Cave Science

The Transactions of the British Cave Research Association

BCRA

Volume 11 Number 3 November 1984

Luwang Jurangjero

Caves of Gunung Sewu, Java

Hypothermia in Cavers

Flooding and Survival

Accident First Aid

Expedition Medical Equipment

Unconformities in Cave Sediments

BRITISH CAVE RESEARCH ASSOCIATION

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ISSN 0263-760X

CAVE SCIENCE

TRANSACTIONS OF THE BRITISH

CAVE RESEARCH ASSOCIATION

Volume 11 Number 3 November 1984

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Cover photo: Luwang Jurangjero main stream passage, Java

Published by and obtainable from:
The British Cave Research Association, 30 Main Road, Westonzoyland, Bridgwater, Somerset TA7 OEB.

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CAVE SCIENCE

Transactions of the British Cave Research Association. Vol.11, no.3. November,1984.

THE CAVES OF GUNUNG SEWU, JAVA

R.G.Willis, C.Boothroyd and N.Briggs

ABSTRACT

Gunung Sewu is an area of spectacular limestone cone karst in southern Java and contains many cave entrances, the majority of which were explored in 1982. The remaining caves have now been explored and surveyed and a descriptive catalogue of caves in the area has been produced.

INTRODUCTION

The 1982 Gunung Sewu Cave Survey carried out a comprehensive programme of cave exploration and scientific study in order to provide information for the Ministry of Public works of the Governement of Indonesia. This work was carried out on a sub-contract to Sir M.MacDonald and Partners, Civil Engineers, of Cambridge, with the purpose of identifying exploitable water resources. Due to a shortage of time it was not possible to carry out the survey of all caves in the area and the authors of this article returned to Java in August of 1983 in order to complete the project. This visit was undertaken at personal expense although considerable logistical support was provided in the field. 97 sites were visited of which 34 were caves in which almost 11km of passages were surveyed; the deepest system was 194m.

The Gunung Sewu karst, its geology, surface features and cave hydrology have been thoroughly summarised (Waltham et al. June 1983). The results of the 1983 explorations confirmed rather than altered the conclusions of this earlier study and this article therefore contains no discussions of geomorphology or hydrology.

The following catalogue, together with the report of the 1982 survey (see above) is intended to be a comprehensive and descriptive reference text for the Caves of Gunung Sewu. The suffix "82", folowing the description indicates that the survey of that cave was published in Cave Science Vol.10, No.2. The suffix "83" indicates that the site was visited in 1983; reference is made to other surveys contained in this text. The locations are marked on Plate 1. A key to the map references and corresponding site numbers is given at the end of the text.

Conventional notation is used on the cave surveys, except for three additional items added to evaluate the water resources which were the original purpose of the surveys. These are:

1) Figures beside water-flow arrows refer to dry season flow in litres per second.
2) Figures in square boxes refer to the depth in metres below the entrance.
3) Figures in round boxes refer to pool capacities in cubic metres.

The number sequence is the same as that used in the Luwang Register (Waltham et al, 1983) and reflects only the date of investigation. Each site description starts with a number, name and grid reference; G = Gua or cave, L = Luwang or sinkhole, S = Sumber or spring. After the grid reference, lengths and depths, P = pitch and C = climb are given in metres.

SINKHOLES AND CAVES OF GUNUNG SEWU

1. L.Bodeh. 740102. Depth 151m Length 238m. A descending passage leads to a series of short pitches to a horizontal passage and a choke. 50m before the choke a P14 and P22 lead to a narrow meandering passage which becomes too tight. Strong draught. Survey, Figure 1. 83.

2. L.Ceblok. 615128. Depth 92m Length 600m. P23,P25 to passage with pools to P9, two large chambers separated by a duck. Sump. 82 (Fig.6)

CAVES OF GUNONG SEWU
Cave
Cave passage
Underground drainage
Contour in metres
Major village
Principal road
Kilometres
0 1 2 3 4 5
N
INDIAN OCEAN
Wonosari
Kendal
Tangung
Baron
Baran
L.Bandung
L.Soga
G Sumurup
L Towati
G Nutcingong
L.Gondang
G Lebak Bareng
G Suci
G Buri Omah
L Grubug
L Ceblok
L Bedesan
L Seropan
G Semulah
L Sinden
G Bribin
L Jurangjero
L Tong Pocot
L Buhputih
G Sodong
G Gilap
G Jomblang
L Jati
L Sonjembul
G Sodong
200
100
300
400
500

MAP 1

Fig 1

Fig 2

Fig 3

3. L.Goplak. 538068. Depth 85m. Large bell shaft entered by a 70m pitch. Dry and floored with mud and boulders. 82 (Fig.17)

4. L.Karangwetan. 515099. 50m of passage to pool. Narrow canyon continues.

5. L.Bendo. 663113. Depth 48m Length 86m. C2,P8,P6,P16,C2 to sump. Survey, Figure 2. 83.

6. L.Karang. 658114. 50m rift to choke. Very small stream leads off too tight. 83.

7. L.Karanglamper. 659114. Depth 89m Length 234m. A series of short shafts, each with a small pool at the base, are followed by a section of passage containing a percolation fed stream of about 0.5 litres per second. A 0.5m free-diveable sump leads to about 70m of canal passage with a capacity of about 100 cubic metres which terminates in a sump. Survey, Figure 3. 83.

8. L.Jurangjero. 669111. Depth 64m Length 587m. An impressive open shaft is situated at the end of an overgrown dry valley. The edge of the shaft is reached by an 8m pitch. The main 30m (P23,P8) shaft drops into a dried-up plunge pool from which a 3m climb up and a similar climb down lead via two 12m shafts into a roomy passage with a large population of bats. The passage closes down into a static canal with a capacity of about 100 cubic metres beyond which is the main streamway of the Kali Bribin. This runs for about 400m in a large passage and sumps in both directions. Survey, Figure 4. 83.

9. L.Kenteng. 621004. Depth 92m Dry canyon passage descending three shafts to head of P20; continues narrow. 82 (Fig.17)

10. L.Jomblang. 613032. Depth 92m Single vertical shaft to blockage of boulders. 82 (Fig.17)

11. L.Song Gupit. 609137. Single dry shaft of 56m with no way on.

12. L.Sumbring. 612148. Dry shaft with climb and P60 to mud floor.

13. L.Balong U. 612030. Entrance too small.

14. L.Balung B. 612030. Entrance too small.

15. L.Sumberejo. 612028. Entrance too small.

16. L.Blekonang. 607024. Depth 134m. Steep descent to a series of shafts becoming progressively smaller until progress is difficult beyond a depth of 134m. Dry. 82 (Fig.15).

17. L.Gesik. 602030. Shaft with strong draught, too narrow to enter.

18. L.Bentar. 598078. Depth 60m. Climbable shaft in hillside to P10 and large canyon passage to chamber blocked by mud floor. Dry.

19. G.Ngrapah. 588078. Dry mud-floored chamber.

20. L.Glesung. 587112. Depth 72m. Shaft into canyon descending to second shaft into dry mud-floored chamber.

21. L.Jomblang. 579111. Blocked sinkhole. 83.

22. L.Macanmati. 574111. Choked daylight shaft. P31 to vegetation covered floor, further climbs down to about 60m and choke. Dry. 83.

23. L.Nglibeng. 565067. Walled-up sinkhole with strong draught, needs removal of boulders to enter.

24. L.Kerwo. 574063. Depth 45m. P10 and P20 in rifts to dry choke.

25. L.Jomblang. 575057. Small dry shaft.

26. L.Jurug. 565074. At end of blind valley, large passage totally blocked with sediment.

27. L.Karang. 573051. No cave passage.

28. L.Tabuhan. 573082. Length 200m. Climb and muddy passage to short pitch and sump.

29. L.Soroiten. 543105. Depth 117m Length 352m. Short climbs lead to the head of a series of small pitches. At the end of the pitches is a canyon passage to a sump. Survey, Figure 5. 83.

30. L.Krinjing. 537108. Depth 60m. Blind valley to P55 to mud floor and small static sump 85m below plain level.

31. L.Gowah. 534108. Depth 170m. Boulder-strewn entrance passage to 70m shaft and further descents to impossibly narrow rift. Dry.

32. L.Tlogodadi. 526081. Large entrance and P25 to chamber floored with dry mud and boulders. 100m long inlet passage from north, also dry.

33. L.Setro. 524058. Depth 140m Length 250m. A succession of shafts in a large descending canyon passage to terminal sump with a minute flow. 82. (Fig.24)

34. L.Katok. 524049. Large sinkhole; long daylight rift climb to P5 and P15 to chamber with mud floor and static sump at depth of 55m. Adjacent dry shaft of 30m to mud floor undescended . Adjacent depression has 20m climb in dry rift to narrowing passage.

35. L.Jowa. 514048. Narrow rift with climbs to P12 into chamber with small static pool of no value. Second entrance in surface ravine leads to same chamber.

36. L.Ngegong. 509028. Walled-up sinkhole over shaft, blocked since 1981.

37. G.Lebak Bareng. 526085. Depth 166m. Length 166m. daylight gorge leads directly into a large entrance passage with dry mud floor. Shafts descend to a low level stream passage and sump. 82 (Fig.22)

38. L.Bamban. 528087. Large shaft descending in steps, not descended and almost certainly leads into Gua Lebak Bareng.

39. L.Tlogolaran. 509094. Blocked shaft.

40. L.Mbibres. 512073. 8m shaft in hillside to dry chamber with mud floor.

41. L.Gelap. 613020. Depth 72m. 60m shaft to descending canyon to static sump.

42. L.Ngoro-oro Ciut. 507073. Walled vertical sinkhole with dangerous walling for top 5m. P32 to descending rift, P39 into small pool. Rift continues beyond, becoming too tight after about 50m. 83.

43. L.Bawongan. 498073. Length 200m. Large entrance with climb and P20 into narrow twisting canyon which extends for 200m to southeast, and ends at 20m shaft. Continues narrow, with draught, and small amount of dripwater. 82.

44. G.Tritis. 449063. Stalagmite cave which attracts tourists. Choked. 83.

45. L.Gunung Betung. 607105. 60m blind shaft. Dry. 83.

46. L.Puring. 597107. 30m shaft and slope to dry mud floor.

47. L.Bawahan. 598097. Dry small shaft which fills to surface in wet season.

48. L.Buhputih. 644082. Depth 200m. Length 850m. A narrow rift passage at the base of a walled entrance descends steeply to a cross rift with small static sump pool. The cross rift opens out into the side of a 10m wide dry canyon passage. This ends in a series of shafts from the base of these a narrow passage with gours and pools leads off via another shaft to a canal which continues almost horizontally to a sump. 82 (Fig.14)

PLAN
Nm
0 10 50
Metres
LUWANG JURANGJERO
SITE 8
G.R. 669111
GUNONG SEWU CAVE SURVEY JAVA 1983
BCRA Survey Grade 5b
-64
-63
P12
P12
C2
C2
C3
P8
P23
Entrance
Entrance
SEMI-EXTENDED ELEVATION
P23
P8
C2 C3
P12
C2
P12
0
10
20
30
40
50
60
70
Metres
Metres

Fig 4

LUWANG SOROITEN
GUNONG SEWU CAVE SURVEY
JAVA 1983
SITE 29
G.R.543104
Nm
Entrance
BCRA Survey Grade 3 and 5b
C7
C4
C3
P7
P11
P6
P12
P5
C2
C2
P6
P13
C2
C2
0
10
50
100
Metres
EXTENDED SECTION
Sump
P13
C2 & C2
C2
C2
P6
P5
P6
P12
P11
C3
P7
Entrance
C7
C4
0
PLAN
0.1
0.1
-117
Sump
0 50
Metres

Fig 5

GUNONG SEWU CAVE SURVEY JAVA 1983
SITE 49 G.R.640112 LUWANG SINDON
Entrance
0 10 20 Metres
sump
PLAN
P11
C2
P6
C3
P3
-88
sump
Nm
EXTENDED SECTION
Entrance
Rock bridge
P36
Static pool
P16
P6
C2
Static pool
P11
C3
P3
sump
sump
BCRA Survey Grade 5b
0
-10
-20
-30
-40
-50
-60
-70
-80

Fig 6

GUA SEMULUH
GUNONG SEWU CAVE SURVEY
JAVA 1982 and 1983
SITE 63 G.R.644139
BCRA Survey Grade 5b
+33
Upstream cave
Main entrance
0
Canal
Nm
-4
+35
18
Sump
-36
C2
P9
15
PLAN
Sump
P8
-72
-11
C2
C1
1983
Series
0 10 50
Metres
Sump
P5
Gour pools
C4
C3
C2
P8
C3
EXTENDED SECTION
1983
Series
C2
P5
Sump
Gour pools
Metres
0
20
40
60

Fig 7

Plate 1. Main river passage in Gua Jomblang.

Plate 2. The entrance to Gua Ngowe-Owe.

Plate 3. Main river passage in Luwang Jurangjero.

Plate 4. Roof pendants and canal before river passage, Luwang Jurangjero.

Plate 5. Passage at the base of the shafts, Luwang Jurangjero.

Plate 6. Mas Sudiyono on Pitch 1, Luwang Ceblok.

Plate 7. Water-carrier and son at the entrance to Luwang Cikal (Site 225).

49. L.Sindon. 640112. Depth 88m Length 85m. A large entrance leads to a 36m pitch to a small static pool, followed by a 16m pitch and a 6m pitch into another drip-fed pool. Beyond this an 11m shaft and short climb lead to a short section of what is presumed to be the Kali Bribin between two sumps, downstream of the Gua Bribin. The stream passage is 5m or more in width and the stream varies considerably in depth. Survey, Figure 6. 83.

50. L.Ledok. 634103. P12 and P5 to into a clear-washed, dry, draughting canyon passage, this is too narrow downstream and is choked upstream, beneath the valley floor.

51. L.Tong Pocot. 631101. Depth 142m. Length 900m. A steeply descending series of small passages leads via ten shafts to a stream passage which can be followed westwards. Two small pitches drop down to a lower level which sumps after two hundred metres. 82 (Fig.25)

52. L.Ledok. 738101. A small entrance leads into a small passage which chokes. No draught. 83.

53. L.Cahkeri. 735118. P3,P7,P22 to choke. Dry. 83.

54. L.Jumbleng. 726035. 7m shaft to small dry chamber.

55. L.Gading. 754036. Depth 112m. Climb down to 68m shaft into canyon with a seris of small pools fed by dripwater. A second shaft leads to a sump.

56. L.Sirik. 746043. Depth 65m. Shaft with P33 to short rift and static sump.

57. L.Sawah. 725078. 5m drop into dry chamber.

58. L.Sruput. 717079. Depth 65m. Fossil shaft mear top of cone, with P40 onto boulder slope which descends to total blockage.

59. G.Blunyah. 713086. Major sink in blind valley. Short passage to P18 into large canyon with terminal choke of dry mud.

60. G.Kalen. 704090. Depth 39m. Length 150m. Low passage with tiny pools, to P29 and P7 into canals ending in boulder choke.

61. L.Ombo. 727116. P13 to rock bridge and P28 to rift with mud floor. P11 and P6 to choke. 83.

62. L.Sawah. 718112. Blocked sink. 83.

63. G.Semuluh. 644139. Depth 72m Length 1559m. The main entrance, south of the road, is formed where a small ravine intersects a major cave passage. Downstream a long narrow canal, with a wider dry passage at a higher level, extends to where the two levels meet and continues as a large tunnel carrying a small stream. Less than 100m further on the stream turns off the main tunnel into a narrow descending canyon passage, which ends in a sump 36m below the entrance. The main tunnel continues and, losing its eliptical cross section runs as a small vadose trench dropping down a series of climbs to an 8m shaft. At this point an inlet enters the passage. The water flows into a pool and from this to a 5m shaft with an inlet.This is followed by a series of small gour pools to a sump. Survey, Figure 7. 83.

64. L.Towati. 690070. Blocked sink.

65. L.Sumur. 693037. P40 to 100m of streamway to undescended narrow pitch.

66. L.Jurangjero. 688037. P12,P8 to mud choked rift. Dry. 83.

67. L.Ngandong. 687045. P35 to mud choked rift. Dry. 83.

68. L.Ngimbes. 686045. Blocked shaft. 83.

69. L.Kluwangan. 692012. Blind dry shaft, 8m deep.

70. L.Glaragahumbo. 693001. Slope to 50m shaft, ending in dry mud choke.

71. L.Sirih. 680006. Two climbable rifts in a small depression, one with a small pool.

72. L.Pucang. 688994. Depth 100m. 70m shaf, to top of undescended P30.

73. L.Kenteng. 680092. Small blind hole.

74. L.Gondang. 682995. 7m climb into small blind chamber, dry but fills to surface in wet season.

75. L.Wates. 417118. P8, P15, P22 to choke. Dry. 83.

76. L.Soka. 416114. Depth 68m Length 135m. A series of short climbs lead down to a pool. Beyond this is a 23m shaft into another pool. The cave continues down further climbs until the passage becomes too tight. Survey, Figure 8. 83.

77. L.Ngrau. 111118. 8m shaft to climb and 20m of canyon to choke. 83.

78. L.Ngledok. 390127. P8 to small chamber and descending boulder floored passage to sump. 83.

79. L.Ceme. 387129. Entrance through boulders leads into 30m of narrow rift ending in a mud choke. 83.

80. L.Bandung. 397128. Depth 92m Length 390m. A dual shaft entrance exists from adjacent depressions. A 27m pitch is followed by a short climb and a 7m shaft to a large passage which closes down into a small canyon. Two small inlets combine to form long muddy canals. A 12m shaft drops into the bottom of a large, unstable, steeply ascending passage. The water sinks in boulders. The cave terminates at the lower end in a blind 18m shaft; the upper section of the passage was not explored because of the danger of rock fall. Survey, Figure 9. 83.

