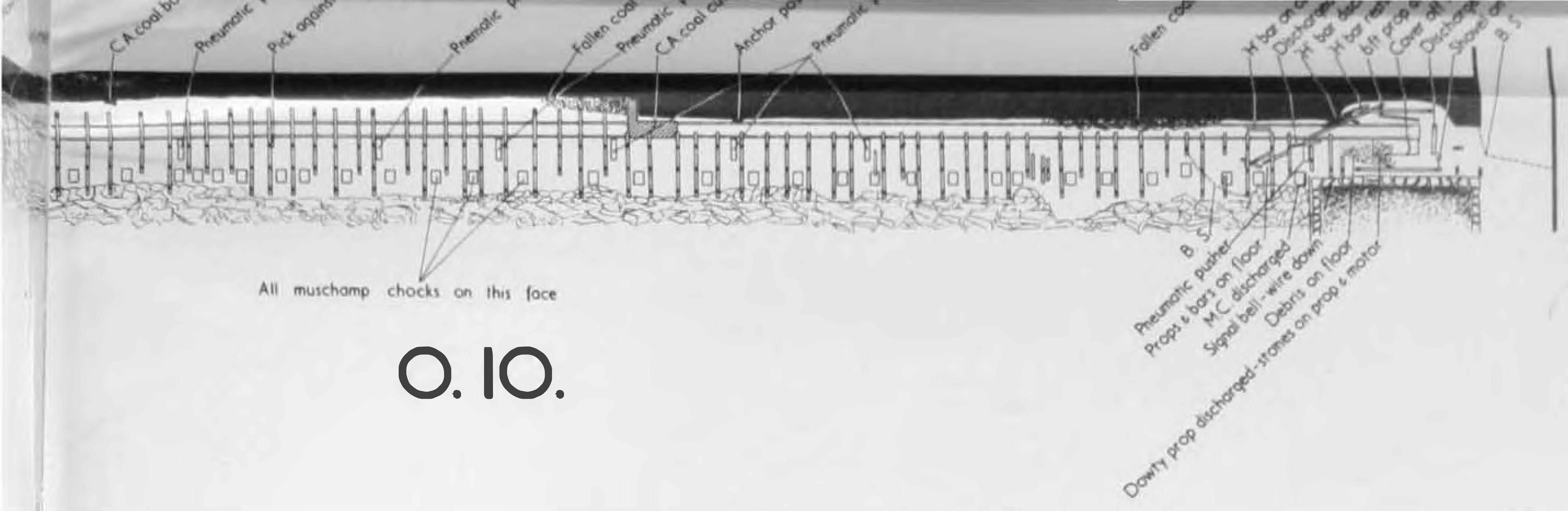


SECTION B-B1





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