BRITISH KARST RESEARCH EXPEDITION TO THE HIMALAYA

1970

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British Karst Research Expedition to the Himalaya 1970

FULL REPORT

Edited by

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Cover Photographs : *Upper* – Annapurna
Lower – Harpan River Cave

June 1971

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CONTENTS

EXPEDITION LOG

The idea for the expedition originated in 1968 when M. Herzog's book on the first ascent of Annapurna was found to mention a cave seen high on the flanks of this magnificent mountain. The geology of the area was subsequently checked and the extent of the limestone looked promising – but it was to take 18 months' preparation before the expedition could leave England to look at the karst (limestone solution topography) of the High Himalaya.

Members of the expedition gathered together and the aims were formulated – a broad scientific study of a selection of karst areas in the Himalaya. A small region in Nepal proved most promising, containing the massive limestone mountains of Dhaulagiri and Annapurna; a second region in Kashmir would also be studied in order to provide geomorphological variety and contrast. The first aim of the expedition was to be research, though we were all active cavers and had hopes of exploring any cave systems which we could discover, within the terms of studying all the components of the karst landscape. Consequently, caving equipment was packed beside our scientific apparatus and the piles of notebooks.

For a year preceding departure, all the members had work to do. Lengthy political negotiations were eventually successful, but the main task was gaining academic and commercial sponsorship and support. In this we were very lucky and we equipped, supplied and financed the expedition by generous assistance from over 150 firms, individuals and foundations.

Very early on we had decided to travel overland, for reasons of both economy and interest, and also to take only one large vehicle. Surprisingly the most suitable vehicle turned out to be a fire engine, which we bought ex-government and had to modify only very slightly.

OUTWARD JOURNEY

We left London on the evening of August 1st and caught the night boat from Dover to Zeebrugge. Almost immediately we were faced with a major crisis when two of our tyres burst in Germany, and we needed to buy four replacements, as they were evidently all perished. Following this a long, trouble-free drive through Europe brought us to Istanbul. Crossing the Bosphorous on a hot summer evening in a chaos of lights and activity, we bade farewell to Europe, set foot in Asia and felt that we were really on our way at last.

Pushing on through Ankara and heading for the Black Sea we gained fleeting impressions of Turkey – empty dry space, "biblical" villages, water buffalo wallowing in muddy pools, sunflowers, and the never-ending hoards of children that we were soon to take for granted. We drove along the rocky, heavily wooded Black Sea Coast to Trabzon where the route turns abruptly inland and we began a series of hot, dusty climbs on to the high deserts around Erzerum.

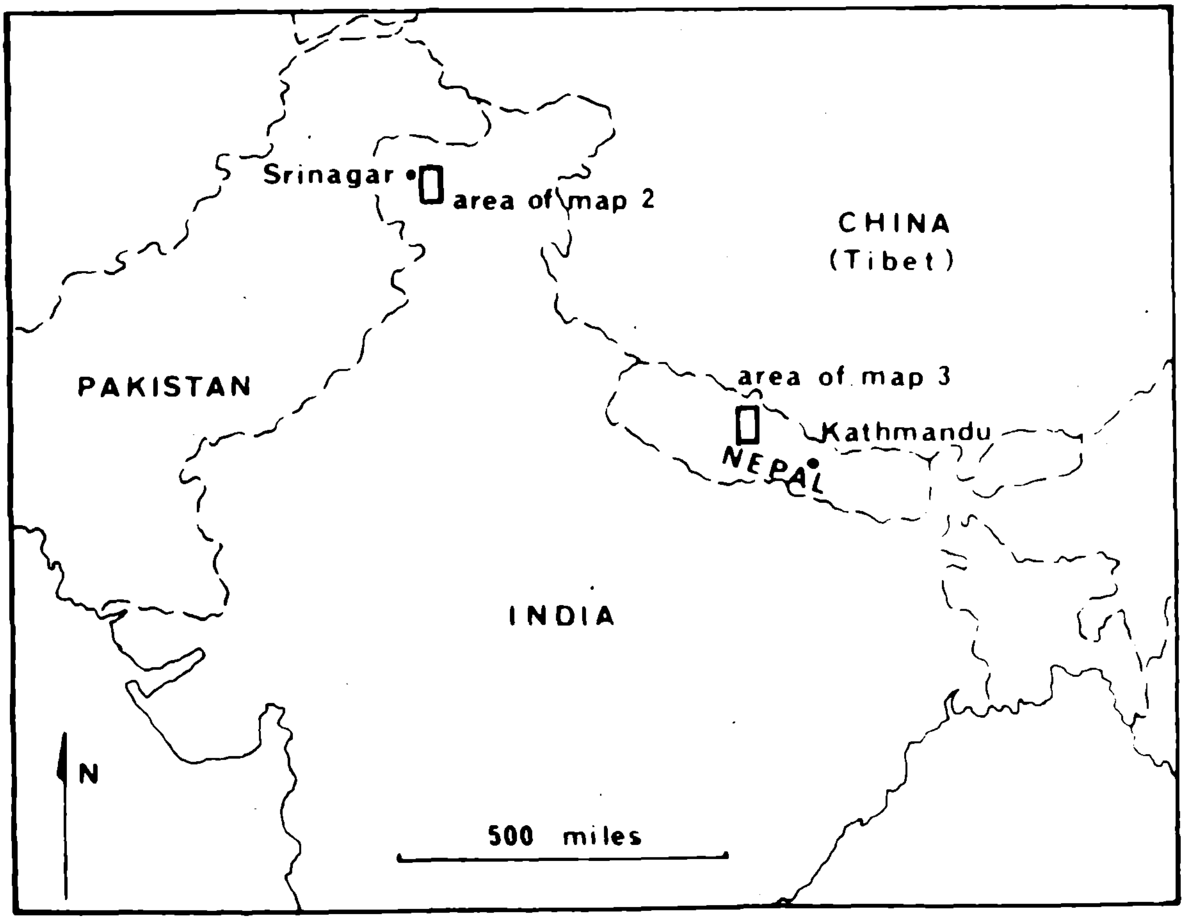
By this time our daily routine was well established. We would get up and begin driving at 4 a.m. and stop for breakfast as soon as we found a bakery that was open, usually sometime after seven. Except for the occasional break, we'd then aim to drive all day and would stop as soon as darkness fell. Our vehicle was well equipped with a spotlight that provided an adequately lit cooking arena. We were in bed by nine, rarely pitching tents and happily oblivious of mosquitoes and scorpions.

On August 12th our breakfast stop was close to the impressive snow capped volcano Mt. Ararat, but by mid-day we were in Iran, travelling along a good tarmac road through wide open desert. Cries of excitement greeted our first sighting of camels, and the discovery of some lava caves and tunnels near Tabriz provided a pleasant break for all and an energetic interlude for some. The next day we arrived in Tehran and were held up for 2½ days before our Afghan visas were issued. Leaving the city at last and heading north to the Caspian Sea we climbed over the 8000' Damovand Pass and traversed the Elburz Mountains via a series of spectacular gorges that funnelled us down to a busy humid plain, with the Caspian Sea a mere line of marshes in the distance.

Turning inland our road took us first into cool, cloudy mountains; "More like Dorset" said Geoff as we drove through a Wildlife Reserve and saw only sparrows and blackbirds. But later we saw the rollers and bee-eaters that the Turnbull brothers had promised and spent the night in a dried up river bed where Phil, Rog and Julian adjusted the gearbox.

No day was without event: in Mashhad we were chased out of the beautiful mosque that dominates the town. Reaching the Afghan border the next mid-day we were almost glad of the three hour hold up, spent waiting in cool stone buildings and in Herat the same evening, we became so absorbed in colourful Afghan coats that we didn't notice all the stickers being pinched from the lorry! Turning south, we had our hottest day (145° sun, 115° shade), reached Kandahar in an electric dust storm and were offered hashish, grapes and half-filled bottles of pseudo-Coca-Cola, in that order, on every street corner. There followed a night spent in the open desert, where a scorpion crawled into the coffee, and we awoke in the morning to find our camp engulfed in a sea of nomads – an endless camel train with a child on every hump. Kabul lived up to our expectation and we found it a colourful city of amazing contrasts. Not for the first time we wished we had five months to spend on the journey alone.

The road to the Pakistan border descends in a series of hair-raising loops, through 3000ft. down the spectacular Tangi Gharu Gorge. That evening we reached the frontier, found the customs post and the Khyber Pass closed, and an assemblage of Comex coach parties. Their leader proudly announced that 2 coaches were being allowed through that night but we met them still trying to get into Pakistan the next day, having spent the night in no-man's-land. We spent a few hours "defense spotting" as we drove over the dusty Khyber,



Location Map

Breakfast stop on the main road near Mount Ararat.

Looking up the Sind Valley toward Amarnath Peak.

then descended onto the sticky Indus Plain where flooded fields bore witness to the recent retreat of the monsoon. We stopped to drink sweet milky tea, sitting on wooden "beds" with parakeets flying overhead and the usual crowd of onlookers. After a brief halt in Lahore the following day, to pick up mail, we were at the border by 3 p.m. and drove into India just before 6 p.m.

Our immediate impression of poverty and crowds was emphasised next day, and on our return to India some weeks later. At Jullundur we made the mistake of trying to drive through the congested town. Several hours of traffic jam later we made a dignified retreat and drove round. Immediately a torrential downpour began. This, then, is the monsoon – 85°, 100% humidity, rivers bulging and roads flooded. At Jammu we gratefully paid 5p each to stay in a Dak bungalow, or resthouse. On August 26th we embarked on a pass crossing at 6200′ and joined a queue of lorries waiting to cross a baileybridge which was in the course of being erected to replace a collapsed bridge over a ravine. Another pass, and the Banihal Tunnel at 7200′ took us through the limestone we had come to see. With the light failing we rolled downhill into the Vale of Kashmir, over 6000 miles from London.

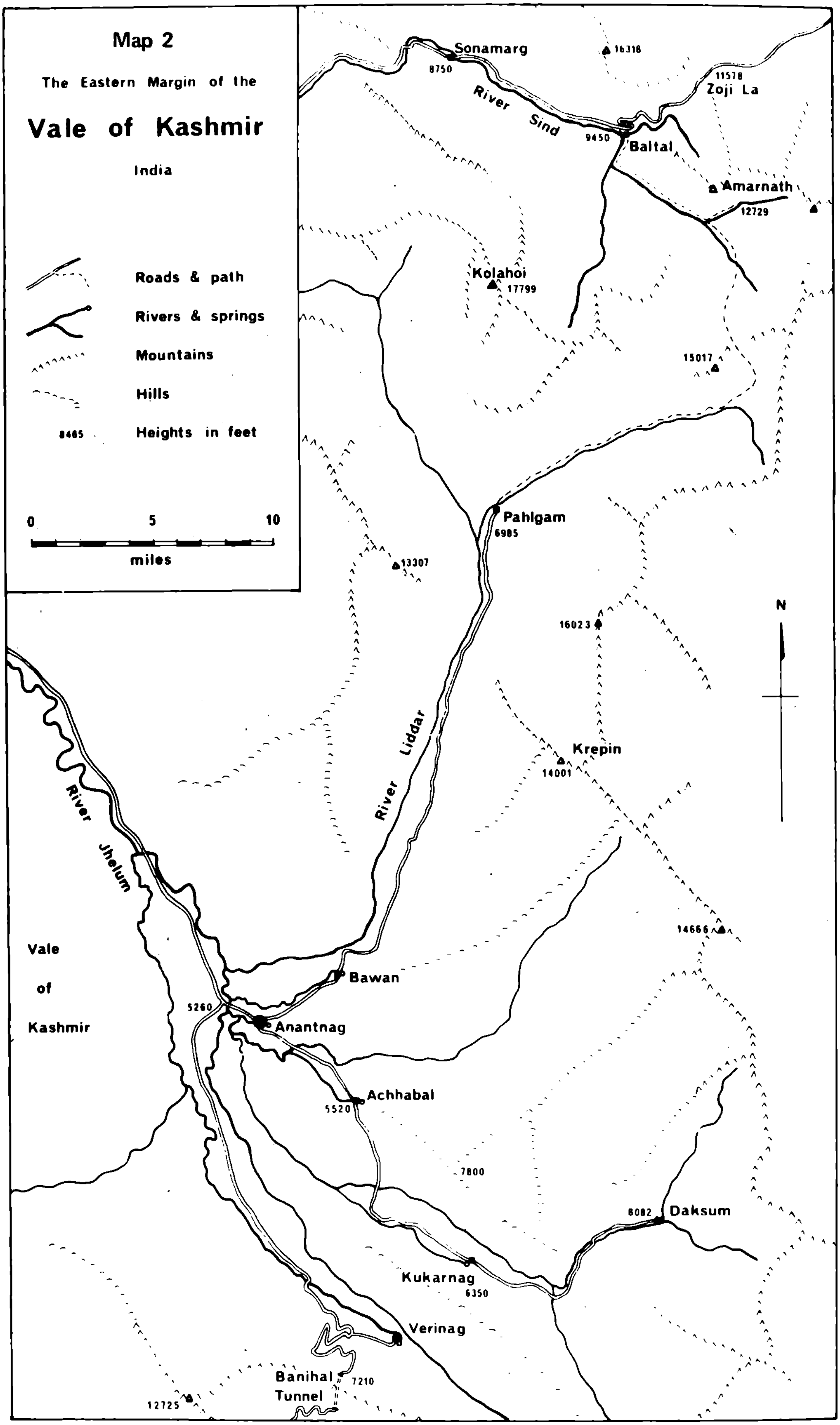
KASHMIR

On arriving in Kashmir, on August 26th, we headed for the capital, Srinagar, to undergo the necessary formalities before entering the Sind Valley. Later the same afternoon we drove up this spectacular valley, on a good road, into the limestone peaks around the settlements of Sonamarg and Baltal. The area is strictly controlled by the army and the guard at a military check post beyond Sonamarg refused access until the police gave their permission. The police, in turn, said the matter did not concern them!!! After much persuasion we were allowed up the valley and camped close to the Baltal army camp. The next morning, August 28th, we established a camp two miles downstream, on the banks of the River Sind, by a spring.