81. L.Ngurik. 386123. Loose shafts to boulder choke. Dry. P8,P5,P8. 83.

82. L.Legundi. 376116. 15m pitch into large collapse doline floor. Second chamber has dry boulder floor.

83. L.Soga. 376108. Depth 177m Length 2428m. A small, strongly draughting, entrance in a depression at the edge of the village drops steeply via a series of shafts 9m, 4m, 32m, 14m, 10m, and 23m to a stream. This can be followed in a low passage upstream for about 200m to a sump. Downstream the passage opens up, after a short low section, into a narrow meandering canyon. This descends gently for about 600m to a 3m pitch into a pool. 100m below this point a major inlet enters from the west. This can be followed upstream for about 250m to a fork, both branches of which lead quickly to unclimbed waterfalls.

Downstream of the junction the main passage continues for about 800m between sediment banks until the stream eventually sinks in boulders. Survey, Figure 10. 83.

84. L.Bledok. 371110. Extended open rift, descended via P10,P3,P7, drops down to canyon which continues down becoming narrow. Continues. 83.

85. L.Ngrejek. 500098. Depth 51m Double shaft drops into large mud-floored chamber. Fills to surface in wet weather.

86. G.Ngowe-Owe. 496104. Depth 156m Length 349m. A large rift entrance, obvious from the road, leads to a 17m shaft. 100m of pleasant canyon passage ends at two short pitches and then a superb 91m shaft into a pool. A small outlet passage extends for 150m through gour pools and ducks to a sump. Survey, Figure 11. 83.

87. G.Ngegab. 492091. 40m of dry canyon passage with 8m shaft and ending in loose boulder choke.

88. L.Gondang. 499089. Depth 123m Length 263m. P21 and P8 lead to a roomy passage which becomes too tight upstream. Downstream it cuts a trench through a bed of volcanic tuff, forming a series of blind pits in the floor which become progressively deeper. Eventually the cave breaks through the tuff and descends a series of shafts into a small passage with static pools. This draughts strongly but becomes too tight. Survey, Figure 12. 83.

LUWANG SOKA
GUNONG SEWU CAVE SURVEY
JAVA 1983
SITE 76 G.R.416114
BCRA Survey Grade 5b
EXTENDED SECTION
Entrance
Limit of daylight zone
Tight
Metres
PLAN
Nm
0 10 20
Metres
Entrance
Tight
C6
C3
C4
P23
C5
-68

Fig 8

LUWANG BANDUNG
GUNONG SEWU CAVE SURVEY
JAVA 1983
SITE 80 G.R.397128
BCRA Survey Grade 5b
Entrance
Nm
0 10 50
Metres
PLAN
Unexplored
Very steep mud bank
-92
P18
P13
P27
C6
P7
0.5
PROJECTED SECTION ON 000
PROJECTED SECTION ON 090
Stream sinks in boulders
Blind pit
Metres

Fig 9

LUWANG SOGA
GUNONG SEWU CAVE SURVEY JAVA 1983
SITE 83 G.R.376108
Nm
Stream sinks in boulders
Cascades
Canal
Pool
Cascades
Pool
Aven
Aven
PLAN
0 20 40 60 80 100 200 Metres
Entrance
Narrow
Aven
Sump
Entrance
PROJECTED SECTION
Sump
BCRA Survey Grade 5b

Fig 10

89. L.Trecep. 486076. Depth 93m Length 93m. A small entrance through boulders opens onto a steeply descending rift. P46 followed by a series of short pitches and climbs leads to the limit of exploration at the head of an undescened P8. Mud on the walls suggests a sump within a short distance. Survey, Figure 13. 83.

90. G.Kenongo. 491070. Length 160m. Wide boulder-floored passage to narrow rift and pitch down onto fossil chamber, floored with mud. Dry.

91. L.Bobok. 487066. Small passage leads through boulders in north end of large depression. P23, P15, P29 to sump. 83.

92. L.Klepu. 490053. Boulder slope down to large passage choked with dry mud.

93. L.Jomblang. 476057. 23m shaft and climb down to dry mud-floor.

94. L.Santen. 464060. Blocked sinkhole.

95. L.Klumpit. 440050. 15m pitch to mud choke in dry rift.

96. G.Klumpit. 439049. 20m shaft ending in choke of dry mud.

97. L.Banteng. 432058. Depth 75m. A broken 54m entrance shaft leads to a steeply descending passage to a sump.

98. L.Karang. 501047. Depth 94m. Length 325m. A 44m daylight shaft into narrow, twisting, gently descending canyon passage terminating in a sump.

99. L.Ombo. (L.Tlempek) 505041. Depth 50m. 35m rope pitch to boulder choke.83.

100. L.Kuang. 435074. Sinkhole, too narrow to enter.

101. G.Jurug. 583137. Passage, too tight to enter. 83.

102. G.Glendu. 591139. Easy passage leads to a pool, beyond which is a large bat-roost and a muddy canyon passage to a sump.

103. L.Kebo. 580130. Choked sink. 83.

104. L.Bedesan. 574124. Meandering canyon leads via short climbs and pitches to an 8m wide river passage which sumps upstream. Downstream a spectacular series of gours and cascades descend to a sump, where a small tributary can be followed to a small sump. From the base of the third cascade a high level passage may be entered and followed in one direction to a choke, in the other direction it may be followed upstream through a duck to an unclimbed waterfall pitch.

105. L.Gedilan. 576126. Depth 34m Length 89m. The descent of the vegetated, terraced depression south of the village leads to a small archway. Beyond this a large passage opens out but ends in a mud-filled choke after 50m. 9m within the entrance a small stream can be just seen, running in boulders. Survey, Figure 14. 83.

106. L.Jero. 612088. Depth 151m. 78m daylight shaft to a canyon and second shaft into a chamber with bats. Boulder slope ends in a small sump pool. 82 (Fig.20)

107. L.Pendul. 602078. Depth 45m. Climbs over loose boulders in tall meandering fossil canyon with dry mud floor, becoming too narrow.

108. L.Wuluh. 623063. P8 down walling to ledge with an excess of dead animals, and 25m shaft into a large dry, choked rift.

109. L.Ngepoh. 630053. A walled entrance slope drops into a passage which narrows to head of broked 60m shaft. Below this a further 100m broken pitch with spray and dangerous rocks. the cave continues down an undescended P30. 82 (Fig.21)

110. L.Toar. 623045. Entrance over boulders to 15m climb down in canyon to head of undescended P20 to dry floor. Fills to surface in wet season.

111. L.Besole. 628033. Depth 70m. Single large dry shaft to boulder floor.

112. L.Puleirang. 596034. Depth 196m. Since 1982 a concrete dam built against the cliff face almost rings the entrance; it is part of a scheme to create a new telaga in the basin formerly drained by the sinkhole. Unfortunately subsequent sinks have opened in the floor of the telaga, draining into the underlying cave. Remedial action has been taken but it is not yet known if this has been successful. The cave descends by a series of shafts to a sump at -196m fed by a very small inlet. Survey, Figure 15. 83.

113. L.Mundu. 628029. Depth 62m. P10, P38 and P8 lead into a small canyon passage ending in a static sump.

114. L.Ledok. 624038. Two adjacent sinkholes. One is P10 into complex of dry canyons in loose and sharp rock, not completely descended. Second has P15 to short passage and dry mud-choke.

115. L.Gebang. 636045. Walled slope to clinb and P10 to top of P25, not descended due to a vast amount of loose rock. The whole cave is dry.

116. G.Penangson. 662158. Two sinkholes, both leading directly to small sumps. Used as emergency supplies in the past, but not now due to nearby borehole. In Plateau facies.

117. L.Kongkang. (L.Ngringjing.) 692124. P41 leads to level floor with low crawl to head of undescended narrow shaft with take-off through loose boulders. 83.

118. L.Grigak. 700108. Blocked sink. 83.

119. L.Jalak Bromo. 684066. Depth 147m Length 250m. P16,P12,P8,P8,P41,P16,P14 to a pool. The passage continues as a low, wet bedding plane. Survey, Figure 16. 83.

120. L.Nglampeng. 595085. A small entrance drops down a climb to a short passage to head of a P13, followed by a P9 into a large passage which becomes too tight in both directions. 83.

121. L.Purang. 727085. 3m entrance climb followed by a P4 into a blind chamber. 83.

122. L.Jambu. 723088. Blocked sink. 83.

123. L.Nujo. 730105. Unvisited.

124. L.Kalen. Unvisited.

125. L.Jarak. 735065. P30 to mud choke. Dry.

126. L.Gedawung. 588125. Shaft, unvisited.

127. L.Cabe. 586125. Shaft, unvisited.

128. L.Blerong. 369142. Length 120m. An entrance in the floor of a rocky doline leads through a small chamber to a descending passage. Steep flowstone steps continue down into a chamber with a roof inlet, and downstream the water flows into a low and unpleasant bedding plane passage.

129. L.Sentul. 456040. A climb down a walled entrance leads to a meandering dry canyon passage with a series of drops whcih ends in a 4m deep sump pool 51m below the entrance.

130. L.Tjabe. 591062. Blocked sinkhole.

131. L.Bandung Sumuran. 492120. 40m shaft and climbs to choke, not visited.

132. -

Fig 11

Fig 12

Fig 13

Fig 14

Fig 15

Fig 16

133. G.Sodong. 762112. Depth 46m. Length 4290m. A fine dendritic cave with three major branches. An inlet inside the entrance is heavily used and pools beyond are badly polluted. Beyond these the passage becomes more pleasant as a high tunnel broken by two short handline pitches and long canals. The main stream passage is almost two kilometres long, a high canyon with a sizeable stream. The water issues form a top sump and eventually feeds a terminal sump from where it has been dye-traced to Pracimantoro, two kilometres away. The northern tributary is a long inlet, half of which is a long meandering canyon with deep water. In its upper reaches its morphology becomes more complex and contains spectacular displays of white calcite. 82 (Fig.29)

134. G.Songgilap. 755101. Large entrance and descent over boulders to short dry passage to sediment choke.

135. L.Watugajah. 727048. Small entrance, choked. 83.

136. L.Buh Kidul. 728032. 8m climb to small dry chamber.

137. L.Gandek. 728031. Depth 138m. Two deep shafts end in a bedding plane passage which continues low and contains shallow pools of standing water. 82 (Fig.16)

138. L.Jurug Watu. 575036. Shaft, 5m deep, too narrow for descent.

139. L.Ngirowari. 578036. 40m shaft ending in a dry rift.

140. L.Gupakwarak. 528018. Small dry hole 10m deep.

141. L.Blubug. 573070. Small dry cave with 5m climb to terminal choke.

142. L.Tirisan. 596074. Shaft and boulder slope climb to dry mud choke at depth of 35m.

143. L.Mojing. 603063. Climb down to P10 and further climb to dry choke of mud and boulders at depth of 25m.

144. L.Branjung 1. 588032. Dry rift 25m deep floored with mud and boulders.

145. L.Branjung 2. 588032. 20m shaft to canyon, dry and descending to where it is too narrow at depth of 40m.

146. L.Bete. 778091. 16m bellshaft and second dry chamber ending at depth of 28m.

147. L.Gadjah. 778089. Doline with perennial pool used for supply. No cave except for adjacent 3m deep dry shaft.

148. S.Sodong. 359129. 10m of low muddy canal between upstream and downstream sumps.

149. S.Sungei Besar. 358135. Large entrance blocked by choke.

150. S.Ngerenean. 462023. Large spring on foreshore very close to low tide level.

151. L.Puniran. 628110. Depth 118m. Steeply descending succession of shafts, leading to a 20m undescended shaft down to a pool which appears to be a sump. 82 (Fig.23)

152. L.Kamal. 533133. Depth 106m Length 212m. A large ravine in a depression below the village ends at a 10m shaft. At the base of this is a short climb to the head of a 16m shaft into a large boulder-floored chamber. A 14m shaft leads to the head of a larger shaft broken into a 47m pitch and a 9m pitch. At the base of this is a large passage which drops into sump pools at both its southerly and northerly ends. Survey, Figure 17. 83.

153. L.Towati. 527115. Depth 111m Length 564m. A clean and pleasant entrance passage leads via climbs and short pitches to the head of a 32m shaft. At the base of this is a pool fed by drips from above. Wading across this pool leads into a passage which descends gradually, increasing in size and collecting several small inlets. The passage becomes progressively more muddy and unpleasant and eventually inter-

sects a large passage in which a small and highly polluted stream meanders between huge mud banks containing much unpleasant flood debris. Downstream the stream flows at about 1.5 litres per second into a sump. Upstream the stream emanates from a sump at the base of a massive sediment bank which rises towards the roof. The entire passage floods to the roof in the wet season. Survey, Figure 18. 83.

154. L.Setro. 539122. Choked depression. 83.

155. L.Gempal. 607094. Blocked sink. 83.

156. Unnamed. 605186. Air photo feature. No cave. 83.

157. Unnamed. 610078. Air photo feature. No cave. 83.

158. Unnamed. 619087. Air photo feature. No cave. 83.

159. L.Bendo. 657138. P5 and climb to very low dry bedding plane passage.

160. L.Lebuh. 677130. Large entrance leads to descending canyon, dry and in very sharp rock, which becomes very narrow after 100m but does continue.

161. L.Sapen. 763108. Length 250m. P36 into small streamway with a sump in both directions.

162. G.Kajubang. 422076. Dry fossil passage into collapsed and blocked chamber

163. L.Pringwulong. 432084. Shafts of 8m and 35m ending in narrow dry rift.

164. L.Ngampal. 458056. 25m shaft to rift ending in choke. Dry.

165. G.Telogo Teki. 438103. Large overhanging entrance to mud filled passage, chokes after 20m. 83.

166. G.Ngreneng. 635130. Large doline with choked passages and flooded rift.

167. G.Toto. 619139. Length 925m. Large passage leads to streamway. Upstream to the north alternating canals and breakdown chambers to a boulder choke. Downstream canals leads to a terminal sump.

168. G.Kedokan. Depth 22m. Length 70m. Descending passage to a sump. A dry high-level passage ascends above the pool but requires aid.

169. G.Jomblang. 733158. Depth 134m Length 3326m. A long entrance ramp, with a flight of steps and excavated into bedrock, leads into the main entrance chamber. The steps continue into the smaller supply pool chamber, which is out of daylight. A low muddy passage with static pools can be followed past a high level chamber, to a larger passage with mud and standing water, ponded by breakdown and sediment. An inlet enters as a 0.9m high waterfall, fed from a perched sump to the north. Down stream the water leaves the main passage over a rock lip and drops quickly to a sump pool. Flood flows continue in the upper passage, from which the streamway is re-entered through a short maze complex. The stream passage continues low and sharp with shallow pools and gours until it drops down into a tight sump. Beyond this a dry continuation leads to the head of an 8m pitch into a large chamber. A 14m pitch, starting in loose boulders, drops into a large, well decorated and steeply descending passage which is blocked by stalagmite. A climb down under a boulder on the right leads to the head of a 9m pitch which is immediately followed by a 13m pitch.

At the base of this pitch a further 11m pitch drops into a narrow canyon containing a small stream. Upstream this leads immediately to a waterfall. Downstream the passage continues down climbs to an impressive river passage containing the Kali Bribin. Opposite the junction is a small inlet which can be followed up for about 50m to its source amongst boulders. Downstream leads to a sump after about 100m. Upstream in the main passage the river can be followed for about 350m to another sump. Midway between the junction and the upstream sump is an inlet passage containing a small stream running between sediment banks and rising from a sump after about 150m.

At the head of the final pitch a high level traverse may be followed to the top of the waterfall. The stream appears from a further, unclimbed, waterfall but a phreatic tube leads off due south. This tube,

LUWANG KAMAL
GUNONG SEWU CAVE SURVEY
JAVA 1983
SITE 152 G.R.533133
BCRA Survey Grade 5b
PLAN
Nm
Sump
-106
P9
P47
P14
P16
C5
P10
0
Entrance
0 10 20
Metres
PROJECTED SECTION
Water level fluctuates
0
10
20
30
40
50
60
70
80
90
100
Metres

Fig 17

LUWANG TOWATI
GUNONG SEWU CAVE SURVEY JAVA 1983
SITE 153 G.R.527115
Sump
-111
PLAN
Nm
Continues low
C2
P6
P10
P32
P4
P7
C3
C4
Entrance
Gorge
0 10 50 100 Metres
PROJECTED SECTION
BCRA Survey Grade 5b
0
20
40
60
80
-100

Fig 18

Fig.19.

GUA JOMBLANG

GUNONG SEWU CAVE SURVEY

JAVA 1982 and 1985

SITE 169 G.R.733168

BCRA Survey Grade 5b

Fig 20

Fig 22

Fig 21

Entrance
SITE 212 G.R.576177
GUNONG SEWU CAVE SURVEY
JAVA 1983
Nm
PLAN
C9
P24
C2
0 10 50 Metres
Static pool
C3
Duck
P15
-74
Boulder bridge
Entrance
C9
P24
C2
C3
Static pool
P8
Duck
EXTENDED SECTION
P15
Sump
BCRA Survey Grade 5b
0
-10
-20
-30
-40
-50
-60
-70

Fig 23

PLAN
Nm
P23
P22
Entrance
P7
Static Sump
0 10 20
Metres
-57
LUWANG SURU
GUNONG SEWU
CAVE SURVEY
JAVA 1983
SITE 213 G.R.587119
Entrance
P23
BCRA Survey
Grade 3b
P22
P7
Sump
EXTENDED SECTION
0
10
20
30
40
50
Metres

Fig 24

Easter Egg Passage, is floored with superb mud cracks and after 200m drops into a canyon passage with a small stream. Upstream of this point the pleasant, meandering passage terminates in an unclimbed waterfall after about 550m. Downstream, after 150m, it runs into another stream. This second tributary can be followed up a roomy meandering canyon with occasional breakdown for about 700m to two unclimbed waterfalls. Downstream of the junction the canyon continues as easy walking passage for about 120m to a junction with the main river passage. 150m downstream of this point is a sump. The flow at this point was estimated as c.0.5 cubic metres per second. The same distance upstream is the downstream side of the previous terminal sump. Survey, Figure 19. 83.