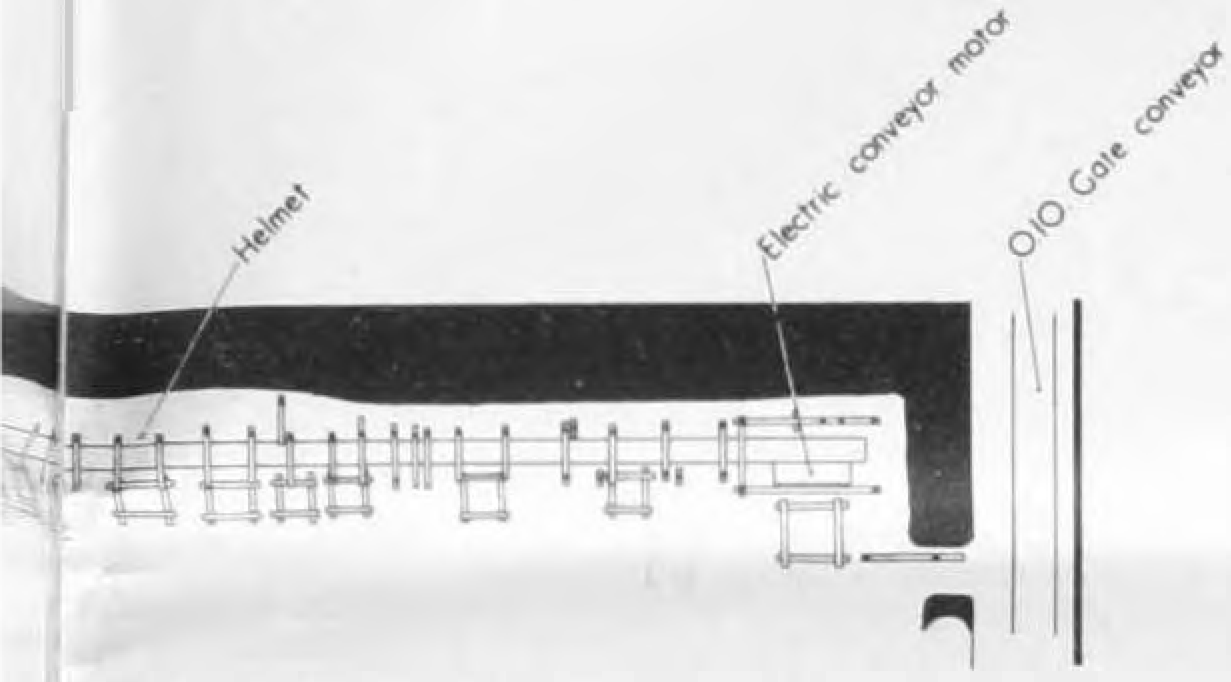
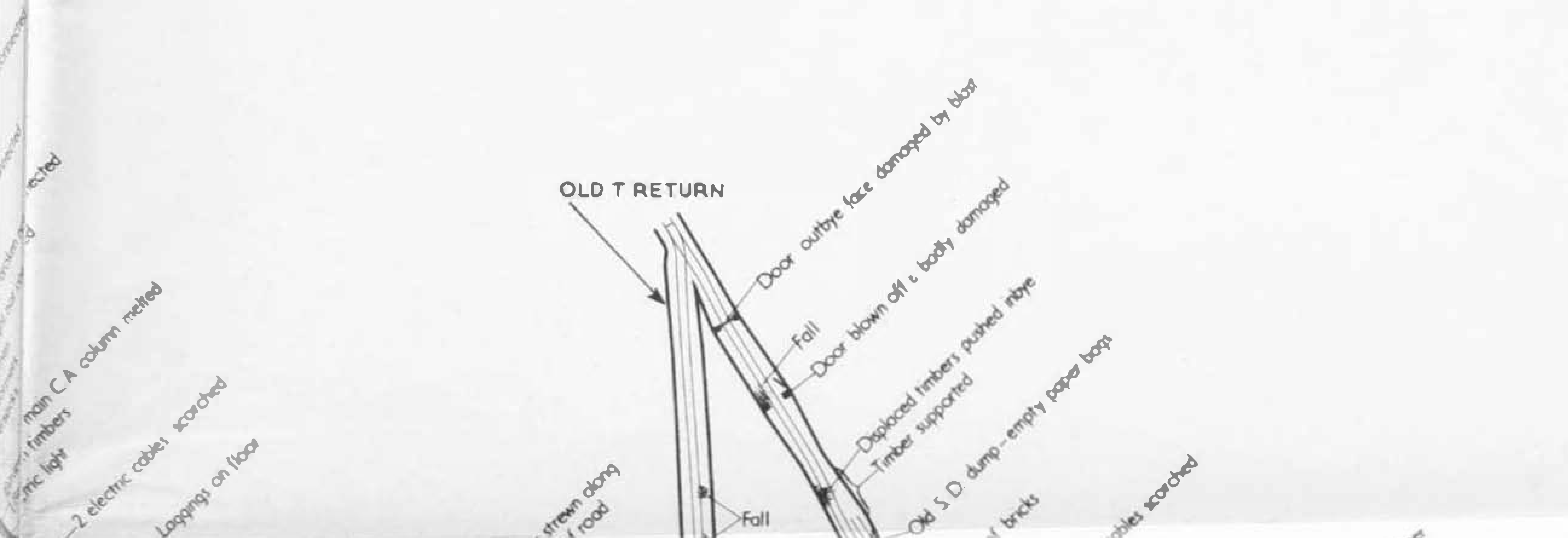