The weather was unstable; generally hot and sunny but with unpredictable storms. We decided to cover as much ground as possible, in small groups. Roger and Phil went in search of the famous Amarnath Cave but route finding was difficult, they were both unacclimatised and, even with a bivouac, they didn't reach the cave. Four weeks in the fire engine had left everyone unfit and needing a fair bit of walking to acclimatize. Keith, Roy and John embarked on a long slog up a ridge south of camp and Geoff, Julian and Roger climbed a high peak east of Baltal. The latter group found some choked shakeholes, but the only "caves" discovered were near camp and proved to be either rock shelters or snow bridges over the river. On the south side of the valley there was less karst but north of the camp Tony and Julian found a number of distinctive tower features. Later Tony reached the Zoji La and was able to locate and photograph a spectacular snow cave which is very likely the "hole" described by R. D. Leakey after he visited the area during the war. Finally, Keith, Roy, Julian and Mary set off for Amarnath. They found that the path is longer than the map would indicate but the first five miles is an easy walk along a good path. Further up the valley narrows and the path, which is not well travelled and very indistinct, crosses several miles of steep scree slope. Then follows a climb to a pony track which leads to the Amarnath stream and joins up with the main path from Pahlgam. The cave is two miles further on. It is a holy shrine with an imposing entrance but disappointing lack of cave development. The object of worship is an 18″ high ice stalagmite. Situated at 12,729′, the cave lies in a region of spectacular geological structures and glaciated mountains.

Realising that there was little hope of finding caves we went back down the valley to Manasbal Lake, where caves had been reported. Limited outcrops of limestone were found and a small cave exists, but the region contained nothing significant and so we drove back to Srinagar. We took time to look around the town and were impressed by both the miles of waterways with their jostling houseboats and the local craft products, carpets, wood carvings, papier maché work and silks.

The source of the River Jhelum was said to be a series of springs and on September 4th we set off to investigate them. At the 'spa' of Kukarnag we rented what seemed a palatial


Map 2
The Eastern Margin of the
Vale of Kashmir
India
Roads & path
Rivers & springs
Mountains
Hills
8465 Heights in feet
0 5 10
miles
N
Sonamarg
8750
16318
11578
Zoji La
River Sind
9450
Baltal
Amarnath
12729
Kolahoi
17799
15017
Pahlgam
6985
13307
16023
River Liddar
Krepin
14001
River Jhelum
Vale of Kashmir
14666
Bawan
5260
Anantnag
Achhabal
5520
7800
8082
Daksum
Kukarnag
6350
Verinag
Banihal Tunnel
7210
12725

wooden tourist bungalow with beds, a dining room and all "mod cons". The rats and centipedes weren't discovered until later! We were joined by Indian holic ay makers who had travelled to the area to "take the waters". The calcium rich springs were full of bathers each day and servants were despatched to remote springs to fetch water if it was suspected of having a slightly higher calcium content. Five villages nearby had grown up around springs which were marked by temples and elaborately laid out gardens with lakes and waterfalls. The springs drain into a rich plain with rice paddies and wide irrigation channels, quite sporting to cross. Between the valleys are bare limestone ridges rising 2000' above the plain and near Bhamajo a well known cave can be seen. Geoff was pleased with the bat colony there and he and Sue braved the stench to catch and examine the bats. Sections of the cave are obviously artificial tunnels but the main passage ends in a boulder choke that Rog tried unsuccessfully to dig his way through

A week was spent at Kukarnag and, except for interrupting bouts of dysentry, everyone was able to work on his own particular project. Our hut's garden was draped with mist nets each night in an attempt to catch bats for Geoff, and during the day to catch birds for Keith who was collecting specimens for the British Museum. Mary and Jan made a detailed study of the human and economic geography of Achhabal village and its hinterland, finding the local people both fascinating and friendly. The geologists scoured the area for the sinks which must feed the springs, and had no luck until September 9th when a sink was discovered in the river bank near a village called Adigam, ten miles from Achhabal. A large quantity of rhodamine B dye was duly tipped in and detectors were put in position at all the possible resurgences. Two days later we left Kukarnag and drove to Achhabal to say goodbye to all the friends we had made. The fire engine never stopped, for, as we reached the village a voice from the back of the cab said "Keep driving" and, looking to our right, we noticed the river was a delicate shade of burgundy!

Back in India we rapidly crossed hundreds of miles of plains and noticed the poor attempts at farming the Punjab. Then New Delhi, a highly westernised city with well planned roads, shopping precincts, and a concrete landscape, contrasting sharply with the intense poverty and crowded streets of Old Delhi. At Agra we were fortunate to see the splendid Taj Mahal by the light of a full moon on a warm, calm evening. As we neared Kanpur and the River Ganges we entered the land of rice-paddies, but found extensive flooding even on the main roads. This continued for the next two days but by a mixture of luck and judgement we managed to stay on the road and find green, if waterlogged campsites. We reached the border, at the small town of Nautanwa, on the evening of Friday, September 18th, and passed into Nepal, with the minimum delay at customs posts, the next day.

NEPAL

On entering Nepal we were greeted with the news that the last one hundred miles of our journey would be impossible by lorry. The road to Pokhara had been washed away in forty eight places and there was little chance of it being repaired that year. We sought the help of some British army officers at a nearby camp and, from the town of Bhairawa, were directed to Paklihawa, a retraining centre for Ghurkas which is run by Col. Langlands and his staff. The army gave us a warm reception, tea, baths, the Times to read and a pool to swim in. They also put us in touch with a Ghurka officer called Omnath who arranged for us to fly to Pokhara, with all our gear, even though all the planes were apparently booked up. So, on Monday September 21st, six of the group flew to Pokhara, with a ton of excess baggage on Geoff's ticket! The others stayed behind, repacking the fire engine, chasing a gun permit for Keith and finally leaving the vehicle in the capable hands of Col. Langlands' mechanics.

Pokhara more than lived up to our expectations, with the water buffalo grazing on the runway, the baked clay and thatched houses and the jostle of smiling faces peering from under huge black umbrellas in varying states of disrepair. At the Parbat Hotel we met Khagbir Pun, an ex-Ghurka officer who was to become our sirdar and good friend. Tony, Julian, Mary and

Jan stopped only briefly before flying on to Kathmandu where, over the course of the next three days they made contact with all the necessary authorities, did a rapid "Cooks tour" of all the sights on hired bicycles, met our two sherpas, Jangbu and Lakpa, and picked up some spare parts for the gear box which Mr. Bowser had kindly had flown out from England.

Eventually, on September 25th, the expedition began the "walk in". Most of the members, plus Khagbir and a line of 47 porters, left during the morning and were caught up by the same evening by the Kathmandu group, who had been delayed by lack of planes. Each porter carried a fibreboard box weighing 60lbs, and was paid the equivalent of 50p a day. The entire weight is carried on a woollen head band that passes across the forehead and the strain is taken by the neck. Despite their loads and the fact that most of them wore no shoes, the porters moved with an agility that the rest of us envied.

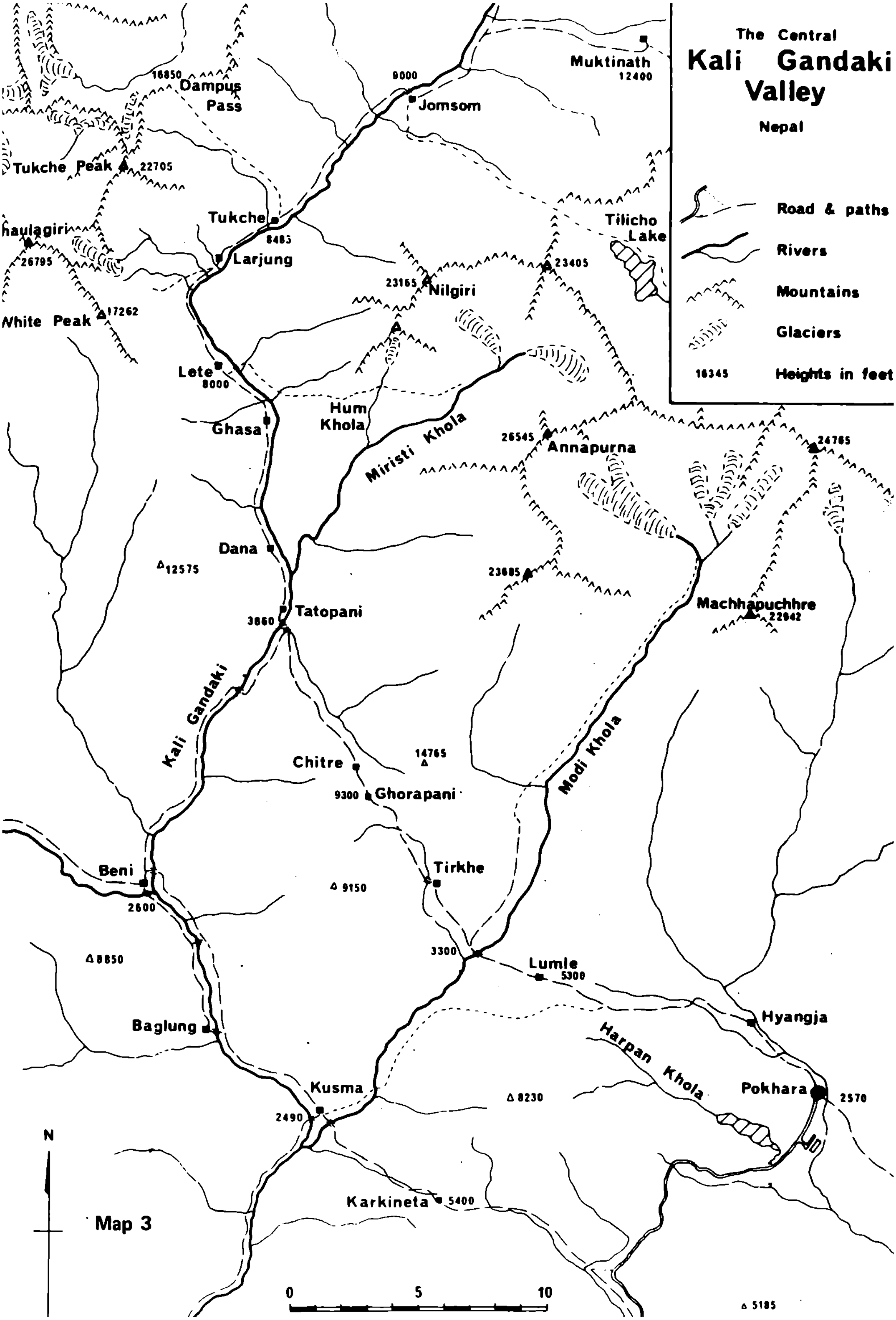
The seventy mile walk to base camp took seven and a half days and we were drenched more than once by the last efforts of the monsoon. The transition from one climatic zone to the next was very marked and, having suffered steep, slippery paths through leech-infested jungle on the first three days, we were glad to reach the valley of the Kali Gandaki and begin following it north into an 'alpine' region of pines and fir trees. The days assumed a quite definite pattern. We would break camp by nine, carrying little but cameras, anoraks and chocolate. The day's walk was punctuated by a number of stops at tea-shops where we drank glasses of strong tea and ate potatoes baked in their jackets, dipped in fresh ground chilli powder. The night's campsite would be reached by two or three, the tents put up, and a meal cooked before darkness fell. Khagbir and the porters slept in nearby villages and seemed to know everyone along the route.

From Pokhara, then, we walked via Hyangja, climbed to Naudanda where our passports were checked and camped below Lumle. Then down to the Modi Khola and via Birethante and the valley of the Bhurungdi River to the foot of a steep climb to Tirkhe Junga and a hot, sticky campsite. The next morning was clear but the mountains too far away for us to see any peaks. The path climbed all day to the Ghorapani Pass at 9300' and then dropped down to Chitre. That evening we watched the clouds lift to expose the snow capped peaks of the Nilgiri and, crossing the final ridge, we reached the Kali Gandaki the next day and bathed our feet in the hot springs that give the village of Tatopani ("hot water") its name. On the morning of September 30th we left the school yard that had been our campsite and followed the river northwards to Dana and another passport check. Still keeping to the west bank of the river we traversed a succession of landslides and took the spectacular path to Ghasa. Khagbir had told us of a recent landslip in the village itself and when we walked through the next morning we found the place devastated by a river of mud and rubble. From Lete, a few hours later, we had impressive views of the mountains; Dhaulagiri to the west and Annapurna and Nilgiri to the east. The scale of these peaks was impossible to appreciate and it was only when we began to climb their flanks a few weeks later that we realised how vast they are. Our campsite that night was unusual to say the least since the only flat area available was the well sprung roof of a house at Kalopani.

The next day we walked up the wide gravel floored valley, sometimes wading streams but often being forced to climb high above the river. By mid-day we had reached the village of Tukche, and congregated on the village green while a campsite was located, the porters paid off and contact made with the head man in the village. He, Mongal Singh turned out to be both the Lama and doctor and gave us access to a room in the village hall that was to become our kitchen, sold us everything we needed and bought all our leftovers some six weeks later. So we reluctantly said goodbye to Khagbir and the porters and watched them set off for Pokhara.