170. G.Ngringong (Mulo). 549126. Depth 74m. Length 380m. Large entrance leads to a passage with shallow pools. Water cascades down three drops, interspersed by deep, wide pools. The stream is lost in boulders but reappears to flow into a sump.

171. L.Ngiratan. 638058. Depth 168m. Length 168m. 28m broken shaft leads to a narrow canyon with small static pools. A tight passage follows to the head of
a 106m shaft into a large pool. An 8m drop gives access to a series of gours and pools and lead to a sump.

172. L.Sumelap. 639065. Depth 43m. 32m shaft to a short rift with a floor of boulders and mud. 10m further, over breakdown, a small stream flows from a shallow pool and continues unexplored.

173. G.Pozo. 640075. Cave used for supply. Not visited.

174. G.Tritis. 537072. P15 into rift, climb up 4m, P8, P5, P3 to head of very tight undescended pitch. Draughts. 83.

175. L.Jomblang. 625011. Depth 125m. 1982 Cave Survey found a 77m entrance shaft with small fetid pools on floor. This lead to a canyon passage ending at an undescended 20m shaft into a much larger passage which continued into darkness. The 1983 Cave Survey found that a major collapse and subsidence had completely blocked the access to the second pitch. 82 (Fig.23)/83.

176. G.Buri Omah. 597142. Depth 33m. Length 570m. A series of climbs can be descended to a major underground river passage. Upstream this can be followed through an impressive break-out dome to a sump pool. Downstream a substantial tributary joins the passage before the terminal sump. 82 (Fig.7)

177. L.Ngelo. 625037. Slope into narrow dry canyon in sharp rock.

178. L.Bohol. 716018. Depth 57m. Length 175m. Daylight shaft and series of climbs to gently graded passage continuing in bedding plane.

179. L.Daren. 742998. Depth 122m. Length 240m. Large daylight shaft descends almost 100m to dry canyon passage which leads to 12m shaft into short stream passage between sumps. 82 (Fig.13)

180. G.Bribin. 647117. Depth 33m. Length 3900m. Dry entrance passage descends to its junction with the underground river, the kali Bribin, which can be followed downstream for 1200m to a sump. Upstream the river passage can be followed through a deep lake for 1000m to a sump after a further 300m. A major side passage continues to the north from just before the sump. 82 (Fig.26)

181. G.Sodong (Dadapayu). 681092. An entrance canyon extends 200m to a supply pool. The way on is normally blocked by a short sump but in low water this can be passed into a passage 5m in diameter which can be followed for almost 2km to a terminal sump. 82 (Fig.28)

182. G.Gilap. 729192. Depth 71m. Length 1090m. A massive cave entrance in the side of large collapse feature continues down a rubble cone, becoming constricted, an enters the roof of a stream passage. Upstream this leads through a large chamber to a sump. Downstream sumps immediately. A higher level tunnel is unexplored beyond a 15m drop. 82 (Fig.27)

183. L.Serpeng 1. 559128. Depth 85m. Large shaft with 60m pitch down loose walls to boulder slope descending into large passage with many bats. Ends in a sump pool with no visible flow.

184. L.Serpeng 2. 557127. 50m entrance shaft drops into large cave passage. Downstream this continues to drop steeply over rock steps and large boulder piles until it breaks out into a chamber which is floored entirely by a lake. 82 (Fig.12)

185. S.Slili. 564995. A large entrance rapidly closes down into a low passage over flowstone giving access to a 20m long pool floored by mud and boulders.

186. S.Sundak. 567994. A double entrance gives direct access to a deep static pool with no further passage.

187. S.Baron. 500016. Length 150m. A short section of river cave with extensive breakdown ends in an

188. S.Ngobaran. 453026. A steep descent leads to the floor of a chamber 30m in diameter and nearly 15m high. The stream flows across the floor with sump pools in either direction.
189. G.Song Tawing. 603122. Depth 76m. Length 355m. A wide entrance passage ends in a 30m high wall of sediment below a skylight. A rift passage leads down to a shallow pool. This can be passed to two further pools and beyond to a 10m wide muddy chamber. A small stream flows in a narrow passage to the head of an undescended 7m shaft.

190. L.Grubug. 600127. Depth 161m. Length 2290m. A 64m pitch onto a rubble cone and a descent of 25m to the edge of a river crossign the floor of a large chamber. From here three passages lead off. Southeast a dry fossil tunnel inhabited by bats leads to the floor of the broken 40m Jomblang pitch. Northwest, the upstream river passage extends for nearly 800m to a sump via lakes and canals of slow moving water. Southwest the downstream passage is a large descending canyon with waterfalls and whirlpools leading to the terminal sump. 82 (Fig.7)

191. L.Kenteng. 731067. Sinkhole with loose dangerous boulders which need excavation before descent.

192. L.Gunong Bulong. 595316. 70m shaft, unvisited.

193. L.Ngluweng. 708042. P25, not visited.

194. L.Pengangson. 377075. Depth 46m. 3 shafts descend steeply to a pool from which a low bedding passage leads off full of water.

195. L.Glagah. 377087. Depth 48m. Length 150m. Daylight shaft to boulder floor with narrow descending rift continuing into hill. Second shaft drops into stream passage which contains only small pools with negligible flow and ends in a sump.

196. L.Watukebo. (L.Macanmati) 395107. Depth 40m Length 186m. An entrance boulder slope descends to the lip of a shaft which drops straight into a pool at a depth of 20m. Downstream of the pool, a passage with further very shallow pools extends over the top of an 8m shaft. Below this a small meandering canyon passage leads to a small chamber with an inlet beyond which the passage becomes too low. Just above the 8m shaft an old bamboo ladder reaches down an aven; no surface access is known and it is thought that this ladder is reached via a traverse above the entrance pool. Survey, Figure 20. 83.

197. L.Seropan. 577118. Depth 65m. Length 650m. A broken entrance shaft 38m deep leads to a high canyon. A low muddy passage through static pools leads into an 8m wide conduit, which can be followed downstream to a ponded sump. The upstream passage leads through low ducks to a deep sump pool. A tributary enters from the south. 82 (Fig.8)

198. L.Besole. 378081. Dry rift descended in stepped pitches of 5, 10, 12, and 12m to where it continues very narrow. Adjacent shaft is 15m deep and blocked.

199. S.Pondjong. 684178. Major resurgence with no enterable cave.

200. L.Jati. 715133. Depth 94m Length 330m P55 and P38 to a boulder floor. Mud climbs and traverses lead up into large mud-floored passage with many decaying stalsagmite; choked in both directions. Survey, Figure 21. 83.

201. S.Pracimantoro. 787097. Major resurgence with no enterable cave.

Fig 25

Fig 26

Fig 27

PLAN
Entrance
C3
P7
C3
C2
-19
Nm
0 10 20 30 40 50 Metres
LUWANG PONGKOK
GUNONG SEWU CAVE SURVEY JAVA 1983
SITE 228 G.R.585136
Entrance
0
P7
EXTENDED SECTION
-10
C3
C3
Too tight
BCRA Survey Grade 5b
-20
C2
Static pool

Fig 28

LUWANG SONGJEMBAL
GUNONG SEWU CAVE SURVEY
JAVA 1983
PLAN
Nm
Static pool
P14
Entrance
C5
P34
P7
20
2
P5
Entrance
SITE 229 G.R.707124
BCRA Survey Grade 5b
0 10 50
Metres
0
C5
P34
20
40
Static pool
P14
P7
60
EXTENDED SECTION
P5
P7
P7
3.6
-90
Sump
80
Metres

Fig 29

202. L.Gembuk. 753059. Choke. 83.

203. S.Piyuyon. 773946. Major resurgence in intertidal zone. The only cave passage sumps 5m from entrance.

204. G.Bendunan. 697095. Depth 37m Length 229m. An entrance passage with pools leads to a small chamber from which a canal leads to a second chamber and, via a squeeze, to a third chamber. A small stream drops into a tight slot, down a 25m shaft and sinks. An unpleasant muddy passage with rotten stal and shallow water leads off and becomes too tight. The main passage continues over the slot beyond the third chamber but is greasy and contains much rotten stal; it was not followed. Survey, Figure 22. 83.

205. Unnamed. 623022. Choked sink. 83

206. L.Kambil Ketil. 350119. Short passage leads to climb down into streamway. Upstream sumps after 3m, downstream continues growing larger but is blocked by flowstone. A low duck continues with no draught but sound of water beyond. Likely to resurge in S.Cacahan, Site 253. 83.

207. L.Wediwutoh. 637137. Dry canyon passage descends to terninal mud choke at depth of 35m.

208. L.Jurang. 634132. Boulder-floored passage descends steeply to small static pool at depth of 20m.

209. G.Suci. 601147. Length 260m. The Kali Suci goes underground at the end of an impressive blind valley incised on the edge of the Wonosari Plateau. The large cave passage has a gentle gradient and crosses the floor of two large dolines, Luwang Songlat and L.Gelong, before a final short passage ending in a deep sump pool. 82 (Fig.7)

210. Unnamed. 587142. Wet season sink on north of road with any cave entrance currently blocked. Second dry depression south of road also has no open cave.

211. Unnamed. 574140. Wet season sink in depression with no open cave entrance

212. Unnamed. 219182. Depth 74m Length 95m. C9,P24,P8,P15 to sump. Survey, Figure 23. 83.

213. L.Suru. 587119. P23,P22,P7 to flooded rift, short passage beyond to static sump. The entrance shaft apparently fills to the surface in the wet season. Survey, Figure 24. 83.

214. G.Song Dangal. 594119. Very large cave entrance at end of blind valley, with passage shrinking to dry mud choke after 100m.

215. Unnamed. 595111. 22m shaft to dry mud floor.

216. G.Serpeng. 562127. Perennial river sink at end of blind gorge. Large cave entrance with considerable bat colony has slope of mud and guano descending to large sump pool of foul water only just out of daylight.

217. L.Banteng. 522122. Distributary of Kali Tegoan which sinks into boulders below cliff. A canyon leads to a P27 into a large chamber from which a large passage leads off to a junction. Upstream approximately 400m of passage leads to a chamber; downstream a terminal sump is reached after about 300m. (Quinif and Dupuis, 1984)

218. G.Sumurup. 519120. Depth 58m. Length 1435m. Beyond the entrance the passage contains a series of almost static pools and drops down a 24m shaft into a small deep lake beyond which opens the spacious Mud Hall. The continuing passage is nearly horizontal with a few pools and extensive mud coatings on the wall. Two inlets join the passage before the terminal sump. 82 (Fig.11)

219. G. Si Karangmiri. 507131. A large gently descending canyon leads to a sump after about 600m. (Quinif and Dupuis, 1984)

220. G.Grengseng. 536060. Fossil cave chambers with an abundance of stalagmite in about 100m of passages.

221. L.Batangan. 512060. P30 and short climb into 30m of passage which becomes too tight. 83.

222. L.Jero. 499063. Depth 163m Length 140m P15,P44,P50,P31 to a sump. A small inlet passage continues tight. Survey, Figure 25. 83.

223. L.Sapi. 458042. Small entrance with climb into small, blind chamber. 83.

224. L.Kapul. 445129. P16 down walled shaft into meandering canyon. After 50m a P6 drops into small chamber beyond which the canyon continues very narrow. 83.

225. L.Cikal. 418134. Depth 7m Length 92m. A small entrance leads into a 5mx3m tube with mud and soot covered walls ending in a terminal sump pool. In dry weather the sump lowers to allow access to about 25m of passage and a further sump. Survey, Figure 26. 83.

226. L.Gondosore 1. 412129. An open 12m shaft drops directly into a pool 8m in diameter and at least 3m deep. 83.

L.Gondosore 2. 413129. Descending rift in side of depression. A boulder slope can be descended for 8m to a passage and a small chamber which is mud choked. Floods to 1.5m above the depression floor in the wet season. 83.

L.Gondosore 3. 410129. Hole under boulders in a vegetated depression leads to the head of P12 into a canyon which ends in mud and calcite choke after 50m. 83.

227. L.Gebang. 372152. Depth 20m Length 200m. Well made steps lead down into the cave where the upstream flow has been dammed and ponded to improve storage capacity and facilitate abstraction. Downstream the passage continues low and badly polluted. A short section of walking passage leads to a sump. Survey, Figure 27. 83.

228. L.Pongkok. 585136. Length 79m. P7 and short climb lead into a canyon passage which rapidly closes down. Survey, Figure 28. 83.

229. L.Songjembul. 707124. Depth 90m Length 331m. A short climb leads to a 34m shaft and further short climbs to a percolation fed pool. Beyond this a series of short shafts and horizontal passage lead to a terminal sump. Survey, Figure 29. 83.

230. G.Tritis. 567057. Large blocked cave entrance.

231. G.Brankong. 536017. Small cave entrance to pool with the remains of a pump system, now redundant.

232. G.Tepus. 761113. Dry fossil cave open to tourists.

233. S.Wonseri. 656970. No cave passage.

234. S.Mutisari. 670977. No cave passage.

235. S.Beton. 698213. No cave passage.

236. S.Beton. 796118. No cave passage.

237. -

238. S.Teleng. 699209. Spring. Not visited.

239. S.Puring. 682966. Cave passage becomes too narrow.

240. S.Sambiroto. 797088. Large perennial resurgence with flow of about 10 cubic metres per second. 83.

241. S.Gedaren. 697190. Spring. No cave.

242. S.Sulu. 711189. A small hole in the base of a depression behind concrete storage tanks leads to a body sized hole which drops 3m into a pool. A passage continues underwater eastwards. 83

Fig 30

Fig 31

Fig 32

243. S.Ngremmeng. 693219. A small stream, used for irrigation and water supply, emerges from the mouth of a cave approximately 4m x 3m. This cave passes entirely through the hill but was not explored. 83.

244. S.Karangmojo. 473173. Pool in the side of a stream. 83.

245. S.Umbuldengkok. 550149. Small spring adjacent to the stream, water sinks immediately. Nearby is a well sunk into the bed of the stream. 83.

246. S.Penuh. 502154. Well, with a capacity of about 24 cubic metres. Extensively used as a supply. 83.

247. L.Butuing. 756055. Depth 138m Length 180m. P117 into chamber with short passage leading to P8. Passage continues low. Survey, Figure 30. 83.

248. L.Ngerong. 718114. Collapse feature with several ways in and down through the margin of the boulders. 83.

249. L.Ombo. 694129. Blind 78m shaft to boulder floor. 83.

250. Unnamed. 735150. Large collapse feature. 20m pitch to boulder floor with trees, no cave passage. 83.

251. Unnamed. 733144. Sink. Takes considerable water in wet season. Small passage 0.5m x 0.4m unexplored. 83.

252. L.Celeng. 723092. Small cave ends after 8m under skylight. 83.

253. L.Cacahan. 347126. Small spring. No cave. 83.

254. L.Danggalo. 392135. Entrance climb with bamboo ladder to small chamber and short drop into dried pool. Small passage continues beyond for 40m until too tight. 83.

255. L.Wotawati. 442126. Depth 65m Length 188m. P17,P7,P6 followed by a descending passage to an undescended P16 into a pool. Survey, Figure 31. 83.

256. L.Buriomah. 427120. Depth 110m Length 211m. An impressive rock arch provides the entrance to a descending passage with short climbs and P9,P5, and P9 into a low meandering passage with a small stream. This leads to the head of a P52 from the bottom of which there is no way on. Survey, Figure 32. 83.

257. L.Bopo. 505045. Large collapse with P15 to vegetated boulder floor. 83.

258. L.Kentu. 83.

259. Unnamed. 648132. Choked sink. 83.

260. Unnamed. 644138. P17, P5 to choke. 83.

261. S.Plalor. Resurgence cave which passes completely through the hill. Water comes from S.Sawar, Site 262, and flows down the valley to feed S.Ngremmeng, Site 243. Unexplored. 83.

262. S.Sawar. Resurgence cave which apparently passes completely through the hill. Water flows down the valley to feed S.Plalor. Unexplored. 83.

263. L.Langkap. 621022. Small climbable walled shaft into narrow rift, continues descending. 83.

POTENTIAL FOR FURTHER EXPLORATION

The work carried out in 1983 more or less completed the exploration of the known sites of speleological interest in west G.Sewu, although a careful reading of the above descriptions will reveal a small number of sites where further discoveries may be made. The dense population of Sewu makes it unlikely that any significant number of unknown sites remain to be visited.

A brief reconnaisance was made to east of Pracimantoro where there is a large area of karst awaiting exploration. The road network in this area is less well developed than in west Sewu and there is considerably more tree cover. A number of sites of potential interest were noted, however, amongst which were a large entrance with cave passage at Sumberagung (782007); L.Saban (787989); G.Calianyar (795988); and the resurgance cave at Kali Maron. This area would undoubtedly repay further investigation. In addition there are a number of unexplored river caves in the north-eastern margin of the cone karst and the area in the vicinity of Site 261, S.Plalor, would merit some investigation.

Cave exploration in Java is coordinated by the national body, now named FINSPEC, The Federation of Indonesian Speleologists, who may be contacted via their Chairman, Dr.R.Ko, P.O.Box 55, Bogor, Java, Indonesia. Any foreign groups contemplating a visit to Indonesia would be well advised to work as closely as possible with FINSPEC in order to obtain the benefits of local advice and cooperation and to support the development of caving in Indonesia.