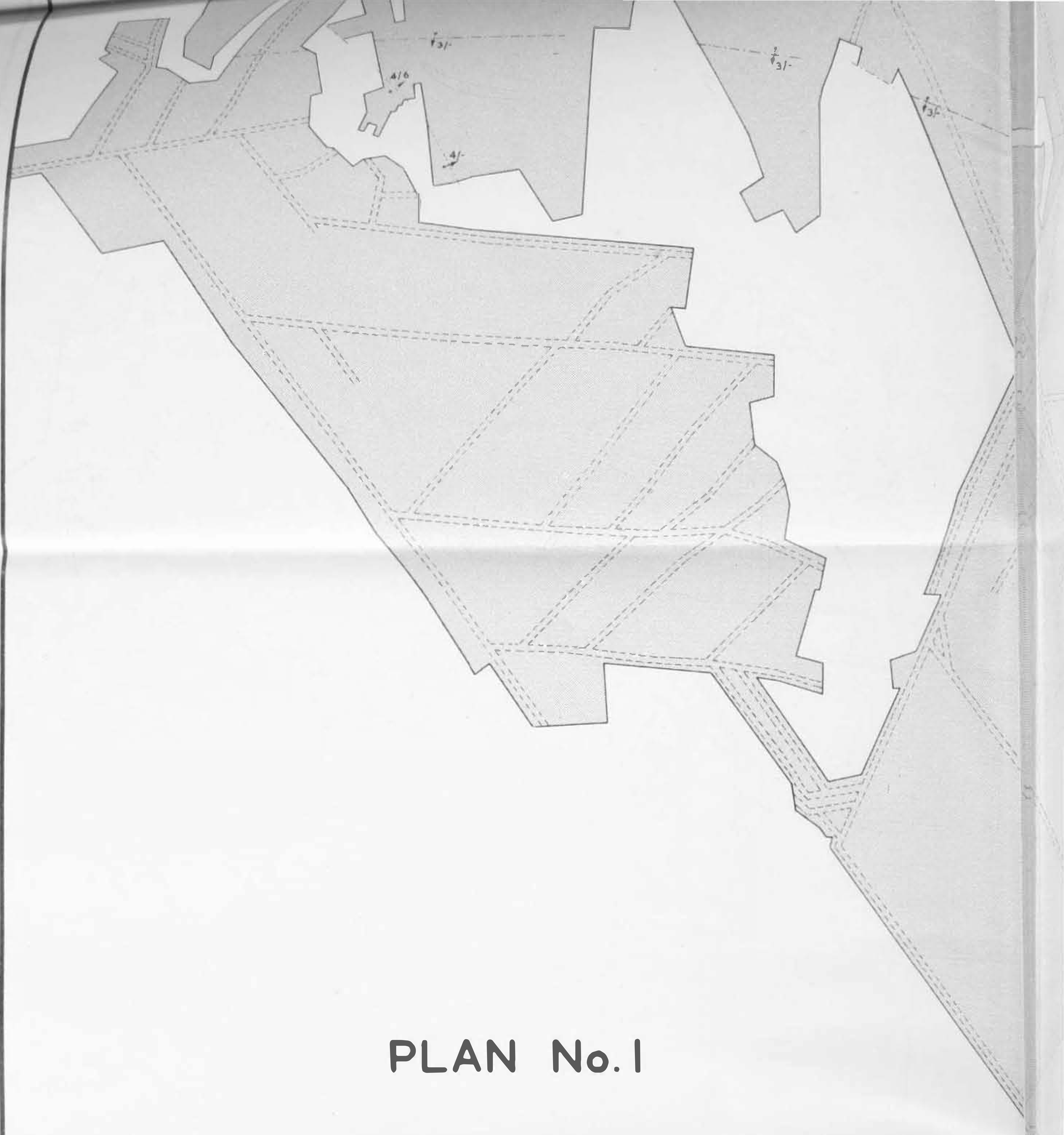


SECTION A-A1

PLAN No. 1

SIX BELLS COLLIERY
WORKINGS IN THE OLD COAL SEAM
showing west side and part


JULY 23 1933
3·0
OLD COAL WORKIN
1/6
1·0
11:1:33
O.18
DIP 1:30
MAY 24 1960
FEB. 24 1960
DIP 1:22
NOV. 28 1959
FULL DIP 1:12
O.12
DEC. 30
25:8:59
26:5:59
25:2:59
WEST
OLD COAL WORKINGS FROM MARINE COLLIERY
1956
22
PPED
1956