TUKCHE

Our immediate plans were to cover as much of the surrounding mountains as possible via a series of reconnaissance trips. Two parties left early the next day, one to walk north to


The Central
Kali Gandaki
Valley
Nepal
Road & paths
Rivers
Mountains
Glaciers
16345 Heights in feet
Muktinath
12400
Dampus
Pass
16850
9000
Jomsom
Tukche Peak 22705
Tukche
8483
Tilicho
Lake
haulagiri
26795
Larjung
23405
23165
Nilgiri
White Peak
17262
Lete
8000
Hum
Khola
Ghasa
Miristi Khola
26545
Annapurna
24785
Dana
12575
23685
Machhapuchhre
22942
Tatopani
3860
Kali Gandaki
Modi Khola
14765
Chitre
9300
Ghorapani
Beni
2600
Tirkhe
9150
8850
3300
Lumle
5300
Hyangja
Baglung
Harpan Khola
Kusma
2490
8230
Pokhara
2570
N
Karkineta
5400
Map 3
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5
10
5185

Jomsom and the other to try and reach the Dampus Pass, north of Dhaulagiri. Tony, Phil, Jangbu, Mary and Jan walked up the main valley past a new agricultural experimental station to Marpha and entered a zone of arid, treeless slopes in the rainshadow of the main mountain range. The skeleton of an aeroplane of the King's flight showed us where the airport runway ended and we walked along its length to a series of military checkposts where the authorities stopped us going further up the valley, but offered to send a policeman to fetch rock samples if we indicated which mountains we were interested in! The next day, while Geoff and Lakpa investigated the lower slopes of Nilgiri and the Dampus Pass party climbed endless shale screes in thick mist, to a height of 16,000', the Jomsom police were kept busy following Tony, Phil and Jan as they climbed the slopes around the town.

On October 3rd the party reassembled in Tukche, Julian, Rog, Keith and Roy having been beaten back from the Dampus by blizzards and altitude sickness. It became necessary to leave a permanent guard in camp as odd personal possessions began to disappear. Mary and Jan began their village study, John and Sue went to Jomsom and helped Geoff to hunt "bugs" on the river terraces behind Tukche.

On October 6th Julian and John entertained the locals by fording the Kali Gandaki but found only a rock shelter on the opposite bank. Meanwhile Tony and Jan had followed the Dambush Khola beyond its gorge section to a valley flanked with thick bamboo. The next day a group left Tukche to find a route onto the Dhaulagiri Meadows, a series of limestone benches at 12-13,000ft, where we hoped to establish a permanent camp. The route was far from obvious and, despite Lakpa's incredible capacity for route finding, he, John and Tony were forced to retreat from a steep shoulder which gave no access to the Meadows. The next day Julian and Mary, and later Tony and Jan, climbed to the Tukche Yak Pastures, finding no caves but brilliant blue gentians, shy yaks and splendid views of the mountains. Later Geoff, Julian and Lakpa went up a ravine south of Chini and found some small risings.

Back in Tukche the locals had been talking about some spectacular caves at Kursangmo and an optimistic party set off with ladder, rope and goon suits. Phil filmed Tony climbing into a very small hole at the head of a pitch, directly under a powerful waterfall. Inside there was a small, well decorated cave with pure white flowstone and an alternative dry entrance that facilitated later photographic trips by Rog and Phil.

By this time a second group, of Keith, Roy, Rog and Jangbu, had established a route up to the Dhaulagiri Meadows by crossing the Ghattekhola and climbing a wooded spur that leads to the yak pastures above. Although the track is good and easy to follow, the climb is steep and long. A camp was set up at 12,100' on a ledge close to a spring, surrounded by limestone outcrops and commanding superb views of the entire region. The camp was occupied continuously for the next fifteen days. Everyone spent some time there, plodding up the track, rucsacs laden with food and supplies. In the morning we would wait for the sun to rise behind Annapurna before venturing out to cook breakfast. A nearby shepherd and his son came to watch us cook and eat and claimed all empty tins. They showed a great deal of interest in all our equipment and laughed when we donned extra layers of clothes after sunset. The evenings and nights were bitterly cold and, unlike the shepherd in his sandals and blanket, we needed duvets and good sleeping bags to keep warm. After watching the setting sun turn the Annapurna Himal pink and orange we would take to the tents to begin the usual restless night. We needed sleeping tablets at this altitude but, even then, were woken by repeated avalanches on Dhaulagiri and creakings from the enormous ice fall that terminated three thousand feet above us. A large area of limestone was studied from this camp, extending up onto the south east shoulder of Dhaulagiri and White Peak at 17,262'. The parties that climbed this peak set up temporary camps at between 14 and 15,000', on the snow line. At this altitude the problem of sleeplessness was more noticeable but everyone was surprisingly fit and well acclimatized, having been to Kashmir and having taken adequate time to adjust to altitude in Nepal. On October 19th Keith, Tony and Roy followed an inclined slab of limestone to the summit of White Peak and, a week later, were followed by Julian, Mary and Rog. Tony, Geoff and

The path along the Kali Gandaki Valley, just south of Tukche, with Nilgiri on the right.

Dhaulagiri seen from a camp on the

Jan also climbed to the col between White Peak and Dhaulagiri but none of the parties found any caves. All the ascents were begun about 5 a.m. as the weather seemed to be following a definite pattern of clear mornings with cloud rolling in about mid-day, totally obliterating all views of the valley below. Unfortunately the mornings were cold, with the tents and zips frozen solid. The rest of the time was spent visiting the ice fall, water testing, filming a spectacular gorge and sampling yak milk, yoghurt and cheese which we were able to buy from the shepherds. With the aid of Keith's binoculars we could just pick out the Tukche camp, way below, and also saw other climbers, some miles away across the Meadows.

At this stage Julian and Mary returned from a successful trip to the Dampus Pass and Geoff and Phil left for Pokhara, having decided that some caves there warranted further investigation. Five days later John and Sue set off to join them, with Jangbu and three porters. Two of these were man and wife, each of whom carried a 60lb. load. Their nine year old daughter was given the job of carrying the baby; a practise we soon became accustomed to.

Our last hope for finding caves was the Miristi Khola valley and the approaches to Annapurna. Thus, on the day that John and Sue left they were accompanied as far as Lete by Keith, Roy, Tony and Jan and a rather colourful character called Kappa, who was their porter. The Miristi Khola party reached the valley of the Tangdung Khola that evening and spent a noisy, uncomfortable night on the shingle banks of the river. Early on the morning of October 25th they began a 6,000ft. ascent to Thulo Bugin, following the path taken by a reconnaisance party of Roy, Julian, John and Lakpa, who had been driven back by bad weather a fortnight before. After 3,000′ through dense bamboo jungle, on a steep slippery path made worse by bamboo "rollers" at every step, they climbed a steep grassy couloir, traversed below a series of cliffs and came out onto the meadows, above the tree line, by a shepherds camp. The tents were pitched beyond this and snow had to be melted before cooking the usual A.F.D. food that had become our diet. Kappa spent the night in Keith and Roy's tent and remained lifeless until the next day when Keith shot a grouse and Kappa rushed out to help cook it, before returning to Tukche. Tony and Jan set off immediately, crossing Herzog's Pass of April 27th at 14,200′ and dropping down to camp at 13,600′ near the Hum Khola. Keith and Roy spent all day crossing the Hum Khola Basin and camped in cloud on a second pass at 14,400′ that was again devoid of water. The spectacular gorge and resurgences of the Hum Khola were examined in detail and then everyone moved on to the Miristi Khola. While Keith and Roy made their way to the Annapurna Base Camp and ice fall, Tony and Jan visited Herzog's "cave" but were disappointed to discover it was precisely 12ft. long. They then returned to Tukche, passing en route, Rog, Julian and Lakpa, who followed the same route to the Miristi Khola but, in addition to low cloud and poor visibility, suffered continuous heavy snowfall.

POKHARA

On November 2nd we were all reassembled in Tukche and had decided to return to Pokhara immediately, to continue to search for caves. The old trading centre of Tukche had been a fascinating place to stay. The local people were friendly, inviting us into their teashops to try the local delicacy of "saltea". Teashop stops had become quite a feature of our lives and the Ghattekhola teashop was a regular port of call for people heading down the valley. Although trade between Nepal and Tibet has officially ceased, the Kali Gandaki is still used as a regular routeway for trekkers and Tibetan refugees most of whom called in to see us. One group of American Peace Corps. workers invited us to stay with them in the village of Beni and when two groups later walked out by an alternative route they were able to accept this offer. Tony and Jan, and later Rog, Julian and Mary, all walked out via Beni and Kusma in order to visit the well known Gupteswary Cave, a Hindu shrine that the King of Nepal had visited the year before. The cave was unique for many reasons, one of which being that the entire exploration had to be carried out in bare feet. Fortunately the cave was interesting, beautifully decorated and more than compensated for this minor discomfort! Meanwhile Khagbir, nineteen porters, Roy and Keith were following the normal route back to Pokhara. Everyone noticed changes from the walk in. Now the rivers were lower, paths were being repaired, poinsettias bloomed everywhere and oranges were almost literally ten a penny.

The attraction for us at Pokhara was the Harpan River which disappears into a deep sinkhole a few miles south of the town. This had first been visited on the days just before the walk-in to Tukche when Phil, Geoff, Rog and Keith had found it in full flood due to the monsoon. A ladder had been put down but Keith found a descent ridiculously impossible – the river was a rushing torrent 20 feet wide and 10 feet deep. Though the potential for caving looked doubtful a considerable bat population in the area aroused Geoff's interest.

Having returned early from Tukche, Phil and Geoff had first visited Mahendra's Cave, north of Pokhara, but found more bats in large cave chambers south of the Harpan River sink. Geoff and Jangbu spent many days in this area, catching and recording the bats, and Khagbir's back garden was used for the subsequent dissections. It was on November 9th that the last of the expedition arrived in Pokhara and some members then paid short visits by air to Kathmandu. However in the side of Geoff's bat caves were two open passages awaiting exploration.

Early on the morning of the 10th a large group set off to the Harpan River sink, situated just by the main road, with teashops adjacent. Geoff and Tony were the first to arrive and in an attempt to see down the shaft, 150 feet deep, the latter fell down it. Fortunately he discovered, by landing on it, a narrow ledge 20 feet down and then climbed out with the aid of a rope secured by Geoff. This afforded much amusement to the local populace who seemed to think that this was our normal mode of exploration. By then others had arrived and by partly laddering the sinkhole we realised a descent would be extremely difficult due to the amount of water. Consequently everyone climbed down into the deep jungle covered gorge, a quarter of a mile south of the sink, and clambered along to the entrance of the bat caves. Julian, Tony and Phil then looked into the unexplored passages and were pleasantly surprised to find large clean canal passages, mostly about 12 feet square containing pools of standing water, clear and warm, which made wading through them a delight. Having first found the link between Bat and West Chambers they waded along Canals Passage and arrived in the roomy Main Rift with the river thundering down a series of cascades from the sink. The Harpan River Cave had been discovered. The rest of the day was spent surveying and photographing and some large scale passages were left for later.

The same trio returned the next day to explore further while Geoff and Jangbu continued to catch bats in Bat Chamber. South Passage was traversed just once. Again a large and pleasant passage was found and Tony and Julian surveyed while Phil took photographs; then, at the end, Jungle Exit was found, conveniently near to the risings. Julian and Tony then looked at a passage in the roof of the Main Rift and discovered another entrance – Collapse Entrance – now the easiest way into the cave. Large logs found even in this high level passage testify to the effect of flooding; in the monsoon most of the passages flood, and all the time people were in the cave someone had to be stationed at the dam at Phewa Tal lake, a mile upstream, to ensure the sluice gates were not opened.

Phil had to leave for Bhairawa on the 12th and Julian and Tony had to spend most of the day on a surface survey. It was only late in the afternoon that they went to explore the main streamway downstream from the Main Rift. The passage floor was occupied by a deep lake with a strong current at the start, so, with the assistance of Geoff, Mary and Jan, they roped up and floated on lilos down to the final sump. In all over 4,500 feet of passage had been explored in the system. It was on this last day that Julian was chased across one of the deeper pools in the cave by a none too friendly snake. Also, on the very last visit to the cave, the spiders were found – great, hairy animals, 5 inches across, a group of which were resting on the walls of the Collapse Entrance, cooled by the breeze which blows through. As the passage was no more than two feet square at this point, it was a nerve-racking experience to enter or leave the cave.

RETURN JOURNEY

The departure date was fixed for Friday 13th November, a good day for travelling we thought, and John, Sue and Phil had already gone to Bhairawa to make ready the lorry for the long trek home. It was a reluctant departure from Pokhara as Julian, Mary, Rog, Geoff, Tony and Jan set off by plane and bus with the remainder of the gear, because we could have enjoyed longer searching for caves in the valley. The next day Keith and Roy flew in from Kathmandu and, for the first time since October 6th, all expedition members were in the same place at the same time.

The customs post was closed on the Saturday but we were into India early on the 15th, and, covering what seemed tremendous distances in a day, after our weeks of trekking, we drove past the dried out paddies to Delhi. It took a day for our Afghan visas to be issued and we were glad of an opportunity to see more of this fascinating city. The days were pleasantly warm but the nights bitterly cold and the sundeck soon lost its attraction. On the plateau of Afghanistan we needed duvets as soon as the sun sank and were loathe to rise before it in the frosty mornings. We soon came to admire the stamina of the desert nomads, with their thin blankets, bare feet and cumbersome black tents. "Frozen camels" weren't quite what we had expected after our sweltering journey out. Stops became infrequent. At Herat we admired the mosaic covered minarets and invested in elaborately embroidered sheepskin coats. Close to the border police patrols warned of bandit raids and once across we were twice stopped by the "Hashish Patrol".

In Iran we followed a southern route to Tehran across the Great Salt Desert. The monotony of the scenery was more than offset by the nature of the road, with its corrugations, pot-holes and clouds of dust. We were intrigued by the lines of shafts connecting ancient underground irrigation channels, and, belaying to the bumper of our fire engine, laddered a 60ft. shaft into one of these "canaats". Passing lorry drivers were obviously amused by our apparent efforts to draw water.

Countless stories of snow in Turkey proved to be unfounded. To our relief we only encountered much snow between Agri and Erzerum, and were able to cut straight through the mountains to Ankara, but in Sivas we were held up by festivities celebrating the end of a period of fasting called Ramadan.

Later the same day we unexpectedly drove into a region of gypsum karst around Imranli and Zara. Impressive dolines, sinks and a few caves suggested that the area would repay further examination. (Waltham, A.C., 1971, The gypsum karst of Zara, Turkey; Newsl. Cave Res. Gp. n.125, p.24).

From there the journey home was speedy, helped by a forced non-stop drive through Bulgaria which the authorities insisted on as there had been outbreaks of cholera in Turkey. It was generally agreed that we couldn't drive straight through Munich without visiting the Hofbrauhaus and a welcome evening was spent anticipating the celebrations when we got home.