CAVE BIOLOGY

Small, apparently cave adapted fish were observed in the entrance stream to G.Jomblang (Site 169). Several specimens were caught and brought back to the UK where they have been examined by Dr.K.E.Banister of the British Museum (Natural History). They have been identified as Barbus microps (Gunthor, 1868) which is "quite widespread". (Proudlove, pers.comm. 1984). At least one of the specimens shows evidence of reduced eyes and specimens from caves elsewhere have been observed to show similar features. Since there is no permanent surface water in the vicinity of G.Jomblang it is possible that the population of B. microps in the cave may be an incipient cave fish although further information is required to substantiate this. Unfortunately the experimental practice of stocking Sewu telagas with high-yield fresh-water species in order to generate a crop of fish during the wet season may make this impossible. There is a temporary telaga very close to the cave and introduced species might well reach the cave and swamp the population of B. microps.

Specimens of fresh water shrimps were collected in 1982 from L.Tong Pocot (Site 51) and G. Sodong (Mudal) (Site 133) and in 1983 from L. Jurangjero (Site 8). These have been examined by Dr.L.B.Hulthuis of the Rijksmuseum van Natuurlijke Historie, Leiden, The Netherlands, and are a new species Macrobrachium poeti (Crustacea Decapoda, Natantia). (Proudlove, pers.comm. 1984). The type specimens have been retained by Dr.Hulthuis.

ACKNOWLEDGEMENTS

The authors are grateful to the members of FINSPEC, in particular Dr.R.Ko,for their superb hospitality and assistance; to Soedigdo W. and the staff of P2AT at Yogyakarta and Wonosari for their assistance, support and facilities; to the staff of Sir M.Macdonald and Partners, Civil Engineers, for their practical support and generous hospitality; to our interpreter and excellent caving partner Mas Sudiyono, our driver Mas Sunarto, and our cook Sumiati, without whose help our stay in Wonosari would have been far less comfortable and much less productive. We are grateful for the financial support of the Ghar Parau Foundation and the Sports Council. The members of the 1982 G.Sewu Cave Survey team provided us with our motivation and background information and infected us with their enthusiasm for the area. Finally, and in common with the 1982 team, we would like to express our gratitude to the people of Gunung Sewu whose charm and boundless hospitality made our work a pleasure.

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MAP REFERENCE KEY TO SITE NUMBERS

347126	Site 253
350119	Site 206
358135	Site 149
359129	Site 148
369142	Site 128
371110	Site 84
372152	Site 227
376108	Site 83
376116	Site 82
377075	Site 194
377087	Site 195
378081	Site 198
386123	Site 81
387129	Site 79
390127	Site 78
392135	Site 254
395107	Site 196
397128	Site 80
410129	Site 226iii
411118	Site 77
412129	Site 226i
413129	Site 226ii
416114	Site 76
417118	Site 75
418134	Site 225
422076	Site 162
426023	Site 150
427120	Site 256
432058	Site 97
432084	Site 163
435074	Site 100
438103	Site 165
439049	Site 96
440050	Site 95
442126	Site 255
445129	Site 224
449063	Site 44
453026	Site 188
456040	Site 129
458042	Site 223
458056	Site 164
464060	Site 94
473173	Site 244
476057	Site 93
486076	Site 89
487066	Site 91
490053	Site 92
491070	Site 90
492091	Site 87
492120	Site 131
496104	Site 86
498073	Site 43
499063	Site 222
499089	Site 88
500016	Site 187
500098	Site 85
501047	Site 98
502154	Site 246
505041	Site 99
505045	Site 257
507073	Site 42
507131	Site 219
509028	Site 36
509094	Site 39
512060	Site 221
512073	Site 40
514048	Site 35
515099	Site 4
519120	Site 218
522122	Site 217
524049	Site 34
524058	Site 33
526081	Site 32
526085	Site 37
527115	Site 153
528018	Site 140
528087	Site 38
533133	Site 152
534108	Site 31
536017	Site 231
536060	Site 220
537072	Site 174
537108	Site 30
538068	Site 3
539122	Site 154
543105	Site 29
549126	Site 170
550149	Site 245
557127	Site 184
559128	Site 183
562127	Site 216
564995	Site 185
565067	Site 23
565074	Site 26
567057	Site 230
567994	Site 186
573051	Site 27
573070	Site 141
573082	Site 28
574063	Site 24
574111	Site 22
574124	Site 104
574140	Site 211
575036	Site 138
575057	Site 25
576117	Site 212
576126	Site 105
577118	Site 197
578036	Site 139
579111	Site 21
580130	Site 103
583137	Site 101
585136	Site 228
586125	Site 127
587112	Site 20
587119	Site 213
587142	Site 210
588032	Site 144/145
588078	Site 19
588125	Site 126
591062	Site 130
591139	Site 102
594119	Site 214
595085	Site 120
595111	Site 215
595316	Site 192
596034	Site 112
596074	Site 142
597107	Site 46
597142	Site 176
598078	Site 18
598097	Site 47
600127	Site 190
601147	Site 209
602030	Site 17
602078	Site 107
603063	Site 143
603122	Site 189
605186	Site 156
607094	Site 155
607024	Site 16
607105	Site 45
609137	Site 11
610078	Site 157
612028	Site 15
612030	Site 13/14
612088	Site 106
612148	Site 12
613020	Site 41
613032	Site 10
615128	Site 2
619087	Site 158
619139	Site 167
621004	Site 9
621022	Site 263
623022	Site 205
623045	Site 110
623063	Site 108
624038	Site 114
625011	Site 175
625037	Site 177
628029	Site 113
628033	Site 111
628110	Site 151
630053	Site 109
631101	Site 51
634103	Site 50
634132	site 208
635130	Site 166
636045	Site 115
637063	Site 168
637137	Site 207
638058	Site 171
639065	Site 172
640075	Site 173
640112	Site 49
644082	Site 48
644138	Site 260
644139	Site 63
647117	Site 180
648132	Site 259
656970	Site 233
657138	Site 159
658114	Site 6
659114	Site 7
662158	Site 116
663113	Site 5
669111	Site 8
670977	Site 234
677130	Site 160
680006	Site 71
680092	Site 73
681092	Site 181
682966	Site 239
682995	Site 74
684066	Site 119
684178	Site 199
686045	Site 68
687045	Site 67
688037	Site 66
688994	Site 72
690070	Site 64
692012	Site 69
692124	Site 117
693001	Site 70
693037	Site 65
693219	Site 243
694129	Site 249
697095	Site 204
697190	Site 241
698213	Site 235
699209	Site 238
700108	Site 118
704090	Site 60
707124	Site 229
708042	Site 193
711189	Site 242
713086	Site 59
715133	Site 200
716018	Site 178
717079	Site 58
718112	Site 62
718114	Site 248
723088	Site 122
723092	Site 252
725078	Site 57
726035	Site 54
727048	Site 135
727085	Site 121
727116	Site 61
728031	Site 137
728032	Site 136
729192	Site 182
730105	Site 123
731067	Site 191
733144	Site 251
733153	Site 169
735065	Site 125
735118	Site 53
735150	Site 250
738101	Site 52
740102	Site 1
742998	Site 179
746043	Site 56
753059	Site 202
754036	Site 55
756055	Site 247
762112	Site 133
755101	Site 134
761113	Site 232
763108	Site 161
773946	Site 203
778089	Site 147
778091	Site 146
787097	Site 201
796118	Site 236
797088	Site 240

Transactions British Cave Research Association. Volume 11, no.3, November 1984

HYPOTHERMIA IN CAVERS

J. C. Frankland

Caving is one of many sports where participants need to protect themselves against heat loss. This is usually done as a compromise whereby normal caving activity will generate enough heat to maintain thermal equilibrium in the body if clothing with adequate heat insulation properties is worn.

Thus any caver immobilized through injury or trapped by any cause can lose heat and deteriorate dressed in what would normally be adequate clothing unless extra measures are taken. Paul Ramsden has covered many techniques appropriate for this problem in an extremely practical way (this issue of Cave Science).

Cavers in the United Kingdom do not generally face the low temperatures and high wind chill cooling to which climbers are exposed but they may in some caving area, e.g. in the entrance to ice caves, and they can in England when leaving a cave in blizzard conditions and facing a walk to shelter particularly if soaked. For this latter extra windproof clothing left at the cave entrance for the walk out may be sensible and life saving. A wind chill chart is given in Fig.1.

Hypothermia is simply a fall in body temperature inevitable when heat loss exceeds heat production in any circumstances. It is defined as being present when the core or inner temperature is below 35°C (normally 37°C). This is simply an arbitrary point on a continuum of deterioration and instead of being pedantic about the level of cooling achieved it is more relevant to decide if an individual is losing heat and if so to take appropriate measures. The symptoms of acute hypothermia are shown in Fig.2.

A core temperature of 35°C also represents a stage where appreciable heat loss has occurred, where the sufferer is at risk, and where deterioration can be rapid.

Though the inner body (core) temperature may have fallen by just 2°C, the outer layers or shell will be appreciably below this level, considerable total heat loss having already occurred. Oliver Lloyd's classic paper of 1964 described two Mendip cavers dying in 1 and 1½ hours after showing the first features of hypothermia in flood conditions.

The level of hypothermia is classically defined as

Mild	Core temperature 34° - 35°C
Moderate	Core temperature 30° - 34°C
Severe	Core temperature below 30°C

If labelling any caver mildly hypothermic as defined above were to give the impression that he is hardly at risk, it would be a profound error!

Differences exist between the clinical features and the management of those cooled rapidly, for example after immersion in cold water (known as acute hypothermia), and those cooled slowly, for example lying immobile down a dry cave (known as chronic hypothermia).

In practice cold cavers tend to fall between the two extremes with the likely added extra insults of exhaustion and mental stress. The "Exhaustion Exposure Syndrome" combining all of these can be highly lethal.

At risk are all immobilized particularly the thin, those inadequately clad, the young, the less experienced, the unfit, the recently ill and anyone hungover!

Non-sporting hypothermic victims are mainly the elderly, infants, those with suicidal intent and drunks. The writer has seen more than one cold caver from the latter group due to collapsing outside after caving club Winter dinners! Beware and look after your less temperate colleagues at these functions.

How can hypothermia be detected? The victim may be completely unaware of any deterioration and lacking any subjective sensation of feeling cold particularly if exertion is continued up to the point of collapse. The American militia in cold conditions work a "Buddy system" where all are paired and given the responsibility of watching for exposure in their colleague. Perhaps cavers could profitably apply this concept on cold arduous trips!

Its onset is insidious and difficult to detect starting as just the discomfort, inertia and shivering known to all cavers whilst waiting their turn to climb pitches and which is totally reversible by brief activity. Further features are vague, including fatigue, pallor, violent shivering, feeling cold, lethargy and cramps. These can progress to violent trembling, confusion, unreasonable behaviour, slurring of speech or irrational speech, muscular weakness, lack of co-ordination, inability to perform difficult moves and then even to walk, delirium and finally a state of coma progressing to apparent death.

At times victims may be awkward or aggressive and display bursts of irrational undirected activity. When they show by their speech and their actions that judgement and logical thought has disappeared, a critical stage has been reached as incorrect decisions may be taken in a survival situation.

Almost 100% of exposure-exhaustion victims will have a detectable smell of ketones on their breath (resembling acetone, pear drops or nail varnish). This feature is easy to detect if the nose is placed near to the victim's mouth whilst he breathes out. Its presence is significant and puts victims at risk of rapid deterioration. However, many cavers with this feature have exited from caves unaided after being lost or trapped. Their attendants should be aware that they are at risk, should feed them, watch for deterioration and protect them carefully on even minor hazards.

ESTIMATED WIND SPEED IN M.P.H.	ACTUAL THERMOMETER READING (°F)											
	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
	EQUIVALENT TEMPERATURE (°F)											
calm	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60
5	48	37	27	16	6	-5	-15	-26	-36	-47	-57	-68
10	40	28	16	4	-9	-21	-33	-46	-58	-70	-83	-95
15	36	22	9	-5	-18	-36	-45	-58	-72	-85	-99	-112
20	32	18	4	-10	-25	-39	-53	-67	-82	-96	-110	-124
25	30	16	0	-15	-29	-44	-59	-74	-88	-104	-118	-133
30	28	13	-2	-18	-33	-48	-63	-79	-94	-109	-125	-140
35	27	11	-4	-20	-35	-49	-67	-82	-98	-113	-129	-145
40	26	10	-6	-21	-37	-53	-69	-85	-100	-116	-132	-148
(wind speeds greater than 40m.p.h. have little additional effect)	LITTLE DANGER (for properly clothed person)				Increasing DANGER			GREAT DANGER				
					Danger from freezing of exposed flesh							

Fig.1. WIND CHILL CHART

Fig.2. SYMPTOMS OF ACUTE HYPOTHERMIA

English hill climbers have been taught for many years that when exposure develops it is safer to seek shelter, change to dry clothing and rest than to continue walking. If rescue does not arrive then after rewarming and nourishment victims can continue walking with more safety. All of this presumes that dry clothing, food and some shelter are available.

This good advice must have saved many but may have been overdone at times, particularly if just a few minutes walking could allow several hundred feet of descent and much improved weather conditions and chance of rescue. The most extreme example was that of a lone slightly cooled Yorkshire teenager who lay in his sleeping bag for five days within a couple of miles of a road whilst several hundred rescuers searched for him.

Some have claimed that British cavers are spoilt by readily available rescue services and are losing the tradition of self rescue of an earlier generation.

The most important aspect of exposure for cavers is to be alert for the development of the features listed and be aware of their significance. What to do next is more problematical and will depend on the competance and equipment of the party and the remoteness of the situation.

Many victims with mild symptoms can be adequately handled with rest, insulation, feeding and an assisted exit. On expedition caving nothing else may be available.

Above a certain degree of cooling, exercise will be beneficial and due to heat generated totally curative. Below this level when cooler blood is pooled and static in the body shell (principally the skin and muscles) then forcing exercise on victims will merely, divert the coldest blood from shell to core with undesirable results and by opening up the shut-down peripheral circulation actually increase heat loss from the skin. The core temperature below which exercise is detrimental, based on experimental work, is around 35°C i.e. the onset of mild hypothermia as previously defined.

All of this theory supposes that the victim is not too exhausted to cope with further exercise which may certainly not be the case with caving victims. With exhaustion, forced exercise may be rapidly detrimental.

How does one judge the best course of action with a cold caver where rescue is not near to hand and prolonging evacuation may put others at risk? How should British rescue teams, who frequently meet this problem, handle victims who have been trapped or lost and who have become cooled to some degree? With multiple victims stretcher carriers for all will tax rescue resources and are likely to be impractical in the far reaches of some caves.

The arrival of help will boost morale, which is so important and can offer warm drinks and food which is universally beneficial. Much will depend on the ingenuity of those trapped whilst awaiting rescue and their foresight in using adequate insulating clothing and carrying exposure bags.

Fortunately most trapped cavers after a bite of food are only too eager to get out of the cave themselves and often outpace the rescue team. Those in or approaching coma will need carrying out after insulation.

How should the borderline case be dealt with? Measuring rectal temperatures underground is an impractical means of arbitrating. The best guide is probably the level of consciousness as shown by the clarity of thought. If the victim is rational, speaking clearly and not unco-ordinated in his movements he (or she throughout) is probably fit to climb out from his cave, warming up thereby. He will still need carefully protecting from any hazard.

If he is confused in orientation or speech and moves with a staggering or excessively clumsy gait he is probably too cold to have exercise forced upon him. In this case he should be rested, insulated, fed and allowed to rewarm which will happen spontaneously from his on-going body metabolism if insulation is adequate.

If he is borderline and not too exhausted and a rapid evacuation is desirable on other grounds (which is usually the case), then it would seem reasonable to perhaps provide extra clothing and then let him attempt to move out by his own efforts. He should however be protected obsessionally and watched meticulously. If he show signs of deteriorating then this decision must be reversed. He must be rested, insulated, and a stretcher evacuation considered. In my own experience only two such victims have needed a stretcher evacuation after first attempting to walk out - one because of recent influenza and the other due to having been given excessive strong pain-killing drugs. Both survived.

The best practical methods of providing insulation is open to debate and will vary with the problems likely during rescue. The optimal way would be to remove all wet clothing and place him in a dry sleeping bag with a warm rescuer (Yes, we all share a fantasy that one day the victim will be a pretty girl and it will be our turn in the bag - but this never seems to happen).

If a caver is in a wet suit or fibre pile suit them most teams would not undress him as these garments retain their insulating properties when wet and most benefit is to be gained from adding extra insulation on top. Providing gloves and head protection with a neoprene helmet is important. If the victim is just in layers of cotton or wool clothing and these are soaked, their cold insulating properties can be reduced to perhaps 5% of their dry value so the victim is effectively naked. Fibre pile or neoprene clothing needs to be supplied. Whether his original clothing should first be removed is again open to debate. Many rescuers would not remove his innermost garments. If a fibre pile suit is placed over these their moisture will be "wicked" away.

Exposure bags for insulation can vary from the Space Blanket via various gauges of polythene bag to the more definitive rescue bags of neoprene, fibre pile or Flectron.

If immersion during rescue is likely, then both fibre pile and Flectron bags can absorb a considerable weight of water adding to the handling problems of the rescue teams. Flectron is likely to drain this extra load more rapidly than fibre pile but both can add significantly to the bulk of the parcelled victim which may preclude his rescue through a tight cave.