PLAN No. 1

SIX BELLS COLLIERY
WORKINGS IN THE OLD COAL SEAM

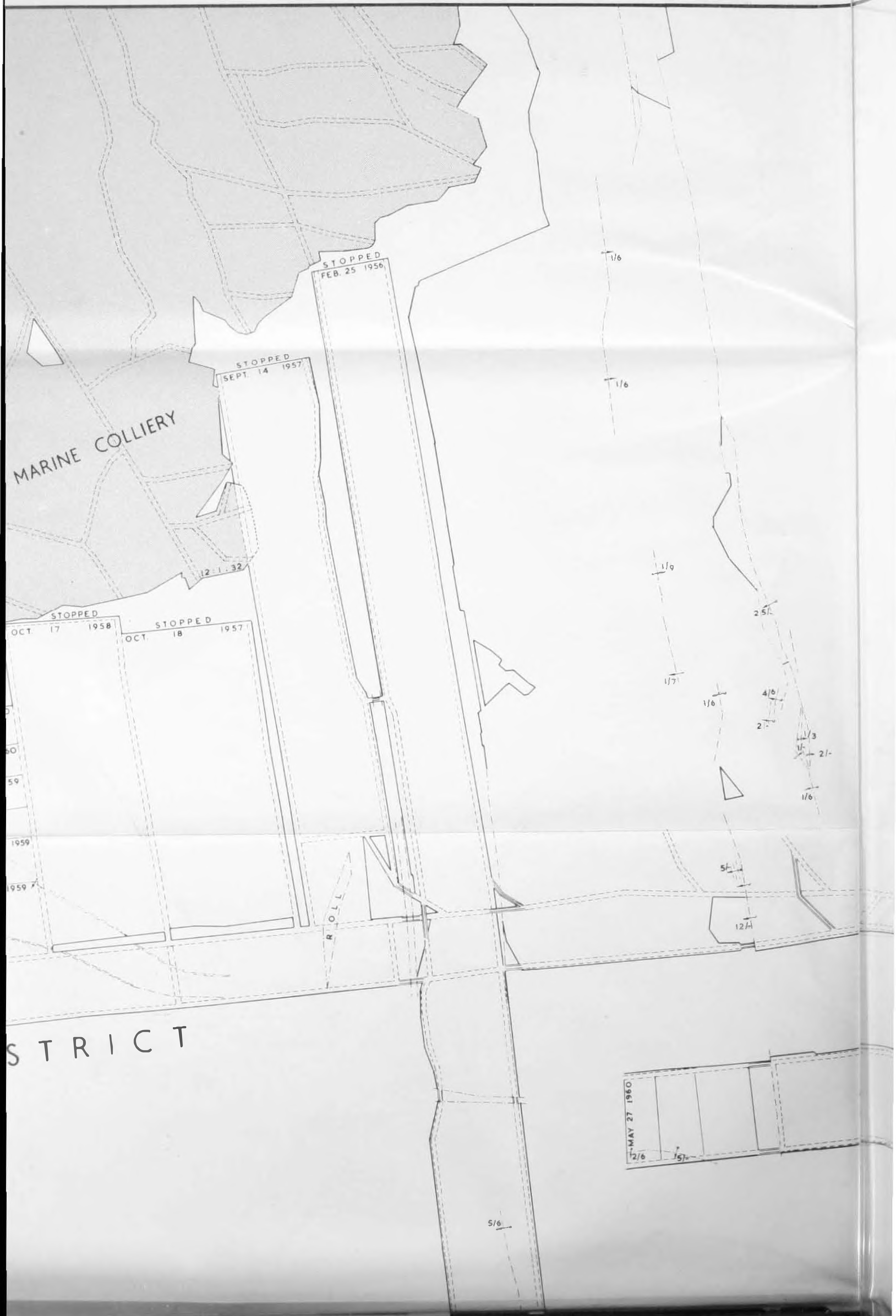
showing west side and part of Marine Colliery goaf