Finally, we landed in England on December 8th, seven days ahead of schedule. The speedometer showed we had driven just over 14,000 miles, but, on top of this, most expedition members had walked well over 250 miles in Nepal alone. Before us was the prospect of clearing up and report writing but Christmas loomed large and, after locking up the fire engine at Dorrin Court, all went our separate ways. (J.M.W.)

SCIENTIFIC REPORTS

GEOLOGY OF THE LIMESTONES AROUND THE VALE OF KASHMIR

R. G. Turnbull & A. C. Waltham.

Geology of Kashmir

Kashmir lies near to the western end of the Himalayan Range, and its geology and structure reflect many features common to the rest of the Himalayas, as well as exhibiting their own particular characteristics. Essentially, the northward movement of Peninsular India has caused underthrusting of Kashmir by the Punjab Foreland along the Main Himalayan Boundary Fault (which is represented by two faults in Kashmir) (see fig. 4). To the north of these faults rises the highly folded Pir Panjal and Great Himalaya Ranges, between which a late phase of gentle downfolding has produced the synclinal Vale of Kashmir. In the Great Himalayan Range another huge thrust-fault brings forward great masses of metamorphic and igneous rocks which then lie above unmetamorphosed sediments and volcanics of the southern parts of this range. All these thrust-faults run parallel to the main trend of the Himalayan Range in this area, that is N.W.-S.E., and the strike of the rocks and the axes of the numerous folds also in general are oriented N.W.-S.E.. Hence Kashmir exhibits a structure with an orientation predominently parallel to the main trend of the Himalayas.

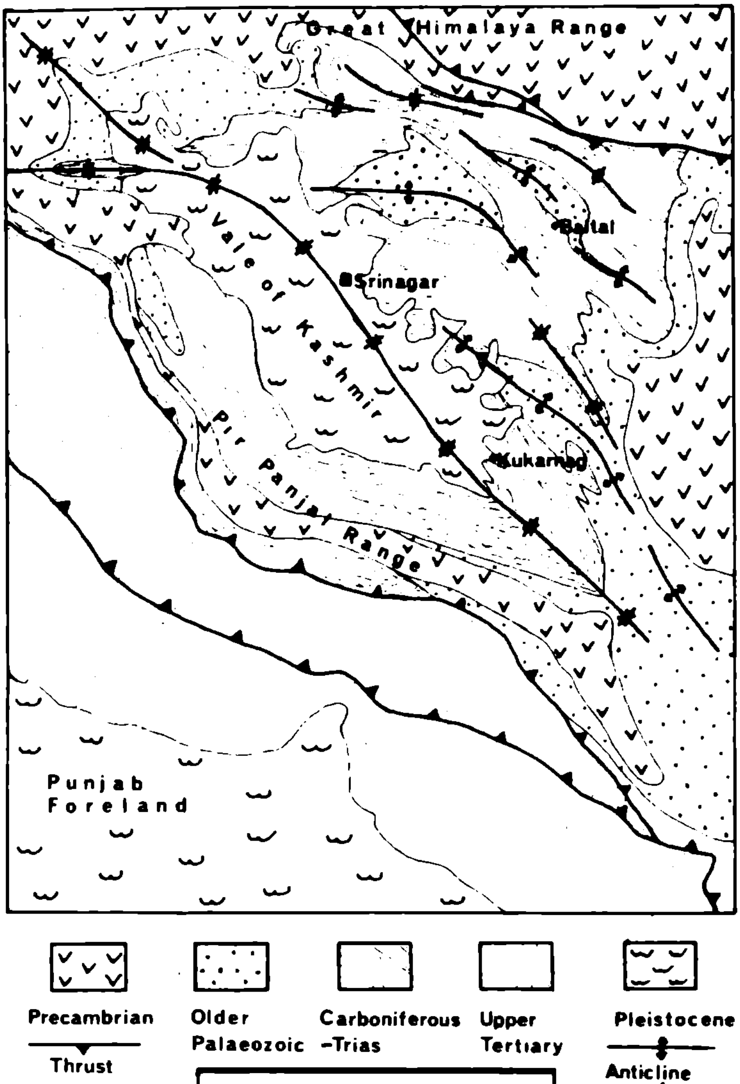
The Vale of Kashmir itself is an ovoid basin some 85 miles in length, caused by geologically recent gentle synclinal folding. Its floor is covered by Pleistocene lake and river sediments which are flat lying or only slightly inclined and which provide the rich agricultural land of Kashmir.

The much folded rocks which occur in the Pir Panjal and Great Himalaya Ranges near to the Vale of Kashmir consist of a well developed and relatively well studied sequence extending more or less continuously from the Pre-Cambrian through to the Jurassic. The Pre-Cambrian rocks consist mainly of moderately to strongly metamorphosed sediments and upon these lie a thick (c.6000ft.) sequence of un-metamorphosed greywackes, shales and thin limestones of the Older Palaeozoic, including the 1500ft. thick massive Muth quartzites of probable Devonian age. This fairly complete and conformable succession is suddenly interrupted by the Upper Carboniferous Gondwana Transgression, which, above a parallel unconformity, gives rise to a thick (up to 8000ft.) sequence of lava flows known as the Panjal Volcanics, which are interbedded with both marine sediments and with plant bearing beds which were deposited on land. By the end of the Palaeozoic most of this volcanic activity had ceased and the lava flows and associated sediments are overlain by a thick sequence of Triassic limestones. It is these limestones which were the main subject of our investigations in Kashmir and they were studied in two areas:— firstly in the upper part of the Sind Valley where a N.W.-S.E. oriented band of Trias is well exposed in rugged mountain country, and secondly at the eastern end of the Vale of Kashmir, where Trias is preserved in more gentle country near to the axis of the broad N.W.-S.E. oriented syncline that formed the Vale.

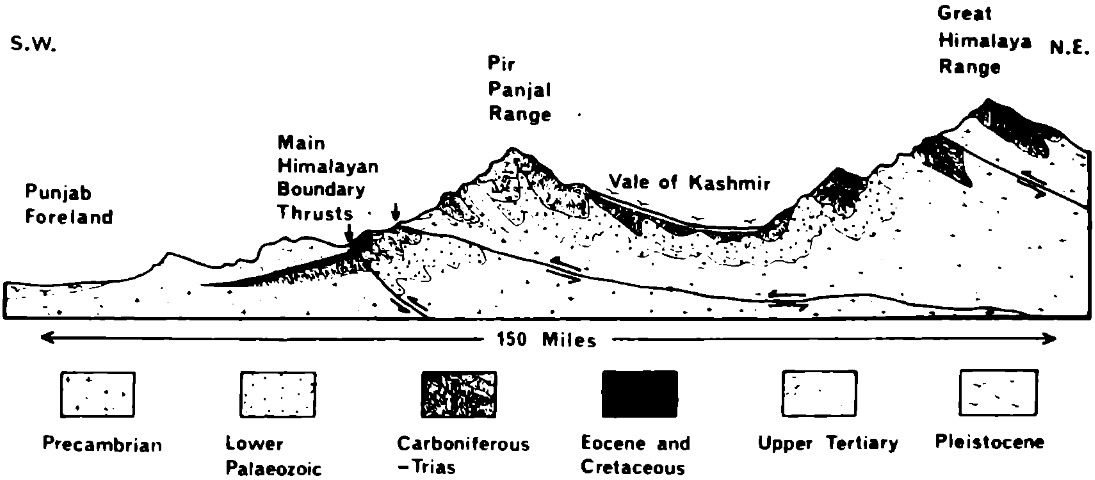
Upper Sind Valley

The structural geology of the Upper Sind Valley region, centered on the old village of Baltal, is extremely difficult to understand due to the tight multi-phase folding. Essentially the Triassic sequence forms a series of tight folds with east-west axes; dips are generally steep and nearly all greater than 60°, while vertical bedding is common and there is considerable overfolding. The folds are all strongly periclinal, with local axial plunges as steep as 60°; this is at least partly due to interference by a subordinate series of north-south folds.

Faulting appears to be minimal. The dominant jointing is along bedding planes, but there are also important systems of widely spaced conjugate joints which have resulted in impressive "sharks-teeth" profiles on many of the vertically bedded limestone slabs. The overall impression of the structural geology around Baltal is best presented by the form of the



Geological Map of Kashmir
(after Gansser 1964)



Diagrammatic section across the Kashmir Himalaya, showing the broad tectonic features.
(after Wadia 1953)

Figure 4. Geological Map and Section of Kashmir.

outcrop of the main limestone unit, which appears to indicate a refolded basinal pericline with its major axis east-west.

The topographically most important limestones form a single unit at least 2,000 feet thick, which, due to its complex structure and pattern of outcrop, forms all the high cliffs overlooking Baltal and also the high ridge continuing to Amarnath Peak and Cave. Most of this limestone is massive with beds about 15 feet thick and only poorly jointed, but its composition varies considerably. The few specimens collected had dolomite contents ranging between 10 and 75%, and some of the more dolomitic beds are extremely porous. Sampling was not adequate to indicate the regional importance of dolomite, but the high magnesium content of stream waters indicates a considerable proportion of dolomite in the limestones. The limestone texture is commonly a fairly pure, unfossiliferous mosaic with a grain size of 0·3 to 0·03 mm., and a common tonal banding in the white or grey rock is due to variation of grain size.

The most extensive exposed section in the Baltal region is stratigraphically downward from the massive limestone, to the Panjal Traps exposed on the Zoji La. The lower beds of the main limestone are interstratified with increasing thicknesses of pelitic material, and the boundary is only gradational into the next main unit. This consists of limestones, phyllites and subordinate sandstones all thinly bedded and including some thin breccia horizons while the limestone is less important lower down; the exposed thickness is well over 6,000 feet, but much of this may be due to isoclinal repeating of the succession. Below this is a further 1,000 feet of massive limestone, then 1,000 feet of phyllites and another 1,000 feet of thinly bedded limestone, which overlie a few hundred feet of hematitic ironstones forming the uppermost bed of the Panjal greenstones. All of these thicknesses are approximate and the ironstone crops out just north of the Zoji La in a band oriented NW-SE. Stratigraphically above the main limestone at Baltal, is at least 3,000 feet of phyllites and calc-schists, interbedded with subordinate pure or shaley limestones, and grading up into a purer pelitic succession.

Superficial deposits in the area are patchy and not very extensive. Thick alluvial cones have formed at the foot of most tributary valleys, and scree deposits occur at the base of most of the cliffs. Boulder clay occurs in many parts of the valley floors but true alluvium is only important in the Sind Valley downstream of Baltal where it also forms some thin terraces.

Vale of Kashmir

The solid basement to the Vale of Kashmir consists almost entirely of Triassic limestone, but, except round the margins, it is everywhere covered in thick Pleistocene sediments. The geology of the Vale was only observed at its eastern end, though the limestones at least are very similar in the Manasbal area, northwest of Srinagar.

Within the limits of the Vale, the Paleozoic and Triassic beds are strongly folded, though not as tightly as to the north and south. The structure in the Achhabal region is typical of the Vale (see figures 6 and 7). Dips generally range between 25° and 75°, though locally reach a vertical position, and overfolding is common in the high limestone ridge south of Verinag. Fold axes are oriented NW-SE and plunge only a few degrees to the northwest, but the axial planes hade at up to 30° to the north giving the structures a marked assymetry. No significant faulting or major joint patterns were observed in the limestones. The Pleistocene sediments are only very gently tilted to the northwest.

Prominent among the pre-Triassic rocks are the Panjal Traps whose light grey sandy tuffs and agglomerates form the high scarp of Krepin (see Map 2), though the beds immediately below the limestones consist of rather finer clastic sediments. The incredible abundance of fossils in the Carboniferous Fenestella Shale makes it also worthy of mention as it provides a stratigraphic marker very valuable in structural analysis of the area.

The full thickness of the Triassic limestone is never exposed but it almost certainly exceeds 3,000 feet (the sections in figure 7 can only be taken as approximate). The limestone is by no means pure and contains from 15 to 90% of dolomite, though no systematic chemical variation was detected in rather minimal sampling. It is generally a very fine carbonate mosaic of grain size commonly less than 0·01 mm, and contains small proportions of fossil fragments and, mainly ferruginous, insoluable grains. It is thin bedded, and thin shale partings occur in most bedding planes, rarely more than 5 feet apart. Horizons of shale and sandstone up to 20 feet thick are also common throughout the succession, and it is very likely that the thick sandstones in the synclinal core east of Bawan are not at the top of the limestone series, which appears to be much thicker and purer south of Verinag.

Resting unconformably on the Triassic limestones is the Pleistocene Karewa Series, now only exposed as remnant terraces projecting through the thick widespread cover of Recent alluvium. The Karewa beds are highly porous and permeable lacustrine sediments, mainly sandstones, but including important beds of loessic material and many alluvial cones round the margin of the Vale.

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KARST GEOMORPHOLOGY AROUND THE VALE OF KASHMIR

A. C. Waltham

Members of the expedition examined the limestone outcrops in two separate areas in and adjacent to the Vale of Kashmir (see map 2). Altitudes in the Anantnag region range from 5,300′ to 9,200′, while in the Baltal area the outcrops were followed from below 9,000′ to over 13,000′. The limestone is the same unit in each area, though significant geological features – steeper dips, tighter folding and a slightly higher metamorphic grade in the Baltal area, together with highly variable dolomite contents – make purely morphological comparisons between the two areas slightly suspect.

Surface Karst Features

Dolines or any form of closed depression are almost entirely lacking on the Kashmir limestones. A group of large shallow depressions are situated at over 12,000′ altitude on the ridge just east of Baltal, but they are floored by loose boulders and show no signs of engulfing any but the smallest flow of drip-water.