Keighley has shown the fibre pile bag to be optimal for mountain rescue by both laboratory tests and field trials. Despite this work cavers needing help in the Yorkshire Dales are likely to be placed instead in an all enveloping 6 mm neoprene exposure bag which with wet and tight caves best suits our purpose. (A space blanket can be used inside this as an extra layer with no extra weight or bulk). Its design includes a helmet and a full length waterproof zip which is very expensive and for which velcro would probably be an adequate substitute under most circumstances. It can either include arms with closed sleeves - as most rescue victims in a stretcher prefer their arms free for self help and protection - or can be just a bag without arm tubes which is slightly more efficient. Inside such insulation cold cavers will warm up measurably over several hours.

There is a need to monitor body temperature in hypothermia - if it is falling then victims are in fact dying. Academic precision demands rectal or oesphageal temperatures which are not feasible underground. As a simple workable compromise a temperature reading below the tongue can be taken and changes in this reading more than absolute levels monitored over a period of time.

A subnormal clinical thermometer is essential - with a standard clinical thermometer readings will be off-scale. All rescue teams should carry these. Shake well down and place beneath the tongue for a measured three minutes and note the reading. This will be below core temperature probably by about 5°F but do not be alarmed, do your best and repeat the reading in perhaps half an hour. If it is falling your victim is deteriorating and if rising he is rewarming. At least two thermometers are suggested as the user's fingers can be cold or muddy and breakage through fumbling is likely. Do not use within say fifteen minutes after a hot drink.

An average rescue incident in the Yorkshire Dales with a wet-suited caver lying immobile through injury for two to three hours before rescue help arrives gives a mouth temperature of perhaps 91° - 92°F measured with a subnormal thermometer. With the neoprene exposure bag insulation this is likely to rise by perhaps 1°F per hour during rescue. Such figures are of course unpredictable and just averages. Colleagues waiting in support of injured cavers seem more likely now to be carrying exposure bags and to lie with close body to body contact to prevent heat loss than was generally the case a decade ago - to the definite benefit of victims.

The perceptive and critical reader will have noted that hypothermia theory comes in °C, as in all the best literature, but that working observations recorded down caves come in °F as do the available subnormal thermometers. Resolving any difficulties this causes is left to the reader's ingenuity.

Many rescue teams now carry airway rewarming equipment. This technique was first described by E. Lloyd in Edinburgh hospitals in 1972 and the C.R.O. were the first rescue team in the world to use this method in the field. The concept was controversial initially with a Scottish academic telling the mountain rescue world that it was ineffective long before his experimental data, which was done on animals, was published. The early equipment (the Reviva) was bulky and undoubtedly carrying it up Scottish hills to find that the vast majority of victims did not need it was a deterent (some were dead and the majority of survivors fared well without it).

The American Coastguards later published experimental work on humans and claimed it was the method of choice for acute hypothermia as it minimised the "After Drop" in core temperature which is a continuing fall after the victim is removed from a cold environment and which can cause appreciable deterioration or death after rescue. However, the most recent work on immersion hypothermia victims who die after rescue has shown that a fall in blood pressure due to removal of the external hydrostatic pressure afforded by the water is more dangerous than the "After Drop" in core temperature.

The heat provided by this technique is small due to the low thermal capacity of air being of the order of around $5KJ/M^2/hr$ - air at around 50°C and with 100% water saturation is inspired. However, in the critically cold with peripheral circulatory stasis a significant amount of heat is lost in warming and saturating the expired air with water. This is of the order of 35 $KJ/M^2/hr$ and can be totally prevented by the airway warming equipment. It is an adjunct to and never a substitute for adequate insulation.

Perhaps the method remains controversial. American and Canadian rescue teams are avidly acquiring such equipment and have added the refinement of several face masks to allow treatment of multiple victims. The "Little Dragon" equipment fits comfortably inside a single ammunition box. There are limitations on what equipment can be carried down to rescue victims and perhaps the most relevant appraisal of the method is the judgement of experienced rescue controllers who find the benefits to victims worth the effort of carrying the equipment. Most of our victims are fortunately not critically cold and certainly derive enormous subjective benefit from breathing the warm air almost to the point of addiction. Their recovery is hastened, their morale boosted and many have been able to walk out, avoiding a stretcher carry.

The U.S. Army use chemical packs which provide heat for several hours after the addition of a small quantity of water. These are placed against the trunk of hypothermic victims as a rewarming measure. Only small heat packs designed to warm the cold hands of skiers are currently available in U.K. I believe that this technique could be developed to be of considerable use in cave rescue in future years.

The Thermal Sarong is a sleeping bag containing tubes through which ethylene glycol heated by a butane burner is pumped. It was designed to help rewarm cold American military divers. The biggest disadvantage is the cost of this equipment which is around $2000.

The Braemar Mountain Rescue Team in Scotland acquired a Thermal Sarong in 1979 but its use in cave rescue has not been evaluated.

The value of alcohol in hypothermia is slightly controversial. It will act as a skin vessel vasodilator and can thus allow heat loss to the victim's disadvantage. Some of the survivors from the most severe levels of hypothermia (as low as 17°C core temperature in a now legendary alcoholic Chicago negress) have been very drunk and it has been claimed that their elevated blood alcohol levels have protected against the final circulatory collapse which causes death.

A small draught of spirits to an incipient exposure victim in bad conditions could just boost morale and determination enough to be of value but this is problematical and probably the best advice is to withhold alcohol from rescue victims and keep it for the team to enjoy after the incident.

The consensus of medical opinion is that no drugs are of specific value in treating hypothermia. Some will give parenteral hydrocortisone which is probably not rational and some European rescue teams may still give strong sugar solutions intravenously which is almost certainly not rational.

Massaging the limbs is of no value. It may traumatise skin with frost bite or frost nip on mountains and can assist cooled peripheral blood to return to the core with undesirable effects.

I have never heard of cavers going through the stage described as "warm euphoria". This is a late event in mountain hypothermia in which the victim feels warm and sheds clothing. Scottish teams have described following a trail of discarded clothing to a dead victim. It is common for those collapsed with cold in the hills to have neglected to have donned protective clothing they were carrying in their rucksack or to have ignored nearby sources of shelter.

In rescuing hypothermia victims minimal handling, avoiding in particular sudden postural changes from horizontal to vertical, is desirable. This is obviously totally impractical throughout most cave rescues.

When victims reach the surface helicopter evacuation from the cave entrance to a hospital with intensive care monitoring facilities is justifiable if their condition causes concern and weather conditions permit.

If a helicopter evacuation is not feasible and the journey to hospital could be prolonged then rapid rewarming in a hot bath must be considered.

This technique should never be considered for infants or for the elderly and is of most benefit to victims who have cooled quickly and who are deteriorating despite help. For some co-existing injuries will make it impractical.

Its main value is for the critically cold but in practice it is mainly used for the slightly chilled so that they and the rescuers can more speedily depart for home or some hostelry!

Facilities should be arranged during rescue and not just considered when the victim arrives on the surface.

A deep bath in a warmed room with the water at 41°C is necessary (or 45°C if a clothed victim is to be immersed). Does your caving hut have a thermometer available to measure this bath water temperature? If the water temperature cannot be measured it should be as hot as a bare elbow can just tolerate.

Keep the victim horizontal throughout - remove clothing apart from underclothing in the warmed bathroom and lift him into the bath. Immerse the trunk but not the limbs. The head should be firmly held throughout by one man who has no other responsibilities. It is important to keep the head securely held and as low as is practical without risking immersion of the face.

The victim may thrash about, move violently, become aggressive and reach a state of near convulsion after immersion. Be aware of this possibility and be able to offer appropriate restraint.

A cold victim will cool the bathwater so that it should be constantly stirred to avoid a cold layer round his person and its temperature maintained by "topping up". Thus more than one bath full of hot water is necessary and around 40 gallons should be aimed at. Pans and kettles may have to be used.

The patient should be observed closely throughout and if he seems to be deteriorating removal from the bath and stabilization lying flat in a warmed bed should be considered. Medical supervision of this procedure is desirable for a critically cold patient, if available.

As a general rule the victim should be kept in the bath until visible sweating appears on the forehead. Even after this a period of a couple of hours lying flat in a warmed bed is desirable before allowing any activity.

The diagnosis of death in hypothermic patients is difficult and fraught with hazards. With profound cooling a state of almost suspended animation develops where respiration and heart beat may be undetectable. It represents the commonest cause of the dramatic recovery on the mortuary slab after death has been confirmed medically and children submerged in cold water for up to 45 minutes have recovered without cerebral impairment.

Common sense with allowance for the unique difficulties met during cave rescue must prevail but if in any doubt the diagnosis of death should only be made after failed resuscitation. This could involve maintaining slow cardio-pulmonary resuscitation throughout the transfer to hospital.

However, prevention is better than cure and better equipped and better informed cavers will be our best resource. The last caving hypothermia death in the Yorkshire Dales was in 1969 although walkers and a fell runner have succumbed since then.

Well before this, in both caving and climbing, there were deaths during rescue when exercise was forced on uninjured cold victims to their detriment, this risk not being recognised at the time.

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APPENDIX

SUPPLIERS OF EQUIPMENT REFERRED TO

FLECTRON BLANKET	J.C.Jones, CUIC, University College, PO Box 78, Cardiff.
LITTLE DRAGON	M.F.Mitchell Capplerigg, Kentmere, Kendal, Cumbria.
REVIVA	Peter Bell Engineering, The Slack, Ambleside, Cumbria.
THERMAL SARONG	Energy Systems Cop., 1, Price Street, Nashua, New Hampshire, 030 60 U.S.A.
SUBNORMAL THERMOMETERS	Can be ordered at any chemist
NEOPRENE EXPOSURE BAG	Not commerically available but easily made. Can be seen at C.R.O. Depot, Clapham, Nr. Settle, Yorkshire.

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CAVE SCIENCE

Transactions British Cave Research Association. Volume 11, no.3, November, 1984

CAVE FLOODING AND UNDERGROUND SURVIVAL

Paul Ramsden

Abstract

Flooding is one of the main causes of cave rescues. Finding out as much as possible about the cave and its flood characteristics, together with an up-to-date weather forecast, is good practice before going caving. If, despite the above precautions, you are trapped underground, your chances of survival or physical state will be greatly improved by having a polythene survival bag, gloves and balaclava, all of which may easily be carried on a normal caving trip.

CAVE FLOODING

To many the sporting wet trip is what caving is all about, yet the fun and enjoyment can turn into tragedy if the weather conditions have been misjudged. After all, many caves are really just underground water courses, which often flood, sometimes to the roof, due to their constricted nature. To the inexperienced, caving is a form of Russian Roulette, because they don't know if it is safe to go underground or not. This is not altogether surprising, for relatively little has been written about cave flooding and most of the better material is either out of print (Heap, 1969; Hanwell & Newson, 1970), or not widely available (Halliwell, 1983). Guide books - probably the most widely read caving literature, are generally very poor in this respect. The introductory caving code of Pennine Underground or the early Northern Cave guides did not mention flooding at all. More recent editions have a section on hazards, which includes flooding right at the end, after free-diving sumps.

The thunderstorms of June 1982 produced severe flooding and some caves became impassable less than one hour from the onset of the rain, and caused several rescues. I wrote a warning in both *Caves and Caving* (No. 17) and *Descent* (No.53), intending to inform a larger number of people than had the misfortune to get first-hand experience. Halliwell (1983), in an otherwise excellent article, misunderstood the educational logic of my warning, saying had I forgotten "Cave rescue record as flood traps 40 (1975) or even the Mossdale tragedy (1967)". This is a common misunderstanding by the old brigade - many of today's active cavers have not been around long enough to recall these events. Unless you have seen a major flood or have detailed information on the effect of flooding you will probably not treat caves with the respect they deserve. Cavers have been criticised for not knowing that Kingsdale Master Cave floods to the roof, because it was written up in the U.I.S.A. Explorations Journal of 1969. The caver reading the latest guide book, finding no flood warning for this cave may assume there is no problem. However, to be fair, the guide does say "no warning does not mean no hazard".

Some cavers seem to show an illogical indifference to weather conditions, perhaps they don't appreciate the effect of flooding. Others seem so sceptical of the accuracy of weather forecasts that they ignore them, saying "It'll be right" and trust to luck.

WHEN IS IT SAFE OR UNSAFE TO GO UNDERGROUND?

The sensible approach is to assess the risk of flooding, by taking note of the present weather and ground conditions, local stream levels and up to date weather forecast <u>each time</u> you want to go underground. This should then be related to information about the cave before a decision is made; bearing in mind that no warning in the guide book does not mean no flood hazard. In practice people often plan which cave they want to visit in advance and assess its suitability on the day.

1. <u>Flood characteristics of the cave.</u>

To visit a cave safely you need to find out as much as possible about its particular flood characteristics: Does it flood to the roof? Do pitches, crawls or streamways become impassable? Do sections sump off and prevent escape? Are there sections above flood level where you can wait? It is most unlikely that the guide book will provide sufficiently detailed information and these factors may vary with the magnitude of the flood. The experienced caver will always look for signs of flooding. Flood debris may occur as tide marks on walls, or wrapped around stalactites, other areas may be washed clean. Unfortunately, unless you are a regular visitor to a cave it is difficult to tell the age of flood debris. In the absence of previous knowledge of the cave all you can do is seek advice from others in your club or elsewhere. The Instructors at Whernside Cave and Fell Centre, Dent, read a raingauge, provide a daily weather forecast, cave all through the year, so can make some correlation between weather forecasts and water in caves, as well as having considerable local knowledge of the Dales. For weather forecast or information Telephone Dent (05875)213. However, it would be unreasonable to expect anyone to guarantee the safety of an unknown group, in a cave with a flood risk when the forecast is other than good.

2. <u>The Weather Forecast.</u>

In Britain it can rain at any time of the year, so you must check the weather forecast before going underground. Weather prediction is not an exact science, but is surprisingly

reliable. The most likely errors are in the precise timing or intensities of rainfall, there may also be considerable variation locally in hilly areas. Television weather maps are useful to see the general situation with depressions and fronts bringing rain, but Radio 4 at 7.55 am and 12.55 pm give a more detailed forecast. The problem with both Radio and T.V. is that they are forced to make regional generalisations. By contacting the nearest meteorological office immediately before departure, the errors of timing and generalisation are reduced to a minimum.

3. Ground conditions and the catchment area of the cave.

When it rains a certain proportion is intercepted by vegetation and prevented from reaching the soil. What happens to the remainder depends on the degree of saturation and permeability (infiltration capacity) of the ground. Information on when it last rained is best gained from rain gauge readings, local advice or checking stream levels, especially if you have travelled from elsewhere and possibly experienced different weather. Streams in limestone areas often disappear underground, so looking at these may only be a rough guide.

The size, shape, altitude and slope of the catchment, together with the amount or thickness of soil cover or vegetation and whether it is on limestone or impervious rock will affect run-off following rain. The larger the catchment the greater the volume of run-off, but a small catchment will respond to rain more quickly than a large one. Generally the higher the catchment, the higher the rainfall. Steeper slopes produce faster run-off. Windward slopes, usually west-facing, will be wetter than the lee side of a hill. Streams will tend to rise simultaneously in a semi-circular catchment while tributaries to a long thin valley will tend to rise at different times producing a smaller peak discharge. Similarly, rain falling onto a limestone catchment will often go underground at many separate points, producing several smaller floods, rather than one large flood where the water sinks at one point.

The permeability (infiltration capacity) of a soil is the rate at which water can be absorbed. Thus continuous rain may be absorbed with no run-off until the ground is saturated, but run-off may be produced even on unsaturated ground if rainfall intensity exceeds the infiltration capacity. Given all the above information, it is still not easy to predict how long it will take for a cave to flood, but generally very intense rain will cause more problems than longer periods of steady rainfall.

Ditches in drainage schemes (gripping) or the early stages of afforestation, mean that water has only a short distance to travel before it can flow more quickly in open channels, often draining directly into sink holes. Flooding in recently gripped areas will take place more rapidly and to a greater height than previously.

4. Dangerous weather conditions.

Where the ground has become baked hard in summer, or is frozen in winter, heavy rain is more likely to produce run-off than soak in. This combination in summer is maybe the least predictable. Nice dry weather may lull you into a false sense of security. Thunder may be forecast for days on end, but never seems to happen, at least near you. Convectional thunderstorms are commonly associated with high pressure conditions and occur during the afternoon or evenings. Thunderstorms may be very localised but can be so intense that massive flooding is possible in almost any stream cave in just a few minutes. Major flooding is also likely when there is heavy rain on to snow in winter, though this is more predictable. Cavers tempted underground by a dry forecast in winter, may still be caught out by a snow melt flood produced by rising temperatures.

In most circumstances, rainfall will not exceed the infiltration capacity of the soil and will be absorbed. After a period of continuous rain the soil will become saturated and will produce run-off. Obviously the more rain the soil is able to accept before run-off into the caves, the more time you have to get out of the cave safely. Unfortunately, given heavy rain, many stream caves will flood in less time than the length of normal caving trips. Thus, where stream levels are already high, the only suitable caves are those with known dry sections or where the forecast definitely predicts dry weather and falling water levels.

When it rains the soil absorbs the water until it is saturated, then feeds it quickly into the steams, so water levels rise suddenly rather than gradually. This may be a flood pulse, which has its most dramatic effect in a normally dry, flood overflow passage as it is transformed into a raging torrent. To conclude this section, if in doubt about the conditions, err on the side of caution - the caves will still be there next time.

SURVIVAL

If you have misjudged the weather, your chances of survival are increased if you know the cave well. In 1950 in a flooding cave in the Jura, six cavers tried to get out and were drowned, while Dr. Mairey waited in a high place for 27 hours and survived, with water coming up to his shoulders at one point. In 1963 in Marble Steps pot, one man chose to stay put, while the others rushed out; he was drowned. There is obviously no general rule as to whether you should try to fight your way out against the water or wait for it to subside, except to rely on your knowledge of the cave. In floods people have been swept away and rocks carried down pitches damaging ropes. Marbach (1980) has an interesting quotation for those who think they can climb wet pitches "a cubic metre of water weighs a tonne" don't try to fight against it!