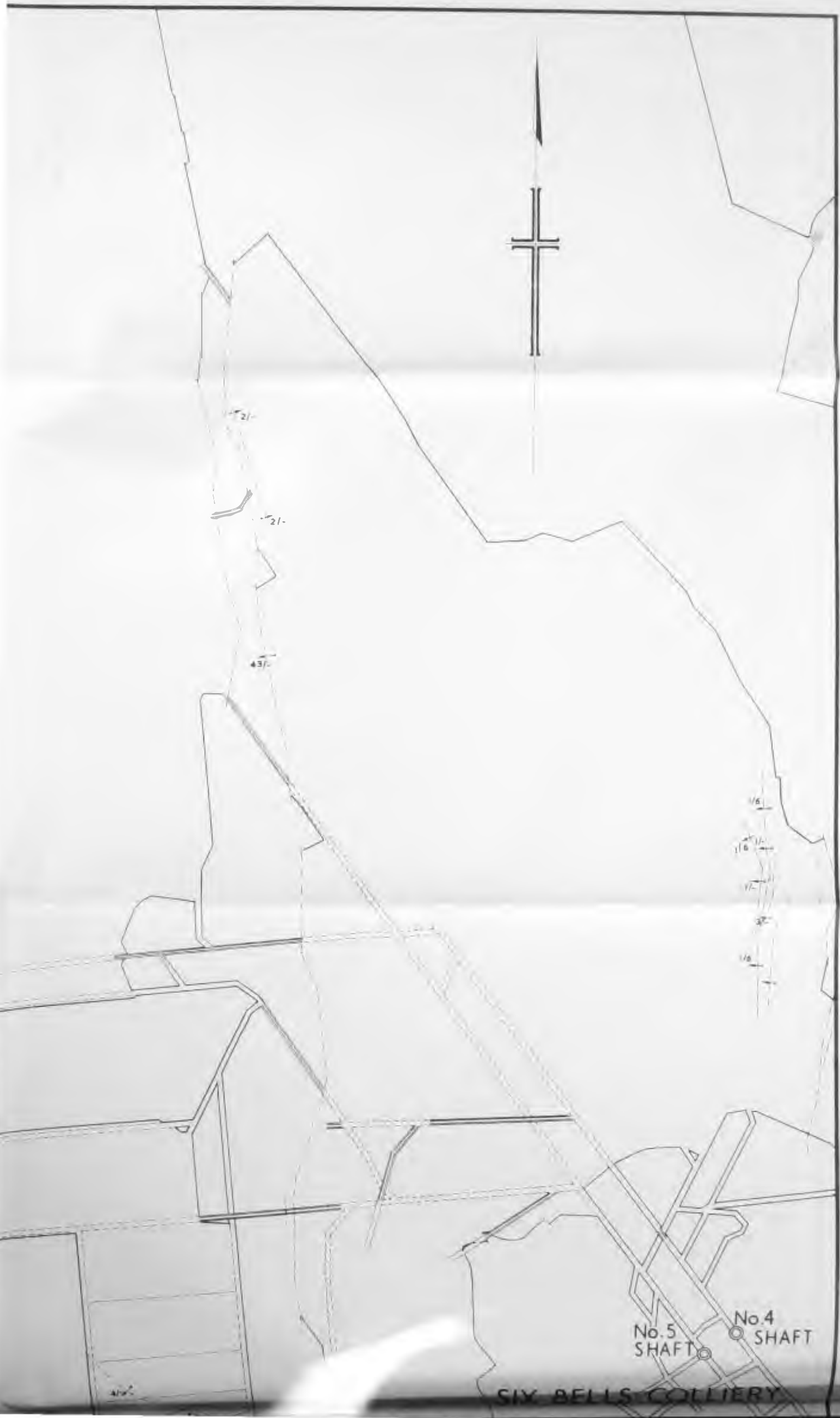
100 50 0 100 200 300 400

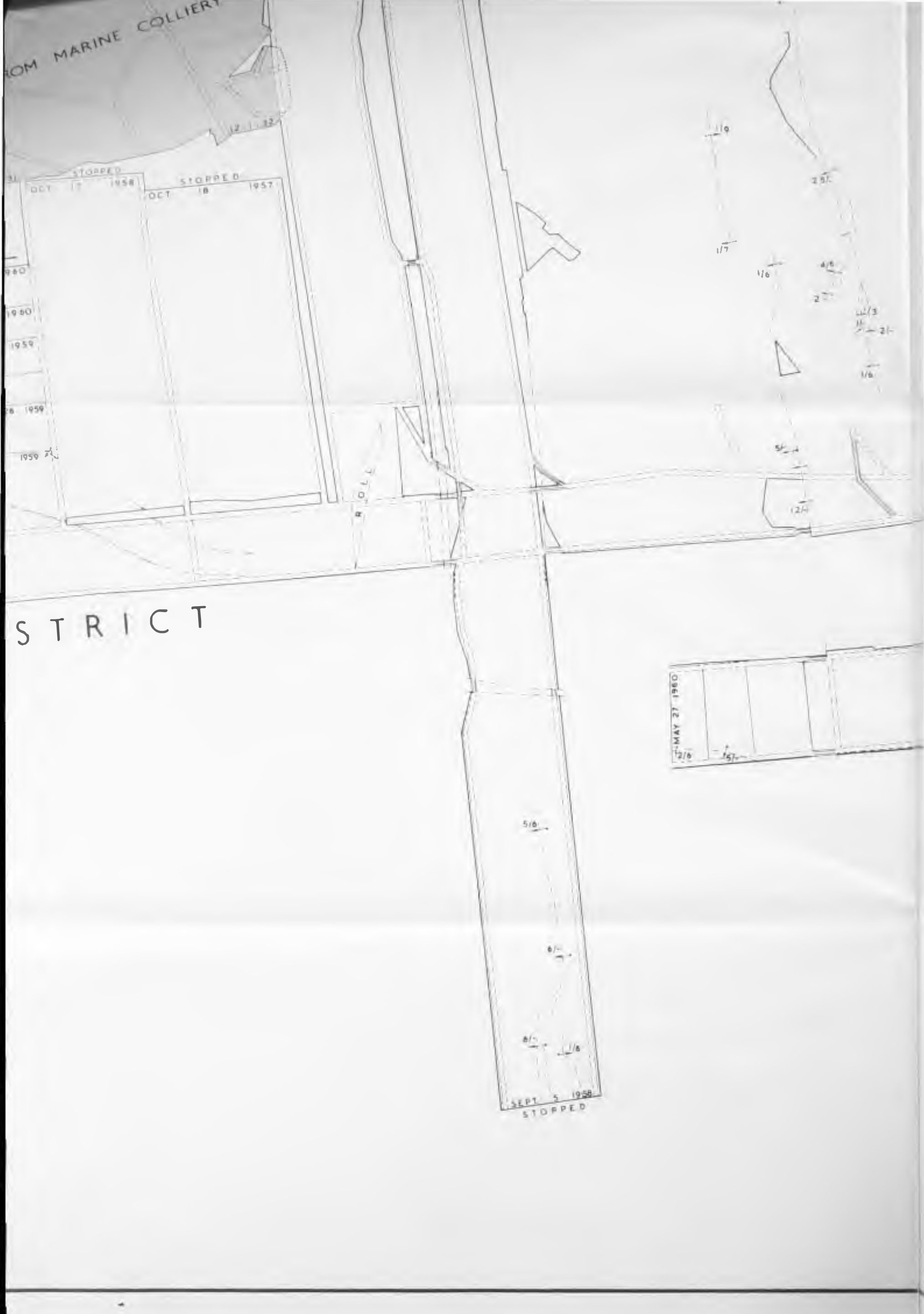
SCALE OF YARDS

C.B.H. 35864


3-0
1/6
JULY 23
OLD COAL WORKINC
1'-0"
11:33
O.18
DIP 1:30
MAY 24 1960
FEB. 24 1960
NOV 28 1959
DIP 1:22
FULL DIP 1:12
DIP 1:1
O.12
DEC. 30
25:8:59
26:5:59
25:2:59
WEST
OLD COAL WORKINGS FROM MARINE COLLIERY
1956
22
DECEMBER
STOPPED
DEC. 22 1956
STOPPED
JULY 4
STO


STOPPED FEB. 25 1956
STOPPED SEPT. 14 1957
MARINE COLLIERY
12.1.32
STOPPED OCT. 17 1958
STOPPED OCT. 18 1957
60
59
1959
1959
ROLL
STRICT
1/6
1/6
1/9
2 5/-
1/7
1/6
4/6
2/-
1/3
1/-
2/-
1/6
5/-
12/-
MAY 27 1960
2/6
5/-
5/6


2/-
2/-
43/-
1/6
1/6
1/-
3/-
1/6
No.5 SHAFT
No.4 SHAFT
4/6
SIX BELLS COLLIERY


OM MARINE COLLIERY
12 1 32
STOPPED
OCT 17 1958
STOPPED
OCT 18 1957
1960
1960
1959
1959
1959
ROLL
STRICT
MAY 27 1960
STOPPED
SEPT 5 1958
STOPPED
1/9
2/5
1/7
1/6
4/6
2/-
1/6
5/-
12/-
2/6
5/6
6/-
8/-
1/8


2/-
43/-
1/6
1/6
1/6
No.5
SHAFT
No.4
SHAFT
SIX BELLS COLLIERY
4/-
4/6
MAY
28
1960
2/6