Karren forms show a distinct variation with altitude, being much more common within the Vale of Kashmir, though in both areas frost shattering is generally more important than solutional weathering. Around Baltal, karren are generally rare and the mainly steep surfaces of exposed limestone are only shattered and broken along joint lines, most spectacularly on the high "sharks-teeth" ridges. Scree slopes exist at the foot of most of the limestone cliffs, though some are grassed over and inactive, suggesting that relatively recent climatic changes may have lowered the extent of mechanical weathering, perhaps with a corresponding increase in solutional activity. Small rillenkarren are developed only locally in the Sind Valley area, the best examples occurring on loose blocks set in the valley soils. The largest karren forms occur on the north side of the Sind Valley at altitudes of 10,500′ to 11,500′. Massive wandkarren, with rounded runnels up to four feet across, are up to 100 feet long, straight down nearly vertical joint faces crossing a dip of about 60°. In places channels appear to have over-deepened and coalesced so that karst towers up to 50 feet high stand isolated from the main cliffs. The occurrence of these large karren suggests that they are a function of the steep dips, joints and topographic surfaces. Their ridges are extensively frost shattered but the main grooves have clean solutional surfaces indicating their present activity. In the same area overhanging surfaces commonly bear one of two solutional forms, either small pitting, with sharp hollows up to 5 mm. deep and wide, distributed independant of geology or micro-topography, or narrow but widely-spaced fluting formed by film-water.

At lower altitudes, in the Vale of Kashmir, both around Manasbal (north of Srinagar) and Anantnag, karren forms are much better developed though still never on a large scale. Pitting and rillenkarren are dominant, though fine examples of trittkarren and hohlenkarren were also observed, and the steep slabs of limestone bear no sign of solutional development. The karren is mainly developed on gently inclined joint surfaces which cut across the steeper bedding, and reveal a considerable variation of morphology from bed to bed; however a rather short sampling programme has not revealed any direct relationship between lithology and extent or type of karren.

Calcareous tufa is locally developed below a number of small seepage risings. The largest occurrence is in a tributary valley north of Nilagrar (midway between Baltal and Sonamarg), where large tufa banks up to 200 feet wide overhang the stream at the foot of very steep slopes. Lesser tufa development was also observed around small springs near to Baltal and on the hill south of Kukarnag.

Cave Development

Undoubtedly the best known cave in Kashmir is Amarnath Cave, situated at an altitude of 12,729′ in a tributary valley of the Upper Sind River (see separate section). However it is only a frost pocket, and is unfortunately typical of the minimal cave development around Baltal. Two other rock shelters just above Baltal have similarly been formed dominantly by frost action, with solution and groundwater seepage only playing subordinate roles in the process of excavation; in each case however variation in lithology of the beds, particularly the porosity, has been an important control in the location of the shelters. The only true solutional caves found in the Baltal area are two small phreatic tubes, each no more than 12 feet long and ending in very narrow joint rifts; both caves contain old stalagmite formations.

In contrast, the Vale of Kashmir itself does contain a number of solutional caves. By far the longest known is the Bhamajo Bat Cave, which has its entrance only a few yards from the main road half a mile north of Bawan spring. The passages in the cave are entirely phreatic, formed along series of nearly vertical joints, with the main rift running obliquely across the 28° dip (see survey). The passage morphology is classicly phreatic with an abundance of roof pendants, anastomosing channels and closed avens, the only vadose activity being some minor wall-fluting and very old, dead stalagmites. The floors are now mostly covered in mud, though varved sands occur locally, and the end of the main passage is blocked by boulders. Beside the joint control of cave plan, some passage profiles are influenced by thin shale horizons. The phreatic origins of the cave, and its present situation, perched above the Vale floor, clearly demonstrate that it was formed in an ancient topography before excavation of the present valleys and the subsequent infilling by the Vale sediments; it is certainly pre-Pleistocene.

A few hundred yards north of the Bat Cave, and in the same cliff face, is the Bhamajo Temple Cave. A single phreatic chamber partly lit by daylight has a Temple built inside it, and there are also some smaller rock shelters adjacent. At Manasbal, north of Srinagar, the limestone cliff overlooking the lake contains a single small cave – a narrow rift passage leads to a pitch down into a small chamber on a cross joint, barely beyond the reach of daylight; again it is a fossil phreatic cave.

No caves were found associated with the major underground drainage systems behind the five springs of the Anantnag area. The only known sink, at Adigam, is into impenetrable rifts, though the bedding planes contain numerous anastomosing channels. The risings are all choked by boulders and the temple foundations, and more promise is offered by a strong draught in a choked rift in the cliff just above the Achhabal spring; the end of Bhamajo Bat Cave similarly contains a slight draught. Furthermore, the dye tests proved a rapid flow from Adigam sink to the Achhabal spring, over a vertical drop of 790 feet, and it is quite probable that large vadose streamways exist under these limestone ridges, though the problems of entry seem too great at present.

Hydrology

By far the most important karst drainage systems in Kashmir are those behind the large springs in the Anantnag area at the head of the Vale, and these are described elsewhere in this report.

In the Baltal area groundwater circulation is far more restricted. Only two karst springs were found, one just over a mile south of Baltal at an altitude of 9,700′ and one just south of the Zoji La at 11,500′. Both occur in thin bands of limestone interbedded with phyllite, and in each case the water emerges from very narrow joint openings – the flow being only about 0·1 c.f.s. Dripwater in the rock shelters near Baltal is only in small quantities, but its analysis indicates the extend of solutional activity (see table 1).

No other springs, or sinks, were seen in the limestone, but there is a large amount of water circulating in and rising from the many alluvial fans on the valley sides. Most of the fragments forming these fan gravels are limestone, and consequently, the rising waters have a considerable content of carbonate in solution (see table 1). Unfortunately this does mask the very real possibility of karst water being added to the gravel groundwater where the bedrock is the massive limestone. A mixture of karst and gravel groundwater, which seeps through a thin

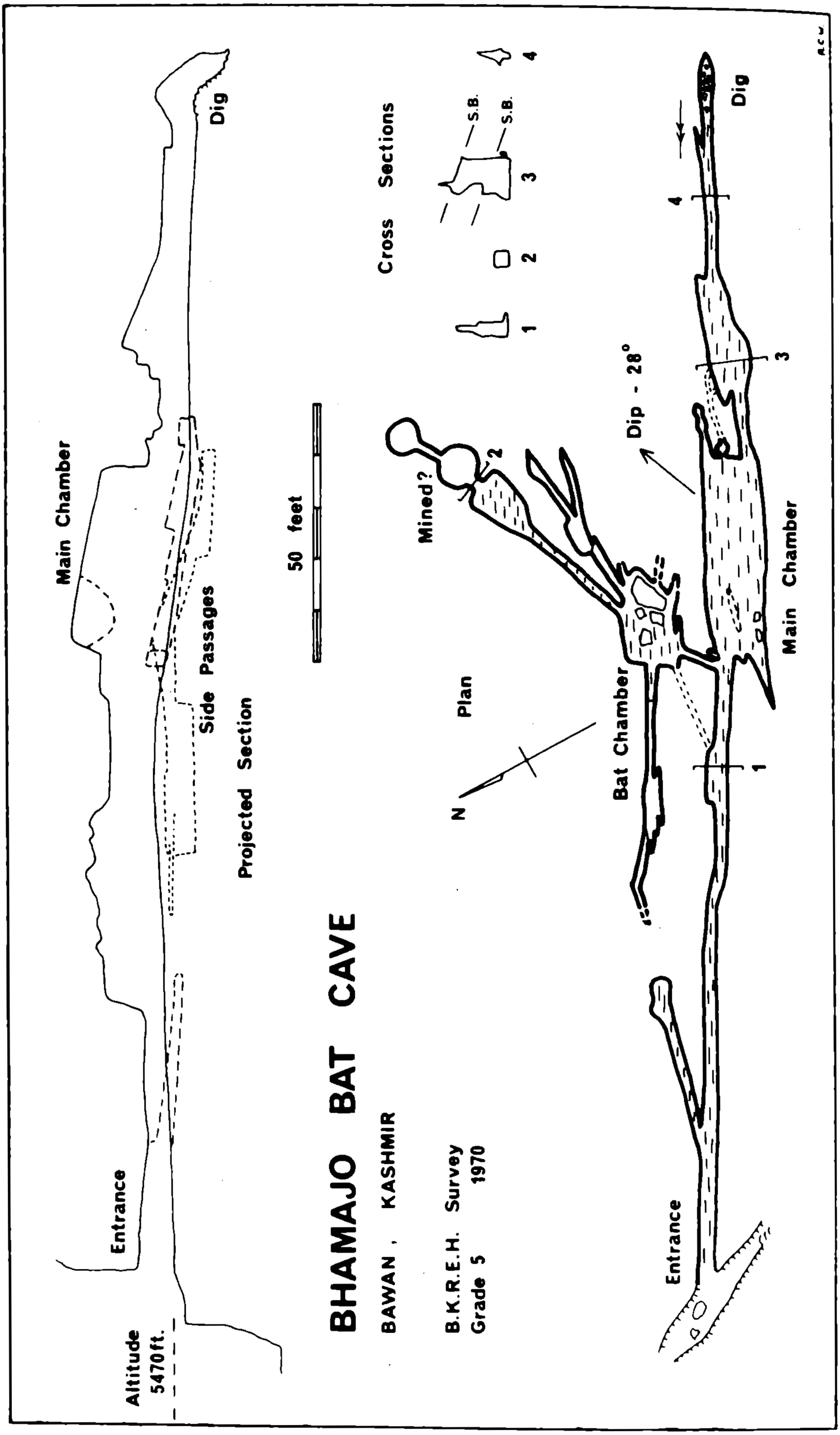

BHAMAJO BAT CAVE
BAWAN , KASHMIR
B.K.R.E.H. Survey 1970
Grade 5
Projected Section
Plan
Cross Sections
50 feet
Altitude 5470 ft.
Entrance
Side Passages
Main Chamber
Dig
Mined?
Bat Chamber
Dip - 28°
N
S.B.
1
2
3
4

Figure 5.

soil cover, appears to have formed the tufa banks in the Nilagrar tributary valley; field analysis of the surface water on the tufa showed a total hardness of 300 p.p.m. Two of the largest risings in the Baltal area are situated just above the river confluence a mile south of Baltal itself. Their very high hardnesses, and particularly the high sulphate contents, (see table 1) suggest that at least part of this spring water may be of deep-seated juvenile origins.

Location	Altitude Feet	pH	Ca^{2+} ppm	Mg^{2+} ppm	CO_3^{2-} ppm	HCO_3^- ppm	SO_4^{2-} ppm	Hardness ppm $CaCO_3$
Seepage, Baltal Cave	9500	6·8	40·4	24·2	25·2	150	–	198
Spring S. of Baltal	9600	6·3	86·2	42·0	–	138	144	383
Spring W. of Baltal	9400	6·4	47·1	24·2	5·0	130	–	214
River Sind, Baltal	9400	6·2	32·2	7·2	10·1	56·3	–	109

Table 1. Water analyses in the Baltal region (Analyst R. J. Bowser)

The regional hydrology around Baltal is typified by that of the River Sind itself. It has a considerable diurnal variation in flow, with a marked afternoon increase due to addition of meltwater provided by the heat of the sun. Analysis also indicated a diurnal variation in water chemistry, but sampling in the limited time available was not adequate to reveal any systematic relationships (the figures in table 1 are means). The high magnesium content reflects the dolomitic nature of most of the limestone.

Conclusion

Karst development in the Vale of Kashmir region is clearly restricted by the climate. The rainfall is nowhere more than 25 inches per year, but more important is the fact that for an average of three months per year in the Vale and about ten months per year in the mountains, the night temperatures fall below freezing point. Consequently mechanical weathering is important, and solution activity is restricted. This climatic variation must relate directly to the diminishing of karst development with increase in altitude.

Undoubtedly the karst is also restricted by the geological environment. Everywhere the dips are steep, which hinders large scale cavern development, and the high dolomite content of the limestones slows down the rate of solutional activity. Except behind the Vale of Kashmir springs, there seems little possibility of large caves existing in the area.

AMARNATH CAVE

J. M. H. Coward & R. G. Turnbull

On many maps of Kashmir, Amarnath Cave is prominantly marked as it is a famous Hindu shrine. The government organises a pilgrimage each year for the faithful, and, in June 1970, several thousand pilgrims set out on foot or horseback from Pahlgam to visit the cave. The round trip takes about ten days, and during a late blizzard in June several dozen ill prepared and ill equipped pilgrims died of exposure – the cave is situated at an altitude of 12,729' just below the snow covered mountain of the same name. Amarnath is also approachable through the military zone, where a shorter but more difficult path leaves the road at Baltal (see map 2).

This path to Amarnath Cave follows the upper part of the Sind Valley, through country mostly consisting of steeply inclined shales and siltstones and occasional thin limestones, striking generally E.-W. to N.W.-S.E. The cave itself is in the side of a small well glaciated valley joining the main Sind Valley from the north east. The lower part of this subsiduary valley is cut through the mainly shaley rocks already mentioned, but in the upper reaches a tightly synclinal band of limestones approximately ¼ ml. across occurs, and it is in these limestones that the Amarnath Cave is found. The axial plane of this syncline, with which are associated numerous spectacular minor folds, dips 20-30° to the west and the band of limestones thus produced forms a conspicuous feature extending N.N.W. and S.S.E. for some miles. Beyond the syncline the shales are again exposed near the head of the valley.