If you are well prepared in terms of taking emergency food or equipment underground, you may be able to survive several days. In the Holloch in Switzerland, a group was trapped for 10 days without special camping gear and rationed themselves to two meals of 300 calories a day. Unlike mountaineers, cavers cannot easily carry things like sleeping bags, spare food and clothing on a regular trip. They cannot change their normal clothing for something different, just because they become trapped. Some knowledge of the ways in which heat loss takes place and the effectiveness of different clothing, may help to prevent unsuitable gear being used.

1. Physiology.

It is useful to look at the physiology of temperature regulation for a person who is not suffering from hypothermia or exhaustion. The "Core" of the human body (brain, heart and lungs) must be maintained at a constant 37°C for normal operation. Heat is produced as a waste product in the burning of food, but most even at rest, is produced in the muscles. Under normal conditions the metabolic processes of the body at rest will produce about 100 W/hr (approx. 80 Calories), but this may rise up to ten times during strenuous exercise. Heat loss must balance heat production if the core temperature is to be maintained.

2. Heat Loss.

Heat is lost from the body by conduction, convection, radiation and evaporation from the skin, and by evaporation from the lungs. Heat is lost in the following ways:

Conduction	- directly from the body by physical contact with cold surfaces.
Convection	- air warmed by the body is carried away and replaced by cold air or water.
Radiation	- by emission of energy to the environment.
Evaporation	- from sweat and from the lungs because of the large quantity of heat needed to vaporise water. To raise the temperature of 1 litre of water from 0°C to 100°C requires 100 Calories, but to evaporate it requires 580 Calories. This is easily the most important cause of heat loss when trapped underground.

In cold conditions body mechanisms act in the following ways:

a) Constriction of the blood supply to the skin and underlying tissues, forming a protective "shell" which reduces heat transfer to the environment. There is little vasomotor control of blood vessels to the head, so at low temperatures, or when the rest of the body is well insulated, the head may loose 50% of the body's total heat loss.

b) Shivering - involuntary, rapid muscular contractions produce as much heat (and exhaustion) as moderate work such as jogging.

c) Physical exercise increasing heat production and ultimately exhaustion. Perhaps this voluntary alternative to shivering may be better for morale. I don't know which is better in terms of heat conservation.

d) Adding more clothing (insulation).

e) Seeking shelter from wind and water.

3. Environmental Factors.

Wind or strong draughts are to be avoided as heat is lost by convection. The phenomenon of "wind-chill" is well known where the effective temperature in moving air is equivalent to a much lower temperature in still air. Wind similarly plays a very important part in evaporation from wet clothing.

Water - this may be difficult to avoid, especially in a flooding cave. Water has over 200 times the thermal conductivity of air, so the efficiency of clothing in terms of insulation is drastically reduced when wet. The evaporation of water from clothing takes enormous amounts of heat from the body.

4. Clothing.

Conductive and convective heat loss is reduced by clothing. The thickness of clothing and its associated trapped air determine the amount of insulation provided. The more layers of clothing you have, the more air is trapped and the better the insulation. If the clothing becomes wet the insulating effect is destroyed as the air is replaced by water. This was shown experimentally by Pugh. Subjects were dressed in 1.8 clo units consisting of a parka, wool jersey, cotton string undershirt, cotton shorts, socks and gloves. (A Clo. unit is equivalent to a businessman's summer clothing = 5mm thickness). When the clothing became wet, it dropped to 0.18 clo. units (i.e. 1/10 of the dry value). With waterproof rain gear the protective effect for wet clothing increased five times to 1.0 clo. units.

Some materials are better than others; wool is generally recognised to be good even when wet, though it tends to hold moisture longer than most synthetics. Cotton jeans, T-shirts, boiler suits etc., are very poor if wet and should definitely be avoided. They hold moisture against the skin and heat is lost by conduction and evaporation. It would appear that much of the traditional caving clothing is only adequate when dry or when heat is produced by moving; an enforced stay could be dangerous.

Most synthetic fibres fall somewhere between wool and cotton in terms of thermal properties, the differences often being in construction and thickness of materials. Fibre pile fabrics are made from various kinds of synthetics in different constructions. Tests at Leeds University comparing Mountain Rescue casualty bags showed that the Eskimo fibre pile bag performed quite well even when wet. Water is taken by capillary action to the

knitted backing keeping the pile, which is against the body, dry. Thus heat loss by conduction is reduced. This "wick" effect varies with different fabrics, but certainly makes the wearer more comfortable. The fibre pile bag showed that retention of body heat cannot be measured in terms of thermal resistance alone and that the mechanism of heat loss depends on the structure of the textile.

The fit of clothing has an effect on its efficiency. Infra-red photographs of someone wearing fibre pile garments show heat loss where there are wrinkles or joins in the material. It is possible to get a kind of bellows action, pushing out warm air as you move about; this is best remedied by having sealable neck and wrists.

Neoprene consists of masses of tiny air pockets embedded in rubber, so that its insulation value is relatively unaffected by water. 4 mm wetsuits seem to be insufficiently warm when you stop moving, though there have been several groups trapped for 48 hours wearing them. Most wetsuits do not have hoods or pockets for emergency gear.

The most effective way of improving normal clothing is to wear a PVC waterproof outer layer. This will keep out the wind and most of the water. Even if clothing is wet underneath, the oversuit will dry off quickly and prevent evaporation which is the largest source of heat loss. Unfortunately, during normal use waterproofs cause you to sweat and reduce the insulation value of the underclothing. The secret is to allow as much air in as possible when moving about.

5. What survival aids can you realistically take with you?

a) Polythene survival bag - thin or thick, probably better than a reflective space blanket or bag. This is the most important single item and easy to carry.
b) Hood/Balaclava/Neck-scarf/Tube hat (covers face)/Polythene carrier bag for a head cover.
c) Gloves.
d) Food - easily digestable, high energy.
e) Closed cell foam "Bum Pad".
f) Spare pullover/waistcoat wrapped in a polybag in tackle bag.
g) Whistle/paper/plastic to write message on.
h) Heat source: Candle/s)/Carbide/Heat Pack.

These will fit into helmet/welly boot/packed into a polythene bag in the hollow in the small of one's back.

6. What to do if you are trapped?

a) Find warmest, safest place available using knowledge of the cave. Make wind break if necessary/possible.
b) Wring out wet clothing.
c) Provide maximum insulation to ALL parts of the body:
   (i) get into polythene bag if available, curl up with thighs to chest, to reduce surface area available for heat loss - helmet on top of polybag.
   (ii) If in a group with a Tent sack huddle together.
   (iii) If no bag etc. huddle/cuddle together for mutual warmth - change around to prevent cramp and take turns at being on outside. Human-Sandwich technique has been used effectively.
d) Sit on insulating material, e.g. tackle bags.
e) Breathe into bag occasionally (see below) or use candle - beware of CO_2 build-up.
f) Exercise - isometric tensing of muscles to keep warm.
g) Eat food - a little every 3 or 4 hours - helps prevent exhaustion and good for morale.
h) Leave message somewhere conspicuous if you have sheltered in an obscure place/Conserve lighting.
i) Be confident, don't give up hope - psychological aspect is important.

EXPERIMENTS

I did a few simple temperature measurements both with groups and alone, pretending to be stuck down a cave, though only for 30 minutes at a maximum (Fig. 1). Having spoken to physiologists about several queries, I am not sure how meaningful these results are. Ideally the tests should have been of many hours duration. Several questions are posed by these tests.

Q.1 One effect of the core/shell variation is that there is a large amount of heat stored in the body which can be lost without untoward effect. This stored heat may be as much as one hour's resting heat production. (Harper, 1975). Does this invalidate the tests?

Q.2 Is exercise useful or harmful, in that excessive exercise may help to cause exhaustion/cooling of the body?

Q.3 If you stay warm (26°C) in the survival bag, will the blood supply to the skin shut down? If not, are you conserving energy to best advantage?

Q.4 By breathing into the survival bag, condensation occurs. The insulation value of clothing will be impaired - is this equivalent to heat conserved by insulation of the respiratory system?

Q.5 By breathing into the survival bag or burning a candle or carbide, carbon dioxide is produced. How dangerous is this with the bag opening downwards, or tiny holes in the top? Is warm CO_2 still heavier than air? Is there a danger of oxygen deficit?

Insulation of the body still leaves the respiratory system as a source of heat loss. Water is evaporated and heat lost in the lungs to saturate air which is expired at 37°C. This is an involuntary process which still continues in cold conditions. Little energy is required to heat the air, but evaporation in the lungs may account for over 200 cal. per day. If air is breathed into the bag, the inspired air will be partially warmed and saturated, though not at 37°C. If this is compatible with not producing excess CO_2 or condensation, it will serve to insulate the respiratory system.

Warming the air in a bag with a candle or carbide lamp has the effect of lowering the relative humidity, because warm air will hold more water vapour than cold air; you might even dry out inside if you are not breathing into the bag.

Experiment 1

9 people in a Karrimor Survival Unit (Tent Sack)
Broadway, Easegill Caverns - Wet conditions

Time	Temperature
Start	11°C
2 min	21°C (70°F)
6 min	24°C (75°F)
10 min	25.5°C (78°F)
20 min	26°C (78.5°F)

Experiment 2

6 people in Karrimor Survival Unit
Holbeck Junction, Easegill Caverns

Time	Temperature
Start	11°C
2.5 min	20°C
5 min	23.5°C
7 min	24°C
10 min	25°C
18 min	26°C

Experiment 3 (See Fig.2).

Ibbeth Peril Cave
Breathing outside bag. No Candle

Time	Temperature
Start	9°C
3 min	16°C
7 min	17°C
10 min	18°C
16 min	19°C
20 min	19.5°C
25 min	20°C
30 min	20°C

Experiment 4 (See Fig. 2)

Ibbeth Peril Cave
Breathing outside bag. Candle inside

Time	Temperature
Start	9.5°C
1 min	15°C
3 min	20°C
5 min	22°C
8 min	23°C
10 min	26°C
15 min	26°C
20 min	26°C

Experiment 5 (See Fig. 3)

Ibbeth Peril Cave
Breathing inside bag. No Candle

Time	Temperature
Start	9.5°C
2 min	15°C
4 min	18°C
6.5 min	20°C
10 min	21°C
14.5 min	22°C
16.5 min	23°C
20 min	23.5°C
25 min	23.5°C

Experiment 6 (See Fig. 3)

Ibbeth Peril Cave
Breathing inside bag. Candle inside

Time	Temperature
Start	9.5°C
4 min	20°C
5 min	24°C
7 min	26°C
10 min	27°C
11.5 min	28°C
15 min	29°C
19 min	28°C

OBSERVATIONS

The temperature rises really quickly, especially with a heat source, to a fairly consistent level. Whether it would be quite different in the longer term requires further tests.

If there are worries about the polythene clinging to the face, the escape technique is to push a finger through it. The polybag was inverted in Fig. 3, leaving feet (Wellington boots) exposed and the bottom of the bag open, assuming CO_2 would drain out being heavier than air. The symptoms of excess CO_2 in the atmosphere are panting, a headache and a racing pulse. None of these occurred during the experiments. Care is needed not to burn or damage the polythene especially if you are waiting for a long time. A 2 oz nylon bag would be better, if heavier, bulkier and more expensive.

Fig.1. Rise of temperature against time for caver(s) in survival bags as in experiments 1 - 6.

Fig.2. Polythene survival bag: opening at top.

Fig.3. Polythene survival bag: opening to bottom

Marbach (1980) described a technique called "the Tortoise" where you crouch under a space blanket, tucked in well under feet and buttocks, with a carbide between your legs for warmth. He suggests taking off oversuit and wellies and sitting on them for insulation. This would not be as weatherproof as a polythene bag. I would need quite a lot of convincing that it was going to be beneficial, before I took off my oversuit.

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M.S.Received June 1984.

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Transactions British Cave Research Association Vol. 11, no. 3 October 1984

PRINCIPLES OF FIRST AID TREATMENT FOLLOWING A MAJOR UNDERGROUND ACCIDENT

by T. Lyons

First aid is the initial care afforded to an injured patient at the site of an accident before definitive medical care is given. In many cases, the eventual outcome of the case may depend on what is done during this period, and life and limb may be saved if the person administering first aid is well trained in its principles. Though there is very little that can be done for an injured patient at the scene of an accident, some things are extremely important and may save the patient's life. The tables below outline the basic aims and actions of the first aider.

AIMS OF THE FIRST AIDER

1. Preservation of life
2. Prevention of deterioration
3. Assist in recovery

ACTIONS AT THE SITE OF ACCIDENT

1. Resuscitation - perform life saving measures
2. Assess overall situation - make a diagnosis from a history and examination; splint fractures, relieve pain and anxiety
3. Alert rescue and arrange transport

For life to be maintained, it is necessary to provide an adequate supply of oxygen to essential organs, carried in an adequate volume of blood. To ensure this, there are important initial steps to be taken in order of priority. These are: AIRWAY, BREATHING, CIRCULATION - "A, B, C". These should be performed with speed, calmness and efficiency, without panic as this will only aggravate the fear and anxiety of the victim.

1. Maintenance of an open airway and breathing

This is the main consideration in first aid. Interference with normal respiration is normally due to an accumulation of blood, vomit, or mucus in the mouth or pharynx (upper airway). This should be removed as soon as possible using one's fingers and the patient placed in the recovery position once their colour is good and breathing regular. In the even of a broken jaw, the tongue may fall back and block the pharynx. This can be corrected by pulling the tip of the tongue forwards thus unblocking the airway. The position can be held if necessary. Normal respiration can be assumed when the patient is maintaining a healthy pink colour with regular easy breathing. If, after initially clearing the airway, the patient's colour remains poor, bluish lips and face, and breathing sounds difficult, there may still be an obstruction. Therefore, the initial steps should be repeated. However, this may be significant of serious damage inside the chest or subsequent to a head injury damaging the brain's control of breathing. If after again ensuring the airway is clear, respiration remains poor, then it is probably worth giving mouth to mouth resuscitation.

2. Circulation and control of haemorrhage

Any obvious bleeding should be stopped immediately by direct pressure over that point using whatever is available as a dressing. Virtually all bleeding can be stopped by the application of firm pressure. The use of a tourniquet would not be advocated except as a last resort to stop uncontrollable bleeding from a limb. If no pulse is felt either at the heart, neck, wrist or groin, then external cardiac massage should be commenced on the assumption that the heart has arrested. This may then reveal an external site of bleeding which had stopped due to blood loss and may now have a pressure dressing applied. A pulse may then return having prevented further blood loss from the circulatory system. If no further bleeding sites are found, then there may have been considerable blood loss around broken bones or from internal chest and abdominal injuries. In which case, little can be done until intravenous fluids can be given. The heart may also arrest from other causes such as lack of oxygen if respiration is impaired from direct trauma or secondary to a head injury.

3. Shock

"What do we do if the patient is shocked"? is a question often asked by the layman. Shock in the medical sense may result from many causes, but following an accident is normally due to blood loss causing a decrease in fluid in the circulatory system, which is manifested in the patient's clinical state. They are drowsy, apathetic, restless with cold, clammy skin and a rapid, poor pulse. This is quite different from the "shock" the patient is experiencing from being in a state of fear and anxiety after an accident, though the latter may in fact aggravate the former. If the layman follows the basic principles of first aid, handles the patient gently, reassures them and keeps them warm, he will have done all he can to help prevent shock before medical help arrives.

4. The recovery position

This position consists of having the patient on their side with the uppermost arm and leg brought forwards to maintain them in this position. The injured patient is very likely to vomit and if this is inhaled into the lungs, breathing problems can rapidly arise. When on their sides, there is less danger of this and the airway can be quickly and easily cleared. Therefore, if possible, it should be used on all patients, especially if there is a head injury and impaired consciousness. If spinal injury is suspected and the patient is likely to vomit, they can still be rolled on to their sides. However, every effort should be made to minimise movement of the spine and the position modified by keeping the arms into the side and legs straight with a tackle bag or something as support against the upper thighs and abdomen.

5. Cardiac massage and mouth to mouth resuscitation

The principles of these techniques can be learnt from any first aid manual and are therefore not described. Anyone so severely injured in the underground situation is realistically unlikely to survive. However, unless the injuries are so severe that the patient is clearly dead, it is probably worth persisting with such attempts until medical help arrives.

6. Assessment of a head injury

If the patient has been knocked unconscious or received a blow on the head, it is important to assess his initial level of consciousness and any change that may occur in it. A patient who is initially alert and orientated after being knocked out and then becomes increasingly drowsy towards unconsciousness, may have internal bleeding in or around the brain. Likewise this may be signified by a decrease in the level of consciousness in the already conscious patient. The four commonly used levels of consciousness are listed below; the original level and any change must be recorded to inform the medical officer when he arrives.

(a) Alert and orientated and responding to all commands
(b) Drowsy and disorientated and responding to simple commands
(c) Comatose and responding to painful stimuli only (pinching the skin will cause the patient to groan and pull your hand away)
(d) Comatose and no response to any stimuli

Also useful in assessing a head injury are the size of the pupils and their response to light. Normally in the dark the pupils are dilated and respond to a bright light by becoming smaller. Pupils which are dilated and not responding to light are suggestive of a significant head injury.

The patient with a head injury is particularly likely to vomit and should be placed in the recovery position.

7. Further Assessment

Following and during resuscitation, if you did not see the accident then further information as to the nature and possible severity of the injuries can be obtained from either the victim or those at the scene should the victim be unconscious. How far did they fall and how long ago; what did they hit, and what position were they in when they landed. Though one is taught not to move the patient until medical help arrives, this makes no sense in the underground situation. Obviously a patient at the bottom of a wet pitch or awkwardly amongst boulders will have to be moved to a more comfortable position. Provided this is done carefully, and movement is minimised, recovery will be aided.

Next, from a history and examination, an overall assessment of the injuries sustained should be made. Enquire as to sites of pain, its character and whether it is getting worse, this will provide pointers for a more careful examination. Are they feeling sick, faint, or experiencing difficulty with breathing, should they be in the coma position? If unconscious, groaning or holding a particular arm or leg may suggest injury. Examination should be carried out in a logical order and is outlined below, think in terms of look, feel, and move. Some aspects of resuscitation are repeated to emphasize their importance.

(a) Look at the patient overall. Note the position of the limbs, neck, and back; are they normal? Is the patient a good colour and breathing normally? Are they visibly in pain?

(b) Look at the head.

- Note the colour of the lips and mouth; are they a good red colour or bluish? If blue, this is suggestive of impaired respiration. What is the cause?
- Look at the mouth; is there any obstruction to breathing? What is it?
- Look at the ears and nose; are they draining blood or clear fluid? The latter, if actually draining, could be cerebral spinal fluid, rather than water. Both blood or cerebral spinal fluid are suggestive of a head injury.
- Look at the eyes; are the pupils dilated and do they react to light?
- Look at the skull; feel it for cuts, lumps, and deformity, which may be suggestive of a skull fracture. Scalp wounds can often bleed frighteningly, but haemorrhage can normally be controlled with simple pressure.

(c) Examine the back and neck (spinal injury)
- Is the position normal?
- Is there any specific site of pain?
- Is there any swelling or deformity along the line of the spine?
- Can the patient feel and move their arms and legs? Loss of sensation may mean damage to the spinal column or nerves. If the above suggests a spinal injury and the patient's position is such that they need to be moved before the rescue team arrives, this can be done with care. In the case of possible neck fractures, all movements of the head, especially forwards, should be avoided. During any movement of the patient, the neck should be pulled gently away from the body and extended backwards (if at all possible, some form of neck collar may be improvised to hold this position) (Fig.1). In movement, the patient's neck and body should be moved in one piece and really several people need to be present to move the patient in this manner (Fig.2.). With the back, if in doubt, treat as if an injury is present. As for the neck, the patient's body and neck must be moved in one piece with the legs and back kept in a straight line and back extended (arched backwards). This can be achieved satisfactorily by several people lifting the patient using their arms and hands as support.

(d) Chest. Bruising over the chest wall with pain on breathing, may suggest rib fractures. This can be very painful and therefore handle the patient carefully and give early pain relief when the rescue arrives. If internal injuries are suggested, little can be done underground.

(e) Abdomen. As above, difficult to assess and little can be done for internal injuries.

(f) Pelvis. Feel for instability or pain by pressing on the pelvic bones which may suggest a fracture. In which case, early pain relief and very careful transport will be needed.

(g) Fractures (broken bones). Fractures are normally classified into two groups close to where the bone is broken and the skin is not torn, and open or compound where a portion of the bone has protruded through the skin. In the latter case, this may only be seen as a fresh wound over the fracture as the bone may re-enter the body. These sort of fractures are very likely to become infected and the earlier they can be covered with some form of dressing to keep them clean, the better. The list below are findings that suggest fractures.

- Pain and tenderness over a bone at the site of injury
- Obvious deformity of the involved area
- Inability to use the affected area without extreme pain or inability to bear weight on the involved area.
- A grating sensation noted with the hands when the affected area is held or moved.

Fractures are very painful and initial treatment is simple splintage by the most practical method available before a more formal splint and pain relief are given. Nerves and blood vessels can be damaged by broken bones. Therefore, before applying a splint, check for feeling, movement, and colour (blue may suggest impaired blood flow) and at regular intervals afterwards. If possible, elevate the affected limb higher than the heart. A simple list of splinting methods is given below.

Fig.1. Supporting a patient's neck with a collar pad.

Fig.2. Multiple carrying points for a patient with a back injury.

Collar bone and shoulder.
Strap the arm bent at elbow across the chest.

Upper arm and lower arm.
Strap either to the side of the body or in a sling.

Wrist and fingers.
Support in a sling if possible and strap fingers together.

Leg.
Strap to the opposite limb.

Foot and ankle.
If a foot or ankle injury is suspected, it is probably better to leave the boot on as this will act as a good splint and reduce swelling and movement.

Now that the general situation is under control and the rescue team is being alerted, it is a question of waiting. The patient is likely to be cold and is in a state of high anxiety and fear. Everything should be done to keep him warm, comfortable and dry. Move the patient carefully if necessary. Sit beside him to keep him warm and out of draughts. Talk to him and relieve his anxiety and fears by your confidence and encouragement that all will be well.

In summary, at an accident, remember the fundamentals of first aid: A for Airway, B for Breathing, C for circulation. Do not panic or flap. Act quickly, calmly and efficiently following a logical set of steps. Assess the patient's level of consciousness and monitor it. Make a list of the injuries you suspect to help the medical officer when he arrives. Above all, do everything possible to keep the patient warm, dry, and in good spirits, as their assistance during rescue may be vital.

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Transactions British Cave Research Association. Volume 11, no.3, November, 1984.

MEDICAL EQUIPMENT FOR CAVING EXPEDITIONS

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What medical gear should we take? This is a question often asked. Caving expeditions vary greatly in size, duration, location and objectives, but none can avoid the possibility of an accident or illness. As seen from the tables below showing the medical problems encountered during the 1982 Australasian Muller expedition to Papua New Guinea, a large, fit group may encounter remarkably few problems in a remote area. However, any illness that occurs can become rapidly more serious due to the remoteness of the expedition. It is therefore worth having some knowledge of the problems likely to be encountered and the facilities to start early treatment.

Muller 82 Medical Survey: Results showing numbers affected from 45 completed questionnaires.

1. Wounds: Clean 23
   Infected 12
2. Musculo-Skeletal problems: Major 0
   Minor 13
3. Diarrhoea and vomiting: 17
4. Fungal infections: Groin, Feet, Hands 14
5. Allergy: Plants (stinging tree) 7
   Insects 7
6. Coughs, colds, bronchitis: 3
7. Urinary tract infections: 2
8. Gastritis, Oesophagitis: 1
9. Constipation: 1
10. Piles: 1
11. Ear Infections: 1
12. Eye Infections: (2 - leech in eye) 1
13. Dental abscess: 1
14. Burns: Fire 1
    Sun 1

The survey shows the vast majority of problems arose from the first four groups, all of which are treatable with a limited supply of medicines to be discussed later.

Expedition medicine, however, should start long before the departure abroad. Members should have adequate immunizations against: Tetanus, Typhoid, Cholera, Polio, Yellow Fever, Hepatitis, Rabies, and antimalarial prophylaxis depending on the area of the world they are visiting. Everyone should have a dental check up before departure, a medical examination if indicated and arrange full medical insurance. Where the expedition is very remote, it is worth arranging some facilities for emergency removal of a seriously injured patient by helicopter if possible.

While abroad, much expedition medicine should be preventative. Meticulous attention should be paid to cleanliness of food and water and adequate sanitary arrangements made away from the camp. Personal hygiene should be of a high standard, paying particular attention to cleaning and dressing cuts and grazes as soon as possible after they occur to minimize infection. When dangerous activities are being performed, greater safety precautions than normal should be observed, to avoid accidents after possibly long and arduous trips.

The recommended treatment of the common conditions likely to be encountered are outlined below:

1. Cuts, wounds, etc.

This is likely to be the commonest problem. The best treatment is to cleanse the area with Savlon, then apply Betadine paint and apply dry gauze and adhesive tape. Alternatively, for an infected cut, a Bactigras dressing may be more comfortable. If not going caving or walking, airing a sore and exposing it to the sun is beneficial. Avoid topical and systematic antibiotics unless indicated. If wounds look bad, with several limbs involved, tender lymph nodes, fever or general malaise, then use Amoxycillin (if allergic, Trimethoprim) or if the wounds are very deep and not responding, Cloxacillin (or Cephradine).

2. Diarrhoea.

The main point here is hygiene. Any sort of gastroenteritis travels; faeces to hands to utensils to mouth, yours or someone else's. So this chain must be stopped from starting and if it sets in, it must be curbed quickly.

So: a) always use your own utensils, and no dipping into the cooking pots
b) always wash your hands with disinfectant soap after toilet visits
c) as much as possible, perform your functions on trips away from camp, otherwise use camp toilet.

If diarrhoea does arise, initially treat with a water only diet and sugar and salt. Diarrhoea spoons are worth having, salt one end, sugar the other. After 48 hours, if this regime fails, codeine phosphate, 2 tablets initially, followed by 2 tablets 6 hourly should stop it. After a few days, Amoxycillin and Metronidazole should be considered.

3. Aches and pains.

Muscular pains and tears are best treated by rest and a simple analgesic such as Paracetamol or DF118, rubbing an analgesic balm such as Transvasin into the affected area will give temporary relief. Ligament injuries (joint sprains) can be treated in a similar manner with support from either an elastic adhesive elastoplast or tubigrip. If possible, the affected part should be elevated to avoid swelling. For severe pain, Temgesic tablets are useful. Place 1 or 2 under the tongue six hourly.

4. Fungal Infections.

Caving activities with damp and sweating lay one open to fungal infection of the feet (athlete's foot) the groin (Dhobi itch) and hands. Prophylaxis is again better than cure. After caving, clean feet carefully, dust with an anti-fungal powder such as Tineafax, and keep them as dry as possible. Wear flipflops or sandals around camp. If affected, regular use of Tineafax powder and cream should cure the problem. Cotton underwear is far less sweaty than nylon! Take your boxer shorts!!

Medical kits can be divided into personal, base camp and emergency kits. They are made on the basis of a 15-man, 4-week trip to an area where it is assumed medical help would be available within a day or two if necessary. Many of the drugs are available on prescription only, but the kits are made on the basis of use by the layman and most things should be purchasable with a prescription if you discuss your needs with a GP. At the end, I include additional drugs and equipment that could be taken on a longer more remote expedition which would have an expedition doctor.

PERSONAL KITS

Each expedition member should carry a personal supply of medical equipment for use to and from the expedition and when in the field. Below is a suggested list and should be carried in a sealed waterproof container. If a member takes any drugs regularly, he should ensure he has an adequate supply for the duration of the trip.

Personal Kit Contents:

Scissors
Elastoplast 2" roll + small gauze dressing and selection of adhesive elastoplasts
Roll 3" crepe bandage, sprains, etc.
Sun tan cream
Lip salve
Insect repellant
Paracetamol 5 gm tablets; quantity 10: 1 or 2 tablets 4-6 hourly for headaches, fever, etc.
Codeine Phosphate 30 mg tablets: quantity 15: 2 tablets 6 hourly for diarrhoea until it subsides
Stemetil (Prochlorperizine Maleate) 5 mg tablets: quantity 10: 1 tablet 4-6 hourly for travel sickness, vomiting
Tineafax: 50 gm tin: fungal infections
Caladryl Cream: 42 g tube: sunburn, insect bites, irritation
Water purifying tablets: cake disinfectant soap
Safety pins also useful

Base Camp Kits

A. General equipment

Quantity	Item	Use
1	Thermometer	
2	Scissors	
5	Scalpel blades	
10	Safety pins	
	First Aid Manual (St. John's Ambulance)	
	MIMs Drug Index	Advice on drugs, quantity, contraindications
2	Splinter forceps	
2	Paper clips	Heat up and drain blood blisters behind fingernails

B. Dressings

30	Savlon sachets 10 mls. (to dilute)	Cleaning wounds
50	Packet cotton wool balls	Cleaning wounds
50	Cotton buds	Cleaning dirt from eyes, applying Betadine paint
20	5 x 5 cm Gauze dressings	Cleaning and dressing wounds
10	5 x 5 cm Melonin dressings	Wound dressing
10	10 x 10 cm " "	
5	10 x 10 cm Bactigras	Burns, infected wound
	Assorted box	
	50 adhesive elastoplasters	
1	Elastoplast dressing strips	
2 rolls	Zinc Oxide Tape	Attaching dressings, etc.
1	Triangular bandage	Arm support
5	5-packet Steristrips	For small cuts instead of sutures
1	Roll 7.5 cm elastic adhesive elastoplast	Sprains Ankles
2	5 cm + 10 cm rolls Crepe bandage	Knees Elbows
1 metre	C/D size Tubigrip	Wrist

C. Drugs

(a) Alimentary System

30	Antacid tablets (many brands)	Indigestion Directions: 1 or 2 as needed
50	Codeine Phosphate 30 mg tablets	Diarrhoea Directions: 2, 6-hourly as needed
25	Stemetil 5 mg tablets	Sickness
25	Sennokot Tablets	Constipation Directions: 1 or 2 at night if needed

(b) Pain Killers

50	Paracetamol 0.5 mg tablets	Mild pain Directions: 1 or 2 as needed
50	Dihydrocodeine: DF118 30 mg tablets	Moderate pain Directions: 1 or 2, 4-6 hourly
20	Bupronorphine:Temgesic 0.2 mg tablets	Severe pain Directions: 1 or 2, 6-8-hourly placed under tongue
2 tubes	Transvasin, 30 g tubes	Analgesic balm Directions: apply to skin over muscle, ligament sprains for symptomatic relief

(c) Antibiotics

84 (4 courses)	Amoxycillin 250 mgm tablets	All common infections Directions: 1 tablet 8-hourly for 7 days
or if allergic to Penicillin:		
80	Trimethoprim 200 mgm tablets	Directions: take 400 mgm 12-hourly for 5 days
56 (2 courses)	Cloxacillin	For deep wounds or severe infections Directions: 500 mgm 6-hourly for 7 days
or		
56 (2 courses)	Cephradine 250 mgm tablets	Directions: 250 mgm 6-hourly for 7 days

Note: People's opinion will vary greatly on which antibiotics to take. The above is my ideal; however, if one took Trimethoprim or Cephradine alone, this would cover most eventualities realistically.

60 (2 courses)	Metronidazole 400 mg tablets	For chronic diarrhoea Directions: 800 mgm 8-hourly for 5 days (only necessary for tropics with risks of amoebic dysentery and grantiosis.

Anti-malarials as necessary: check area

(d) Antisceptics

100 ml	Betadine paint	Apply to all minor cuts and grazes
	Antisceptic soap	
	Savlon sachets	(see General List)

(e) Anti-Allergy

30	Chlorpheniramine Piriton 4 mg tablets	for Allergic conditions to irritations, etc. Directions: 1 tablet 6-8-hourly as needed.

(f) Ears & Eyes

	Chloromycetin:	
5 ml	Eye drops 0.5%	for infections
5 ml	Ear drops 0.5%	Directions: use 1-2 drops 4-6-hourly
5 ml	Saline eye drops	Eye wash
5 ml	Amethocaine	Local anaesthetic to help remove foreign bodies
½ ml	Fluoresceine	eye examination:2

(g) Skin Conditions

	Caladryl Cream	(as Personal Kit)
	Tineafax foot powder	"
25 gm 2-3 tubes	Tineafax ointment	with above for fungal infections
1 tube	Amethocaine ointment	Useful for piles, sunburn to soothe
	Insect repellant of choice	

(h) Vitamins, Dextrose

Of choice, if need is felt

(i) Hypnotics, sedatives

10	Temazepam 10 mgm	For anxiety, sleeplessness if really needed Directions: 1-2 as needed

Additional Drugs; Equipment that might be needed for a major expedition with a doctor present. No quantities given as really a reference list.

General

Sphygmomanometer	Syringes, Hypodermic Needles
Needles	Butterflys
Haemocel solution	Dextrose/Saline solution
IV Giving Sets	Intravenous Cannula's
Suturing set: suture holders scissors, forceps	Sutures
	Surgical gloves
Tourniquet for venepuncture	Plaster rolls
Plaster shears	Velvand for underneath plaster
Splints for fractures } Stretcher } →	Useful anyway if available if first aid trained

Drugs

Antibiotics:	Benzyl-penicillin
for intravenous:	Cloxacillin
or intramuscular:	Cephradine
Analgesic	Bupronorphine : Temgesic Pentazocine : Fortral

Local Anaesthetics : Lignocaine 1% - 2%
Hydrocortisone Injection
Maxolon Injection
Adrenaline Injection
Dextrose 50% Injection
Aminophylline Injection

Emergency Kit : No Doctor

5	Gauze Dressings 5 x 5 cm
2 each	Wound dressings Medium/Large sizes
2 each	Melonin dressings 5 x 5 cm, 10 x 10 cm
2 each	Crepe bandages 5 cm and 10 cm
2 rolls	Adhesive tape
2-3 packets	Steristrips
	Packet of Savlon and Cotton Wool Balls
	Triangular bandage
10 tabls	Analgesic DF118 } for pain relief
10 tabls	Bupronorphine (Temgesic) } for pain relief
5	Stemetil tablets for sickness
	Scissors, safety pins

In addition if doctor present
(additional equipment to cope with major accident)

IV fluids and Giving Sets

Plaster and Velvand

Needles, syringes, injection swabs

IV drugs: Analgesic - Fortral, Temgesic
Antibiotics - Cloxacillin
Antisickness - Maxolon
Steroids/Shock - Hydrocortisone

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Transactions British Cave Research Association. Volume 11, no.3, November 1984.

LATERAL FACIES CHANGES, UNCONFORMITIES AND STRATIGRAPHIC REVERSALS: THEIR SIGNIFICANCE FOR CAVE SEDIMENT STRATIGRAPHY

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Abstract

Lateral facies changes, unconformities, and stratigraphic reversals must be recognised if the often complex stratigraphy of cave sediments is to be understood. The variety of depositional mechanisms operating in caves makes lateral facies changes common.