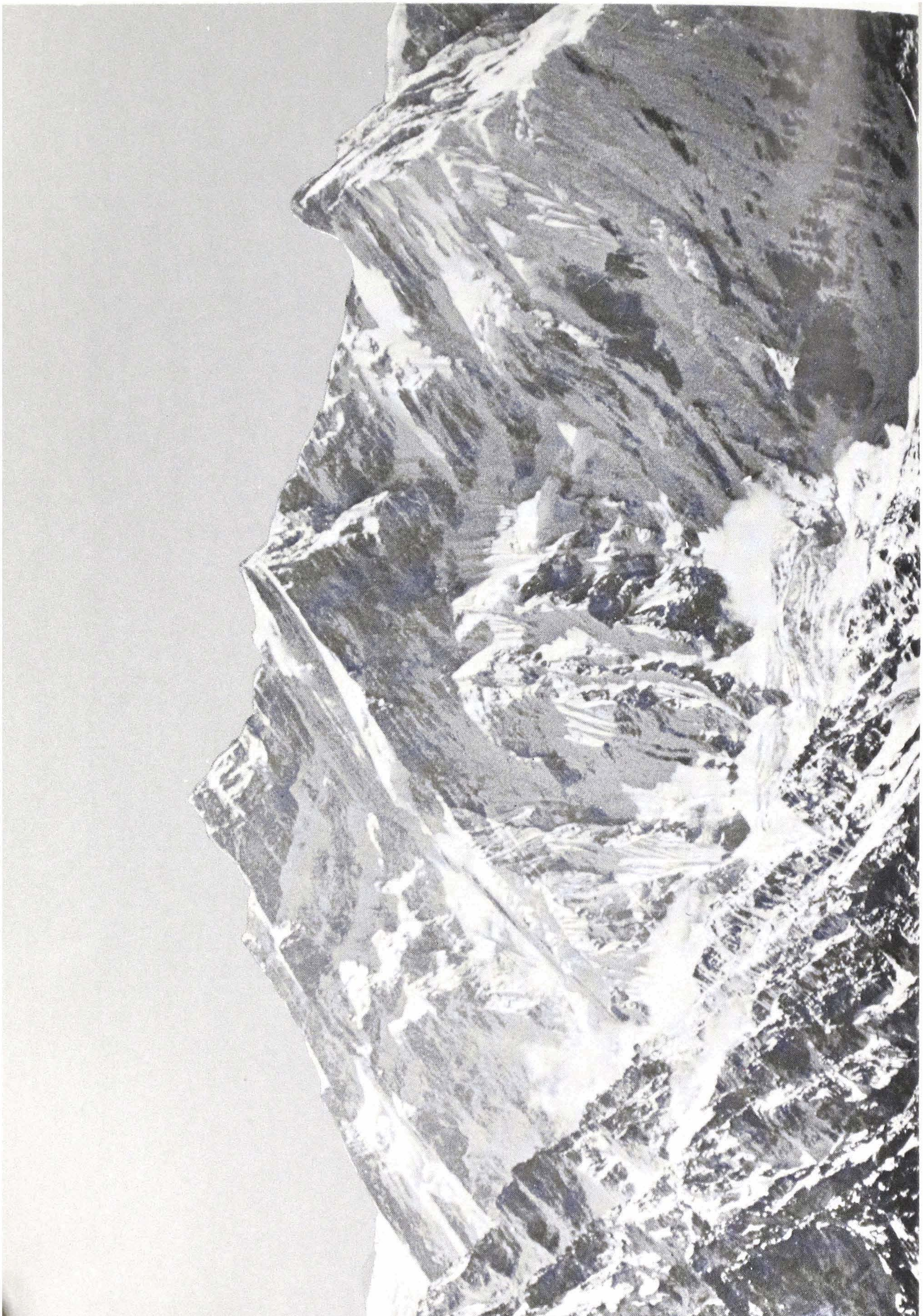
The lowermost limestones are a thinly bedded sequence some 100 ft. thick showing much minor folding, which is well exhibited by the resistance to weathering of certain thin bands. Above these a thick (c.50 ft.) bed of massive chalky limestone occurs, and where this, near the axis of the syncline, is for a short distance horizontal or only slightly inclined, the Amarnath Cave is found. Above this massive limestone more thinly bedded limestones, similar to the lowermost sequence, occur. As is to be expected none of these tightly folded and steeply inclined limestones show conspicuous jointing, and it is perhaps significant that the only development of any form of cave system found was at the only locality where a thick and massive limestone is horizontally inclined.

Amarnath Cave is a large frost pocket. It is about 300 feet above the valley floor, and the entrance is about 100ft. wide by 50ft. high, though the cave is only 50ft. long. The entrance has been gated (but was found unlocked) and inside a small chamber has been further gated off (again unlocked). In this chamber two ice stalagmites have grown, and in early September one had almost melted away and the other was about one foot high and six inches diameter, and covered in rotting marigold flowers. This phallic symbol is the focus of the Hindu devotion.

The cave shows some solutional features, and two small pools in the cave are fed by very small solution channels. However, the cave has mainly been opened out by frost action with the karst water only being important in that it permitted greater penetration of the mechanical weathering. Solutional activity is a subsequent development and the waters in the cave were found to have a hardness of 100 p.p.m. at 5°C. The hardness figure shows the initial carbon dioxide content of the water must be well above equilibrium atmospheric concentration (which gives an open system hardness of about 76 p.p.m.). Some enrichment of carbon dioxide is taking place in the thin soils.

Nearly two miles south of the cave several springs emerge near the floor of the Sind Valley. They are all small, with flows below 2 c.f.s. and the hardness varies from 130 to 200 p.p.m. at 5°C. Issuing from boulders and scree, it is doubtful if they contain much true karst water but most likely that they are just risings of water circulating only in the superficial deposits.

Amarnath Cave in the Upper Sind Valley.



KARST SPRINGS AT THE EASTERN END OF THE VALE OF KASHMIR

J. M. H. Coward

The expedition knew, before leaving England, that a group of large springs existed in the Anantnag area at the south eastern end of the Vale of Kashmir. Dr. O. N. Wakhlu, of the Civil Engineering Department at Srinagar University, confirmed that the springs did rise from limestone, and claimed that one, Kukarnag, "resurged from a cave that one can look into". Consequently we stopped for a week at Kukarnag, and after asking the local people and studying available maps, we found that there were five large springs in the area and that each one was considered holy by the Hindus. The springwater is also important economically, as it is used for irrigation, drinking and, at two springs, to feed trout hatcheries.

Kashmir is on the extreme western end of the N.E. monsoon belt. Srinagar (30 miles to the northwest of Anantnag) has an average annual rainfall of about 26 inches a year, half of which falls in January, February, March and April. November is the driest month with a precipitation of only 0·4 inches. Temperatures are cool, with a January average of 2°C, yearly average of 13°C and a July average of 25°C. During the five months from December to April, the precipitation exceeds the potential evaporation by about 11 inches, most of which goes to runoff. In the other months the potential evaporation exceeds the precipitation, but over the thin soils on limestone much of the heavy summer rains will runoff. The total runoff in limestone areas will probably be about 15 inches a year, with March having the greatest flow.

During our stay from September the 4th to the 13th 1970, we had two mornings of rain. Heavy rain of about 0·5 inches fell on the 4th, and 0·2 inches fell on the 9th. Otherwise it was fine with daytime temperatures reaching 30°C and falling to about 15°C at night. The average monthly rainfall in September is 1·4 inches and the average temperature is 20°C.

Description of the Springs

The springs are at the south-eastern end of the Vale of Kashmir (see figure 6). In this area the Vale is split into a series of broad, almost flat valleys, generally at about 5,500′ rising slightly to the south-east, and floored with alluvium. The valleys are extensively cultivated, as is the rest of the Vale, for rice growing and occasionally other crops. The hills are generally of Triassic Limestone rising to about 9,000 feet with a scant vegetation of scrubs and pine forest, but with much bedrock being exposed. The exposed limestone has produced very few surface karst features. The limestone was found to be dolomitic, but fairly clean, with a typical sample giving about 20% $MgCO_3$, 77% $CaCO_3$, and 3% insoluble.

All the springs have been extensively modified by man which makes detailed study difficult. At all the springs, except Kukarnag, Hindu temples, consisting of elaborate buildings and arches, have been built, which hide the original form of the resurgences. Most of these temples were started in the time of Emperor Jahangir, in the 15th Century, and so the local people do not know the type of resurgence, or the possibility of caves behind the springs.

Verinag, the source of the Jhelum River, appears to be the only true vauclusian resurgence, with the water rising from depth. The spring pool is about 200 feet in diameter, surrounded by an octangonal building, and reputed to be 57 feet deep. The water rises through the valley-side talus slopes and alluvium about 500 feet from the limestone hillside. At Bawan and Anantnag the spring is situated at the base of the limestone hillside, but the buildings hide the actual resurgences, and it seems possible that caves existed behind the springs. No entry could now be gained except by diving, and no caves were found in the neighbourhood of the springs. Diving with aqualungs in the Holy springs, surrounded by Holy carp and trout and many unholy children, would not be difficult as the Hindu priests can be surprisingly understanding.

At Achhabal the water issued from two places about 50 feet apart. The major outlet, carrying about 75% of the flow, leads past some gardens and temples, and a portion is led away for irrigation. The water has been channelled, and it seems likely that the outlet has been

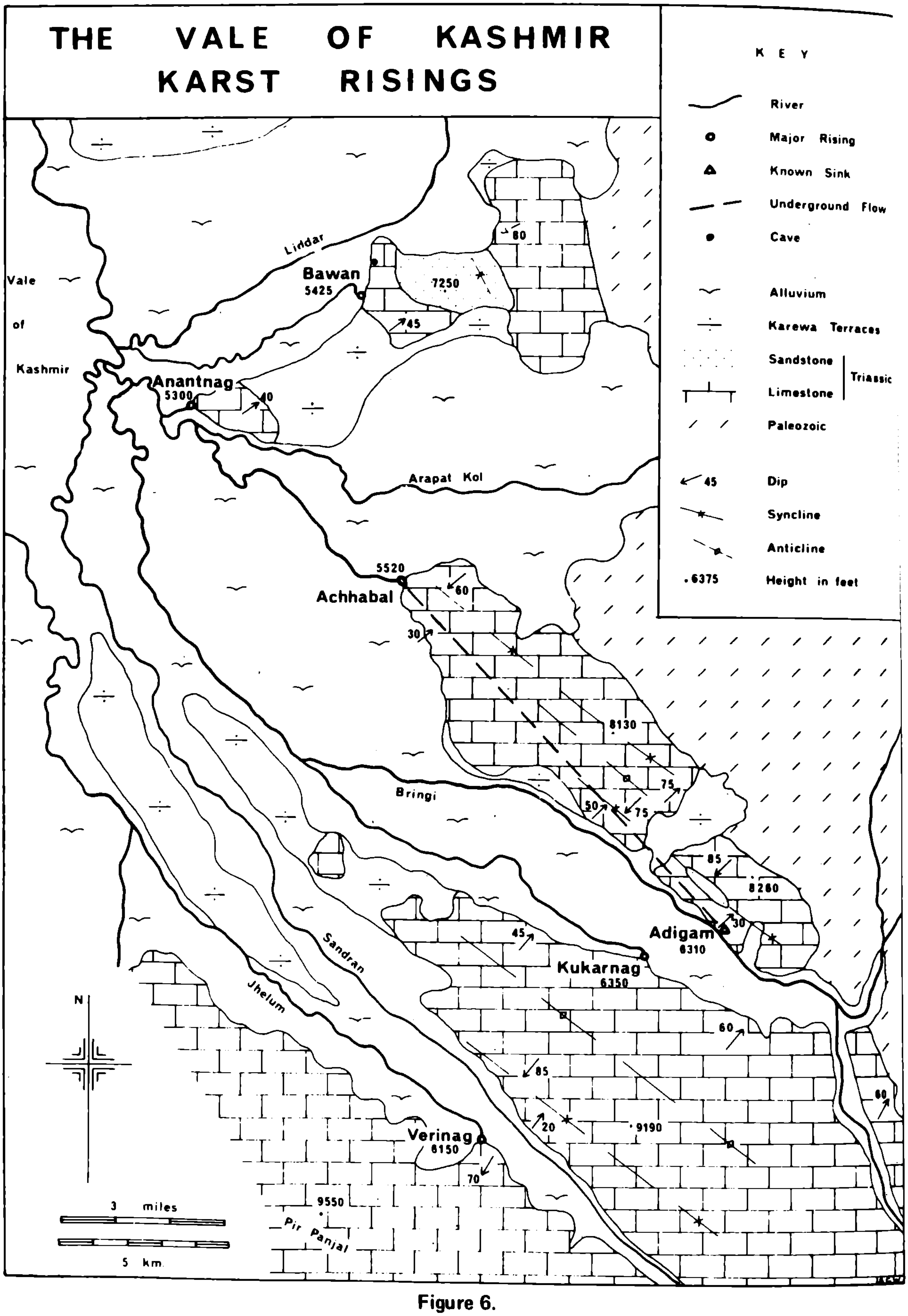

THE VALE OF KASHMIR
KARST RISINGS
KEY
River
Major Rising
Known Sink
Underground Flow
Cave
Alluvium
Karewa Terraces
Sandstone
Limestone
Triassic
Paleozoic
45 Dip
Syncline
Anticline
.6375 Height in feet
Liddar
Bawan
5425
7250
80
45
Vale
of
Kashmir
Anantnag
5300
40
Arapat Kol
5520
Achhabal
60
30
8130
Bringi
75
50
75
85
8260
Adigam
6310
30
45
Kukarnag
6350
Sandran
Jhelum
60
85
60
20
9190
Verinag
6150
70
9550
Pir Panjal
N
3 miles
5 km

Figure 6.

dammed up by several feet so that the flow can be more easily used for irrigation. The water can be seen to well up in a small pool, but some small openings can be felt underwater. Again diving might yield some cave. However a cave entrance was seen about ten feet above the spring, but it closes down within ten feet, and no sound of water can be heard from the cracks at the end of the cave. The smaller outlet of the spring, to the south of the gardens, is used to supply a trout farm. The water comes out of a natural cave resurgence about twenty feet wide and two feet high, which however sumps within ten feet, and even in low water the resurgence cannot be entered (pers. comm. A.B. Hamid, trout farm manager). The two rising points of the Achhabal spring seem connected, as the hardness and temperature are the same and changes in the irrigation sluices at the gardens affect the flow at the trout farm rising.

Kukarnag is a calcium spa. The water issues from several places along a 200 foot front at the base of the hillside, and is channelled through some gardens; part of the flow is used for another trout farm. Walkways have been constructed above and around the spring usually by piling up boulders which could well hide any former caves. As these walkways are a recent improvement, the cave that Dr. Wakhlu saw may well have existed a few years ago although no sign of caves may be seen now.

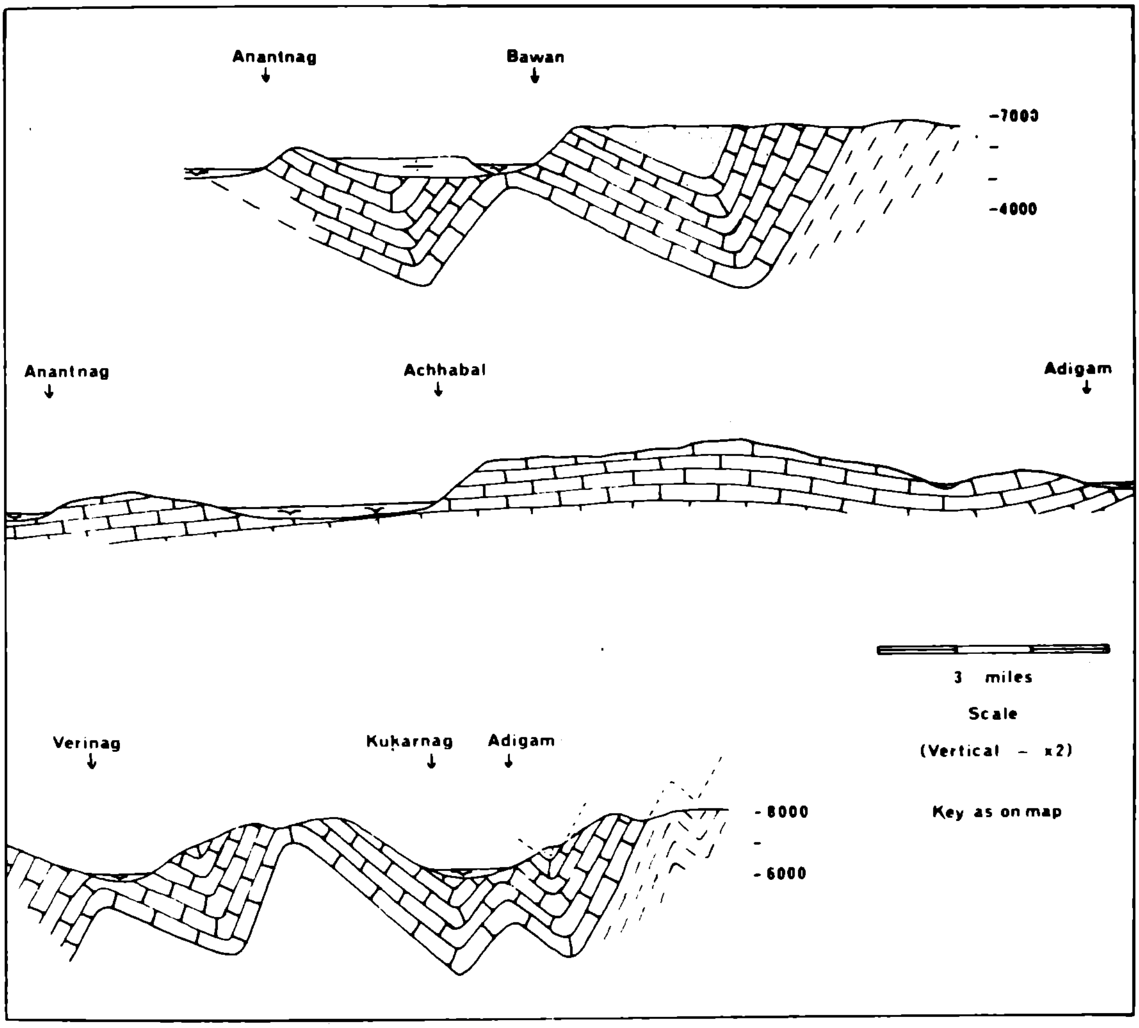


Figure 7. Diagrammatic geological cross sections in the Vale of Kashmir.

In spite of their detailed differences the five springs are similar in many respects. The geology, chemistry, and hydrology of each spring was investigated and the results are set out in table 2. As well as information on the five springs, details of the sink in the bank of the Bringi River at Adigam are included.

For table 2 the dip of the limestone and the dip direction relative to the normal out of the hill, were estimated (lines 1 and 2). Thus a dip direction of 180° indicated that the dip of the limestone beds is directly into the hillside, and away from the spring. The dips are from 30° to 65° at the springs and in each case the dip is into the hillside. Thus the springs rise up-dip, and it seems likely that any caves entered behind a spring would be water filled, running up dip.

No sign of any structural or lithologic control was seen for the spring positions. The springs are at the lowest hydrologic point in the limestone blocks, which suggests that the limestone is very well integrated.

The heights of the resurgences were measured on an aneroid altimeter, and averaged over at least two measurements at each site. The heights were corrected to the map height of Anantnag, and the relative heights are probably correct to within 10 feet. From the topographic maps and geological observations the areas of the immediate hinterland of limestone behind each spring, and the highest point of the hinterland were determined (lines 4 and 5, Table 2).

Water temperatures were measured several times at each site to 0·5°C and averaged. At Kukarnag, 8 measurements were taken with a 0·1°C thermometer over a period of three days. The water temperature was found to be consistantly lower, by 0·1°C, before noon than in the evening. This could be due to thermal pulses coming through from a sink with exactly a one, two or more day lag, or (more likely) due to local heating of the immediate spring area.

The temperatures of the springs relate fairly well to the heights of the springs, but a better fit can be obtained by comparing the highest point in the hinterland, which presumably supplies the springs, to the temperatures. Using this height, an eyeball fit gives a lapse rate of about 1·5°C drop in spring temperature, for every 1,000 foot rise in peak hinterland height. The Achhabal spring is about 2°C warmer than the hypothesis would suggest, while the other four springs are within 1°C of the theoretical temperature.

Discharges were estimated by timing twigs, and measuring channel dimensions, and seem reproducible to about 10% and are probably accurate to about 30%. The discharges at each spring were measured several times, and were constant except at Achhabal which ran at 50 cusecs on Sept. 4th., 60 cusecs on the 6th and 50 cusecs on both the 11th and 12th of September.. The turbidity was also noted, but only Achhabal and Kukarnag were appreciably muddy. Achhabal was cloudy on the 4th, very muddy on the 6th, cleared somewhat by the 11th and was very muddy again by the 12th. Heavy rains fell on the morning of the 4th (0·5 inches), and on the 9th (0·2 inches), and so it appears that the muddy runoff gets through to Achhabal in 2 to 3 days after rain, and heavy rains can increase the discharge within two days. Kukarnag was clear up to the 7th but became slightly turbid on the 8th onwards. This was possibly due to the rains on the 4th.

The springs were visited in September which is the end of the wet season. Mr. Hamid reported that the flow of Achhabal was the highest in March at about double the September flow and that the water fell to its lowest flow in October. He reported that the "old men" of Achhabal think the water comes from a village in the hills called Vardvun about 10 miles to the south-east. The village could not be located on present day maps, possibly because villages are usually differently named in English, Hindu, Urdu, and Kashmiri. Vardvun, however is not the village of Adigam. A very well informed unofficial guide at Verinag told us that the maximum flow there is "170 cusecs in May and June" and the minimum is "55 cusecs in November" while the present flow is "70 cusecs" (we measured 60 cusecs). Assuming the monthly flows vary smoothly the average annual flow for the springs would be about one and a half times the flows that we measured (table 2).

		Kukarnag	Verinag	Achhabal	Bawan	Anantnag	Adigam Sink
1.	Dip (°)	45	65	40	40	30	20
2.	Dip direction (°)	100	110	140	170	180	100
3.	Altitude (feet)	6350	6150	5520	5425	5300	6310
4.	Maximum height in hinterland (feet)	9466	10,000+	8773	8598	5886	–
5.	Area of limestone hinterland (sq. miles)	>40	>60	17	9·5	1·0	–
6.	Water temperature (°C)	13·1	12	17	15·5	18·5	19 (2.00 pm)
7.	Flow in September (cusecs)	40	60	50	30	8	–
8.	Turbidity	Cloudy	Clear	Muddy	Clear	Clear	Muddy
9.	Runoff by calculation (inches per year)	<20	<20	60	68	165	–
10.	Ca (ppm)	30·9	71·3	43·1	45·8	59·9	16·1
11.	Mg (ppm)	5·7	10·1	6·5	12·5	12·1	4·1
12.	HCO_3 (ppm)	96·1	197	124	164	215	58·7
13.	SO_4 (ppm)	11±9	0	0	0	0	10±19
14.	pH	6·4	7·0	6·6	6·8	6·9	6·2
15.	Ion balance (%)	5·3	15·6	14·0	10·6	6·3	-1·8
16.	Saturation Index	-1·86	-0·67	-1·33	-1·03	-0·65	-2·41
17.	Total hardness (as ppm $CaCO_3$)	103	219	135	165	201	57

Table 2. Geologic, Chemical and Hydrologic Data for the Vale of Kashmir Springs and Sink. (See text for explanation).

Hydrology

Except at Adigam, no sinks were found in the limestone hills, but the importance of allogenic water may be calculated by considering the capability of the limestone hinterlands to supply the whole flow of each spring. Knowing that 1 cusec represents 13·7 inches of runoff per square mile per year, one can calculate the runoff needed to supply the springs assuming that they are just supplied by the limestone areas in table 2. The runoff figures are given in table 2 assuming the average annual flow of the springs to be 50% greater than measured in September. As the rainfall is only 26 inches a year, other sources must supply at least part of the flow to the springs of Achhabal, Anantnag and Bawan. A large irrigation channel leads from the Liddar river onto the terraces between Anantnag and Bawan, and this was carrying about ten cusecs in September. Irrigation is carried on throughout the spring and summer, and so the excess water could well infiltrate through the terrace and partially supply the Anantnag Spring. The clarity of the Bawan water suggests that discrete sinks do not supply appreciable amounts of water, and recharge from the Paleozoic rocks (mainly sandstones) or leakage from the Achhabal limestone mass seems more probable. It is also possible that the limestone mass behind Bawan is larger than shown on the area map (fig. 6). At Achhabal however the muddy water suggests a discrete sink and, on searching the hinterland, a sink was noticed along the banks of the Bringi River near Adigam. Two small channels, carrying about 0·02 cusecs, were seen but the whole cliff over a 1,000 foot length could be taking water. The Bringi was flowing at about 200 cusecs, but lack of a current meter prevented accurate measurement of discharge above and below the cliff to determine the quantity of water sinking. However, many tens of cusecs could well sink into this cliff.

A dye test was carried out to determine the path of the sinking water. The sink was only found on the afternoon of September 10th, so 10 lbs of Rhodamine dye was inserted the same day. This quantity was calculated so that if it arrived at the most likely rising (Achhabal) and flowed out for two days, without absorption, it should just be at the visibility limit. Experience of water tracing in the karst of North America told us that a recovery rate of about one tenth of the theoretical amount of dye was usual, which would bring this test well below the visibility limit of about one part in 10^7. The dye is detected in these cases by absorbing it onto activated charcoal which can later be tested in a laboratory. The dye was inserted into one of the small Bringi sinks at 4.00 p.m. on September 10th. That night charcoal detectors were put into Kukarnag, Achhabal, Bawan, and Anantnag. As each spring was in a village we had trouble in hiding the detectors from the inquisitive children, and two were put below each spring. At Anantnag one was placed in the stream almost underneath an 'over-the-stream public convenience', and the lack of swimmers here helped save this detector. The detectors were changed on the afternoon of the 11th and 12th. One detector was left in the Achhabal spring and Mr. Hamid agreed to send this on to us in Kathmandu, after it had been in the water for a week.

On the morning of the 13th of September we had to leave Kashmir, and as we drove past Achhabal we noticed that the water from the spring was pink. This proved the test, and showed that the Bringi water flows to Achhabal. However as confirmation the nine detectors recovered were eluted with a 5% KOH solution in Methanol and the elutant tested on a Turner Fluorometer, model 111, using a Corning 1-60 and Wratten 58 primary filter, and a Wratton 23A secondary filter. The Turner Fluorometer has four ranges which gives the scale an effective length of about 3,000 divisions (in units of fluoresences, from which one can determine the dye concentration in the solution). Readings can be taken to less than a division, corresponding to a Rhodamine concentration of about one part in 10^{10} or one thousandth of visibility. All samples, except the last two Achhabal ones were within 3 divisions of each other and were considered to be background. The last Achhabal sample was, as may be expected, off scale at more than 3,000 divisions, and the second Achhabal sample gave a reading of 27 divisions.

This test showed that some of the Bringi water arrives at Achhabal within 48 hours, and the bulk of the water flows out from about 62 hours to 72 hours, as Mr. Hamid said that dye was only visible for one day. The fact that the dye was visible at all shows that very little absorption of dye took place, and the recovery was high, probably about 50%. The test showed that in 48 hours no Bringi water had flowed to Bawan, or Anantnag. A longer test, however, may prove a connection to either or both of these.

If we make several broad assumptions about the Achhabal aquifer we can infer some factors about the flow. We can calculate an aquifer configuration that would satisfy flow conditions by assuming that: a) the flow is entirely phreatic, and b) takes place entirely in bedding planes and joints of constant thickness (t) and total width (w), c) flow is laminar (see later), d) length of each flow path is constant as the straight line sink to rising distance (l) e) aquifer flow is 30 cusecs, (Q), f) the water sweeps out all of the aquifer in its flow of time (T - 65 hours).