Primary Unconformities separate sequences of cave sediments from bedrock and are distinguished from secondary unconformities occurring within the sediments. Both types of unconformity may have a complex geometry and result in stratigraphic reversal. Erosion of soft sediments from under flowstone and indurated horizons may also result in stratigraphic reversal.

Considerable errors in stratigraphic interpretation will result if these particular characteristics are not recognized.

INTRODUCTION

The stratigraphy of cave sediments is often complex. This results from the variety of depositional environments that occurs in caves and the tendency for cave passages, once formed, to be the loci of a series of depositional and erosional events.

Pengelly (1864) recognised the surface origin of many clastic cave sediments and the existence of unconformable and reverse stratigraphic relationships within them. Summarising the palaeontological and archaeological approaches to cave sediments, Schmid (1963) and Sutcliffe (1976) both illustrate the importance of lateral facies changes.

In studies of cave sediments in New South Wales, Australia, Frank (1969, 1971, 1973, 1974 and 1975), Frank & Jennings (1978) and Osborne (1978) have identified lateral facies changes and stratigraphic reversals. Osborne (1983) recognised unconformities with complex geometry, lateral facies changes and stratigraphic reversals in the Cenozoic sequence in Wellington Caves, New South Wales and Osborne (1984) has described unconformities within sequences of cave sediments and palaeokarst deposits from a number of New South Wales localities. A clear understanding of the problems of unconformity and lateral facies change in cave sediments is found in studies by Goede & Murray (1977, 1979), Murray & Goede (1977), Goede, Murray & Harmon (1978), and Goede & Harmon (1978) of caves in Tasmania, Australia.

Stratigraphic studies of cave sediments in the Transvaal, South Africa, have resulted not only in the recognition of unconformities, lateral facies changes, and stratigraphic reversals but also in the formal stratigraphic definition of units of cave deposits. Significant contributions to this work have been made by Brain (1958, 1967), Butzer (1976), and Partridge (1973, 1978, 1979). A useful summary of this work has been provided by Kent (1980).

Stratified cave deposits have been significant sources of Quaternary and, in places, Tertiary fossils and archaeological material, and have the potential to reveal much about Cenozoic history. Reliable interpretation is not possible unless the complexity of cave deposits and the significance of lateral facies changes, unconformities, and stratigraphic reversals is fully realised.

THE COMPLEXITY OF CAVE DEPOSITS

Compared with many depositional environments, limestone caves are very small indeed. Even the world's largest caves have a volume only in the order of 2 to 3 km^3 (Jennings, 1971). Within these small volumes, however, a number of very different depositional processes may proceed contemporaneously resulting in a diversity of sediments being deposited in spatial and temporal proximity. It is this diversity of sedimentary processes, the action of both vadose and phreatic erosive forces, and the small size of caves that leads to the complexity of cave deposits.

To illustrate this point several types of deposits found in caves are shown in Fig. 1. It is important to realise that clastic and non-clastic sediments can be deposited in both vadose and phreatic environments. In Fig. 1 the phreas is a low energy environment and thus has laminated clays and turbidites deposited in it. In an epiphreas coarse fluviatile clastics would be deposited. Active vadose streams are not illustrated in Fig. 1, but such streams may be both erosive and depositional, behaving much like surface streams.

The presence of dissolved carbonate in cave waters not only results in the deposition of many non-clastic sediments but is also responsible for the cementation of most cave clastics. As with other diagenetic environments both vadose and phreatic cementation may occur in cave sediments and this will contribute to the range of lithologies present.

The contribution of biological activity to deposition in caves is significant. Bioclastic deposits, particularly of bone, are common in caves as are deposits of guano. Both of these act as a source of phosphate which is a significant component of non-clastic deposits. Bacterial action also plays a role in the deposition of non-clastic cave deposits. Burrowing and bioturbation by infauna (Piearce, 1975) adds to the complexity of cave deposits.

The development of high initial dip is also an important feature of some cave deposits. This may develop in fine-grained sediment deposited on a sloping substrate, in entrance facies deposits (particularly those forming part of a talus cone), and in flowstone. High initial dip has been reported at Bungonia Caves, New South Wales, by Jennings et al (1972) and from caves in the south of Wales by Bull (1977). Bull has shown that laminated fine-grained sediments can remain stable on slopes in excess of 70°, and in some instances adhere to vertical surfaces. High initial dip can make the interpretation of palaeokarst deposits in folded rocks particularly difficult.

Fig. 1. Some types of cave sediments: A, stream deposit; B, laminated clay; C, turbidite fan; D, subaqueous precipitation deposit; E, floe calcite; F, spar crystals; G, speleothems; H, talus cone; I, guano; J, breakdown pile; K, entrance facies.

Fig. 2. Effects of lateral facies change on chronostratigraphy.

LATERAL FACIES CHANGES

In their application of the facies concept to cave deposits Kukla & Lozek (1958) recognised that both vertical and horizontal facies relationships occur within the cave environment. Kukla & Lozek's concept of an "entrance facies" and an "interior facies" was based on the recognition that the composition and depositional mode of sediments change with their distance from the cave entrance. These changes are clearly illustrated in hypothetical diagrams of cave deposits, for instance those of Kukla & Lozek (1958), Sutcliffe (1970), and Ford (1976), and in diagrams of sections through actual cave deposits such as those of Gillieson & Mountain (1981) and Hypr (1977).

Since few studies have attempted to correlate strata between localities within cave systems, only the local effects of lateral facies changes on stratigraphy have been considered From the extent of these changes it might be expected that correlation within a single cave or between adjacent caves would be almost impossible. Despite this some correlations have been achieved.

Brain (1958) in his study of the Makapan Limeworks in the Transvaal measured 11 profiles up to 180 m apart within the same cave deposit and was able to correlate between them by recognition of his "phases". Frank (1971) was able to correlate his "units" at Wellington Caves, New South Wales, between caves up to 60 m apart while Osborne (1978), working at Cliefden Caves, New South Wales, recognised the same unit in separate caves 1.5 m apart.

These apparently successful correlations should not be seen as reducing the importance of lateral facies changes in cave deposits. Only a few sequences of cave sediments have been studied in sufficient detail to allow lithostratigraphic correlation to be attempted, and where this has been successful the sediments involved have mostly been low energy phreatic deposits which would be expected to be laterally extensive. It should be remembered that both Frank's and Osborne's correlations are entirely lithostratigraphic and could be the result of similar deposits being produced in adjacent caves at quite different times. Osborne (1983) has suggested that this is the case with the correlations made by Frank (1971).

The effect of lateral facies changes on the chronostratigraphy of cave sediments is illustrated in Fig. 2. Fig. 2A shows a talus cone of entrance facies deposits slumping into still water and producing a fan. As the slumped sediment moves away from the shoreline (as a turbidity current) it is deposited progressively as slump breccia, disorganized conglomerate, organized conglomerate, graded bedded sand and finally as laminated silt and clay. The boundaries between these facies are diachronous, with the depositional surface forming a time line.

Fig. 2B shows the situation when the talus cone has enlarged and the fan prograded. As this process continues the facies boundaries become more horizontal although still remaining diachronous. The air/water interface now marks an important facies change between the subaerial talus cone facies and the subaqueous fan facies. In this simplified example it is assumed that the water level has remained constant and that no major redepositional events have taken place. Under such stable conditions the boundary between the cone and fan facies will be fairly horizontal.

In Fig. 2C deposition has continued and displaced the water with all of the area in question now being a site for entrance facies deposition. The facies boundaries are now almost horizontal and the time line towards the distal end of the deposit is also becoming horizontal.

Fig. 2D shows a lithostratigraphic column taken at "B". Although the entrance facies at "A" and "B" are lithologically equivalent, the entrance facies at "A" is a time equivalent of the laminated silt/clay facies which occurs at the base of the column at "B". It is thus possible for entrance facies deposits to range over the whole time span of deposition in a cave and yet be lithostratigraphically the highest unit.

Lateral facies changes must be taken into account in palaeontological and archaeological studies of cave deposits, otherwise incorrect correlations will occur.

UNCONFORMITIES

Recognition of unconformable relationships between strata is essential to the understanding of sequences of cave sediments. The types of exposure found in caves can often make it difficult to recognise the relationships between units. When considering the nature of unconformities between units within a sequence of cave sediments it is instructive to begin by examining the nature of the primary unconformity between the sequence of cave sediments as a whole and the enclosing bedrock.

1. Primary Unconformities.

A primary unconformity separates sequences of cave sediments from the enclosing bedrock. As can be seen in Fig. 3, the primary unconformity corresponds to the cave walls and floor. In Fig. 3A, the most common case, the unconformity is horizontal at the base of the sequence and then becomes vertical, cave sediments having a lateral relationship with bedrock. Fig. 3B illustrates a completely sediment-filled cave in cross-section. In this case the whole outline of the cave is an unconformity, and at the roof, sediments unconformably underlie bedrock.

Units in any part of a sequence of cave sediments may have a vertical unconformity (i.e. cave wall) between them and the bedrock, however, complex passage shapes, such as vadose canyons, can result in more than one unit having a horizontal primary unconformity. In Fig. 3C both the oldest unit, dashed, and the youngest unit, stippled, have a horizontal primary unconformity.

The exposure patterns of some primary unconformities from caves and palaeokarsts in New South Wales are shown in Plate 1.

Plate 1.

Primary unconformities in caves and palaeokarsts in New South Wales.

A. Primary unconformity exposed in quarry face at Mt Fairy, New South Wales.
B. Primary unconformity between ? Permian palaeokarst sandstone and Silurian limestone in surface exposure at Billy's Creek, New South Wales.
C. Primary unconformity showing tunnel outline exposed in cave wall. Wollondilly Cave, Wombeyan Caves, New South Wales. Lens cap 55 mm.

Plate 2.

Secondary unconformities exposed in New South Wales caves.

A. Secondary unconformity between graded-bedded bone-rich sandstone (older, left hand side) and partly cemented entrance facies (younger, right), boundary enhanced. Phosphate Mine, Wellington Caves, New South Wales. Rule 0.5 m.

B. Vertical secondary unconformity exposed in roof of tunnel. Older unit (light coloured) is on left. Bone Cave, Wellington Caves, New South Wales.

C. Primary and secondary unconformities exposed in wall of Main Cave, Timor Caves, New South Wales. "a", primary unconformity between bedrock and palaeokarst speleothem, "b" secondary unconformity between palaeokarst speleothem and recent flowstone. Pen 140 mm long.

D. Secondary unconformity between laminated clay (older unit, at top and behind) and gravel (younger unit, at bottom and in front). Bullio Cave, Wombeyan Caves, New South Wales. Scale 1 m.

2. Secondary Unconformities.

Unconformities can occur within sequences of cave sediments. It is important to realise that these unconformities are of quite a different level of significance from that of primary unconformities. To make this distinction clear, unconformities within sequences of cave sediments are described here as secondary unconformities.

Fig. 4 shows some of the types of secondary unconformity that can arise when deposition follows a period of erosion of cave sediments. The simplest form of secondary unconformity is a scour and fill structure as illustrated in Fig. 4A. Here a vadose channel has formed in older units and has been filled with sediments. Fig. 4B illustrates the effect of deposition in a channel eroded in sediments when the original cave is a vadose canyon. Of particular importance in this case is the vertical nature of the unconformity and the lateral relationship between units of different ages. In this example traces of the older unit remain in channel cuts. This will not always be the case.

Fig. 4C & D illustrate what occurs when erosion of cave deposits produces a tunnel rather than an open scour. This type of situation is particularly likely to occur if the original sediment is indurated or contains beds of flowstone (Pengelly, 1864). The new tunnels can have a variety of cross-sectional shapes and younger sediments can be introduced into tunnels at any level within the older strata, Fig. 4C & D.

Lack of conformity can also occur where deposition of horizontally stratified sediments follows a period of speleothem growth or wall coating. In Fig. 5A the cave has developed a wall coating as a result of flooding by a mineralizing solution. Lamination within the coating will be parallel to the wall surface while bedding in the younger clastic sediment will be horizontal. Unconformities between units of cave sediments need not represent significant breaks in deposition or periods of erosion. In Fig. 5B a clastic influx has occurred following a period of speleothem deposition. Once again, for most of the contact between the two deposits there is an unconformable boundary although deposition of the clastics may have directly followed, or been partly contemporaneous with, growth of the speleothem.

Brain (1967) noted that floor collapse in caves could result in unconformities similar to those illustrated in Fig. 4. He observed that undermining of a sediment-filled cave (by speleogenesis at a lower level) could cause its floor to collapse, leading to the production of a breakdown chamber within the sediment. Deposition of new sediments within this chamber would produce what he described as a "stratigraphic sandwich" with new deposits interlayered between layers of older sediment.

3. Exposure Patterns of Unconformities in Caves.

In the cases discussed above, the unconformity has been illustrated by diagrams showing cave passages in cross-section perpendicular to their long axes. Natural exposures in caves, and artificial exposures in excavations and mine passages, usually do not have this ideal orientation. It is necessary then to consider some alternative orientations of these structures.

Fig. 6 presents some of the structures illustrated in Fig. 4 viewed in longitudinal section rather than cross-section. Fig. 6A illustrates a longitudinal section through an unconformity such as that in Fig. 4A. In this profile ("1" in Fig. 4A) through the side of the deposit, the two units have a disconformable relationship that would not be as easy to recognise as the scour and fill relationship seen in Fig. 4A. A similar longitudinal section (4B, "1") through the sequence illustrated in Fig. 4B would not expose the younger unit at all.

Fig. 6B illustrates the longitudinal section that might occur at "2" in Fig. 4A. This could easily be interpreted as an interbedded sequence rather than as two unconformable units, as in fact is the case. In Fig. 6C the longitudinal section marked "1" on Fig. 4C is illustrated, while Fig. 6D is the section developed at "1" on Fig. 4D. These cases show how complex the "stratigraphic sandwich" may become.

In Fig. 7 a cave passage has developed along the surface of a secondary unconformity. An observer at point "x" would see a vertical boundary between the two units as is illustrated in Fig. 7B. A relationship of this type is found in the Bone Cave at Wellington Caves, New South Wales and is shown in Plate 2A.

Fig. 8 shows how an irregular original passage shape and an undercutting incision can produce a sloping secondary unconformity. If the areas within the dashed line were exposed in a passage, as in Fig. 8B the first unit could be misinterpreted as being the younger filling a space between the cave wall and the second unit.

Unconformities of these types have been recognised in New South Wales caves by Osborne (1983, 1984) and some of these are illustrated in Plate 2.

STRATIGRAPHIC REVERSALS

Stratigraphic reversal occurs when strata are found with younger beds apparently underlying older beds. In the case of cave sediments this usually means that the younger strata will be physically below older ones.

The formation of passages within cave sediments and their later infilling may result in the production of stratigraphic reversals within sequences of cave sediments. Stratigraphic reversals are most likely to occur if the original deposit contains indurated beds or layers of flowstone. Since layers of flowstone are resistant to erosion they can remain intact as false floors after underlying sediment has been eroded away. This was first recognised by Pengelly (1864).

How a reverse stratigraphic relationship can develop between two flowstone floors is illustrated in Fig. 9. Fig. 9A shows a sequence producing two false floors with normal stratigraphy. In "1" a layer of flowstone is deposited on top of a layer of soft sediment.

Fig. 3. Primary unconformities.

Fig. 4. Secondary unconformities. "1" & "2" are vertical sections illustrated in Fig. 6.

Fig. 5. Unconformities caused by initial dip.

Fig. 6.

Unconformities viewed in longitudinal section.

Fig. 7. Exposure of unconformity in tunnel.

Fig. 8. Exposure of unconformity in tunnel wall.

In "2" more soft sediment is deposited which is followed in "3" by the deposition of a second layer of flowstone. Erosion then cuts down through both flowstone layers to reveal two flowstone false floors in normal stratigraphic sequence.

In Fig. 9B a sequence of events producing reverse stratigraphy is illustrated. In "1" soft sediments are overlain by flowstone. The flowstone and the underlying sediment is then incised by an erosional event resulting in the situation depicted in "2". After further erosion another layer of flowstone is deposited, "3", then a further period of erosion results in the production of two false floors, the lower of which is younger than the upper.

It can be seen that if this process where to continue the stratigraphy of a single cave passage could become quite complex. Since beds of flowstone and other indurated sediments are common in sequences of cave sediments stratigraphic reversal may often occur without being recognised. In many cases radiometric dating of flowstone beds may be the only means of solving these problems.

IMPLICATIONS FOR INTERPRETATION

Lateral facies changes, unconformities, and stratigraphic reversals should be expected to occur frequently in sequences of cave sediments, yet they are not widely reported in the literature. If the stratigraphy of cave sediments is to be correctly interpreted it is vital that these types of relationships do not go unrecognised. Due to the types of exposure in which sequences of cave sediments are found it is often difficult to recognise the relationships between the various units. However, an awareness of the likely stratigraphic complexity of cave sediments among workers should lead to more reliable interpretations than have been available to date.

The progress made by both South African and Tasmanian workers clearly shows what can be achieved in the study of cave sediments if the complexity of cave sediments, lateral facies changes, unconformable relationships and stratigraphic reversals are taken into account.

Fig. 9. False flowstone floors.

ACKNOWLEDGMENTS

The ideas developed in this paper have resulted from the author's continuing studies of cave sediments and the geological history of caves and karst in the Department of Geology and Geophysics, University of Sydney. During the course of the work Dr. E. Frankel, Associate Professor B.D.Webby and, more recently, Associate Professor D.F.Branagan have assisted with both encouragement and criticism.

This paper owes much to the interest of the late Dr J.N.Jennings of the Research School of Pacific Studies, Australian National University, who made many helpful comments on the drafts.

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Revised MS Received 28th August, 1984.

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