Then the aquifer volume = QT = wtl, but: $Q = 30\ ft.^3/sec$
$T = 234{,}000$ secs.
$L = 44{,}200$ feet.

$$wt = \frac{30 \times 234{,}000}{44{,}200} = 158\ ft.^2$$

It can be shown that the flow between two large parallel plates of width w, separation t, viscosity v and hydraulic slope s, is:

$$Q = \frac{s.\,t^3.\,g\,.\,w}{12\,.\,v}$$

$$\text{thus } w^2 = \frac{s\,.\,(wt)^3\,.\,g}{12\,.\,v\,.\,Q}$$

but
$Q = 30\ ft.^3/sec$
$s = 790/44{,}200$
$g = 32\ ft./sec^2$
$wt = 158\ ft.^2$
$v = 1{\cdot}2 \times 10^{-5}\ ft.^2/sec.$ (at 17°C)

$$w^2 = \frac{790 \times 158^3 \times 32 \times 10^5}{44{,}200 \times 12 \times 1{\cdot}2 \times 30}\ ft.^2$$

$$= 5{\cdot}16 \times 10^8\ ft.^2$$

w = 22,500 ft. or about 4 miles

and t = 0·08 inches

The Reynolds Number is 120, indicating laminar flow. Thus for example 200 joints and bedding planes each 100 feet wide and 1/12 inch thick would satisfy the flow conditions.

Along the same lines, one can estimate the time needed to dissolve out this aquifer. The water enters the Adigam sink with a total measured ion concentration of 89 p.p.m. (Table 2), and leaves Achhabal with a concentration of 173 p.p.m. Much of the additional hardness at Achhabal must come from seepage water but if we assume that the concentration of the Bringi water increases by 10 p.p.m. and that the density of limestone is 2.8, then the 30 cusecs of Bringi water would generate the aquifer volume shown above in about 2,000 years.

Of course, the figures obtained for the time of generation and the aquifer dimensions could be very much in error, as many of the assumptions may prove untrue. For example, the measured flow conditions could be satisfied by a section of descending vadose stream cave, followed by phreatic flow through large passages; only further hydrological observations would permit useful estimation of the dimensions of such a compound system. However the figures quoted above do show that reasonable results can be obtained, if qualified by the necessary assumptions, and give at least a clue as to the pattern of karst development.

Chemical Results

500 cc samples of the water from each spring were taken and analysed by Roger

Bowser, within a day of collection. Unfortunately the pH was taken at analysis time and not at collection, so any changes in the CO_2 content in the water would affect the pH and so the saturation index. The figures for the ions, pH and Temperatures were run through a program written by T.M.L. Wigley (Dept. of Mech. Eng., University of Waterloo) to determine saturation indexes.

In table 2 the ions (lines 10-13) are expressed as ion ppm, the ion balance term expressed as Σ (equivalents) / Σ Mod (equivalents), and the saturation index as Log_{10} ($CaCO_{3\,actual}$ / $CaCO_{3\,max}$) where $CaCO_{3\,max}$ is the equilibrium amount of calcite that can dissolve in water at its pH and temperature. A sample with a saturation index of zero is fully saturated, and with a negative index is undersaturated. The samples were analysed by standard wet techniques, with errors on the ions generally at about ± 3% except for sulphate where the error is shown. pH was determined by papers within 0·2 units. Chlorides were determined, but always found to be zero. The HCO_3^- term includes CO_3^{--}.

Inspection of the results shows several points. All samples were undersaturated, the sinking water at Adigam more so than the others. It is surprising that the water leaves the springs still very aggressive, and capable of dissolving much more limestone. It is interesting to note that both Achhabal and Kukarnag are the softest spring waters, when they both appear to respond to rains by becoming murky, indicating fast flowthrough time. Verinag, which appears to be the only vauclusian spring is the hardest, and, with Anantnag, the least undersaturated. The calcium to magnesium ratio of the waters are higher than the calcium to magnesium ratio of the three rock samples taken in the region (Ca/Mg were 1·45, 1·65, 1·54). Selective solution of calcium seems to be taking place. The error involved in the sulphate determination unfortunately does not allow any inferences to be drawn from these figures. The ion balance term was always positive for the springs, indicating relative lack of negative ions. Nitrate was not analysed for and could be present resulting in an ionic inbalance. Small amounts of sulphate ion may not have been detected and could also be present to give the inbalance.

Conclusion

Ten days field work in the Vale of Kashmir have yielded considerable quantities of new and useful data concerning the karst springs of the Anantnag region.

At Verinag, which is unaffected by storms, discharges clear water, has its peak flow in May and June about two and a half months after the peak runoff in March, and has the hardest and least undersaturated waters, the flowthrough time must be slow, and the spring deepseated. The catchment of Verinag is probably the limestone hills to the south of the spring. At Kukarnag, the very soft cloudy water suggests that the flowthrough time is much faster, with possibly some discrete sinks in the catchment. The Anantnag spring must be partially supplied from other than its very small hinterland, possibly from the Achhabal aquifer, or from over-irrigation on the terraces above Anantnag. Bawan must also be partially supplied from other than its limestone hinterland, such as the Achhabal aquifer or from the Paleozoic rocks nearby, and the clarity of the water suggests ground-water recharge rather than sinking streams off these rocks.

At Achhabal, the muddy, warm, and relatively soft water with a very fast response time suggests that a sinking stream partially supplies the spring. The higher flow and cloudyness two or three days after rains, and peak flows in March, all suggest a very quick flow-through time, which was proved by the dye test. Calculations carried out after the dye test show that some sensible aquifer parameters can be derived, even though some of the assumptions that had to be made were very broad.

These five karst springs in Kashmir, although at first glance showing many similarities have very differing sources of water and types of recharge. The springs are fairly important now as sources of irrigation and drinking water, but their use will certainly increase as Kashmir develops.

GEOLOGY OF THE CENTRAL KALI GANDAKI VALLEY

A. C. Waltham

Due to the fact that it completely traverses the major structures of the Himalaya, the Kali Gandaki Valley has been the object of unusually extensive geological study; no other reasonably accessible area in Nepal includes a similar variety of geology.

The most prominent feature of the Valley's geology is its crossing of the outcrops of the main Paleozoic limestones, which form the highest of the mountains – Dhaulagiri, Nilgiri and Annapurna. The most valuable contribution to this part of the geology is by Bordet et al. (1967) who mapped in detail the area from Dhaulagiri to north of Muktinath. Hagen (1968) has described the Thakkola region, but the main mountain ranges were only on the flanks of his study area; he has described, in the same paper, the structure of the Dhaulagiri - Annapurna region, but working only from an aeroplane he omitted some important features. Various other works of less relevance to the limestone geology are summarised in Gansser (1964).

This report only describes the geology of the main Paleozoic limestones and immediately relevant rocks (see fig. 8). To the south of the limestones and Dhumpu Gneisses is a thick series of overthrusted low grade metamorphosed Paleozoic sediments, mainly pelites, which continue at least as far as Kusma, and beyond here are less folded very much younger sediments. North of Tukche are outcrops of a vast succession of strata, becoming younger to the north; around Jomsom the Jurassic beds include some thick limestones, and this series of younger rocks continues to the Pleistocene sediments of the Mustang basin.

Stratigraphy

The main bed of limestone, the Nilgiri Limestone, which formed the main object of study by the expedition, has been ascribed to the Cambrian and Ordovician by Bordet (1967), but also to the Devonian by Hagen (1968). Unfortunately it is almost completely unfossiliferous, but on structural grounds the earlier age appears to be the more likely.

Both above and below the limestones are sharp breaks to non-calcareous rocks. Stratigraphically lower and cropping out to the south are the Dhumpu gneisses, themselves many thousands of feet thick. Their lithology is spectacular; essentially acidic, they are mostly coarse grained often with a sugary texture, and include many zones of migmatite and pegmatite, the latter abounding in large crystals of hornblende, biotite, garnet and tourmaline. North of Tukche the limestone is followed by outcrops of Ordovician and Silurian metapelites. Brown and black slates are dominant, but they include horizons of higher grade schists, quartzites, marbles and calc-shists.

The Nilgiri Limestone is a massive unit about 8000 feet thick and considerably overfolded to give unbroken thicknesses of limestone in excess of 15,000 feet. The calcareous unit of the Lower Paleozoic was divided by Bordet (1967) into the Nilgiri Limestone and, beneath this, the Larjung Limestone, but there appears to be very little lithological difference between these two units, and apparently no structural break, so in this report they are together regarded as a single unit with the name of Nilgiri Limestone. Overall the limestone is not very pure, and most of it has been regionally metamorphosed so that there is now extensive development of biotite and quartz. It is, in many places, conspicuously banded with a dominance of impure biotite rich limestone containing bands, often sheared into lenses, of pure white limestone. The scale of banding varies from 0·1 to 50 inches. About 50% of the observed outcrops revealed this strongly banded variety, while an equal proportion showed a much finer, purer pale grey lithology. This is normally fairly massive, broken only by very thin pelitic bands, though locally it is very thin bedded. The summit of Annapurna is of the pure grey variety (examination of specimens collected by the Army Mountaineering Association, 1970). Other than these two dominant lithologies, local developments were also observed of very coarse grained, pure white limestone in the Miristi Khola valley, and extremely impure material from just north of Tukche which is better described as a calc-silicate marble.

From chemical analysis of five specimens (by R.J. Bowser) and microscopic examination of twelve, the lithology may be described as follows: Calcite content of the normal limestones ranges 62-80% but in the impure bands may be as low as 35%, and is locally more than 90%; dolomite is generally low, 5-8%, except in the impure bands where it may be over 20%; quartz and biotite are the dominant impurities averaging 15% and 5% respectively, and pyrite, epidote, chlorite and muscovite are also present – analysed insoluble contents range 15-34·5%; in many places the carbonate is very dark due to a significant iron content; the texture is normally a uniform mosaic with a grain size of 0·1-0·5mm, with extremes of ·005 and 3·0mm; the degree of banding is highly variable and is caused by changes in both impurity and grain size, the dolomite generally occurring in irregular patches and streaks.

East of the Kali Gandaki, the lowest unit of the Nilgiri Limestone is a thick calcareous sandstone – the Nilgiri Sandstone (see fig. 9). The one analysed specimen consists of 26·7% $CaCO_3$, 3·3% $MgCO_3$ and 70% insolubles and a thin section revealed about 50% of quartz, the remaining insolubles being interstitial limonite and hematite which give the rock a distinctive pink colour in hand specimen. The sandstone is completely unkarsted. As a unit it thins steadily to the northwest, being absent on Dhaulagiri, and its boundary with the main limestone is clean though thin bands of similar sandstone occur within the limestone up to 500 feet above the contact.

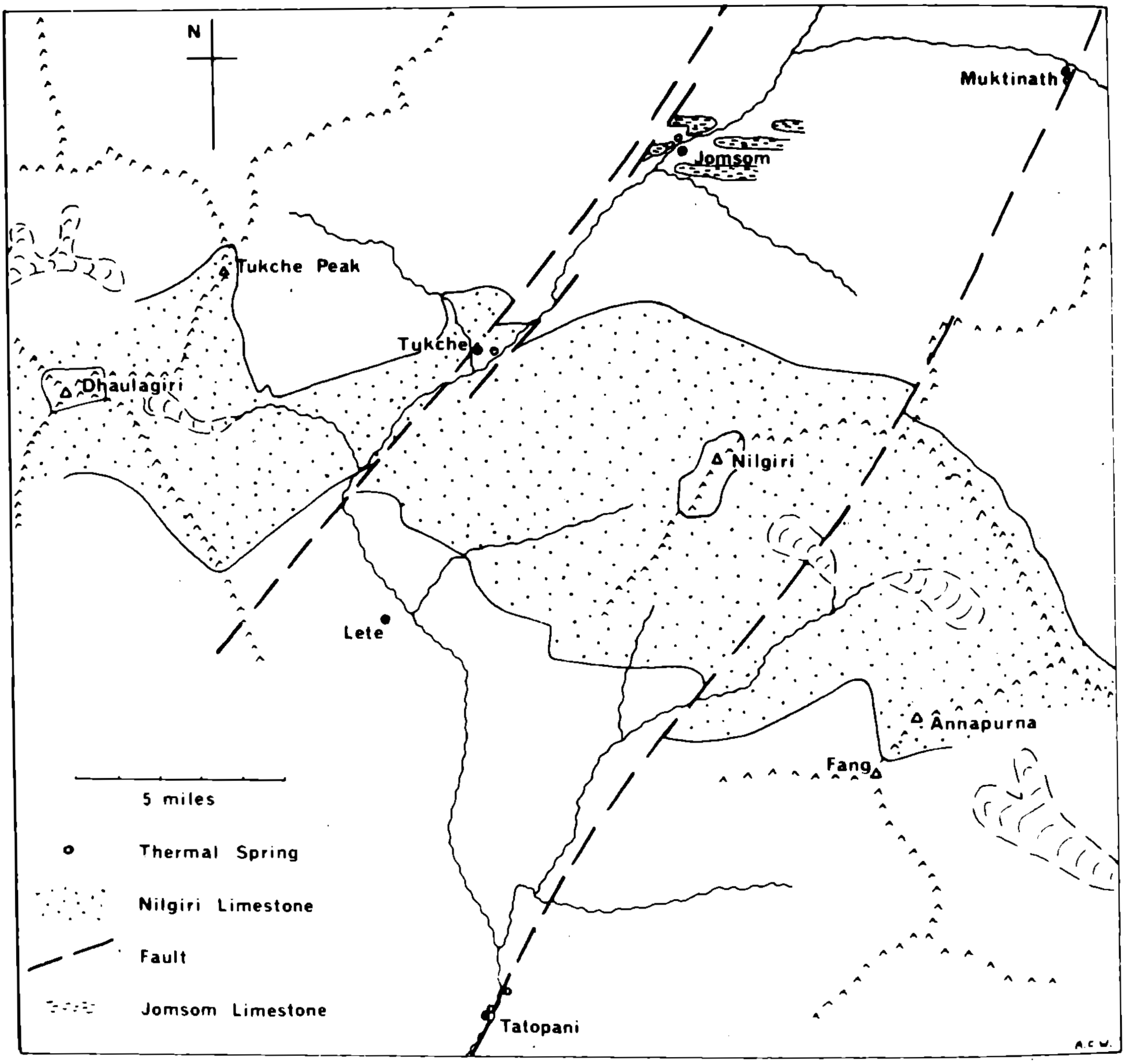


Figure 8. Simplified geological map of the outcrops of the Nilgiri Limestone and the Thakkola graben faults. Outcrops of the Jomsom Limestone are only marked immediately adjacent to Jomsom village.

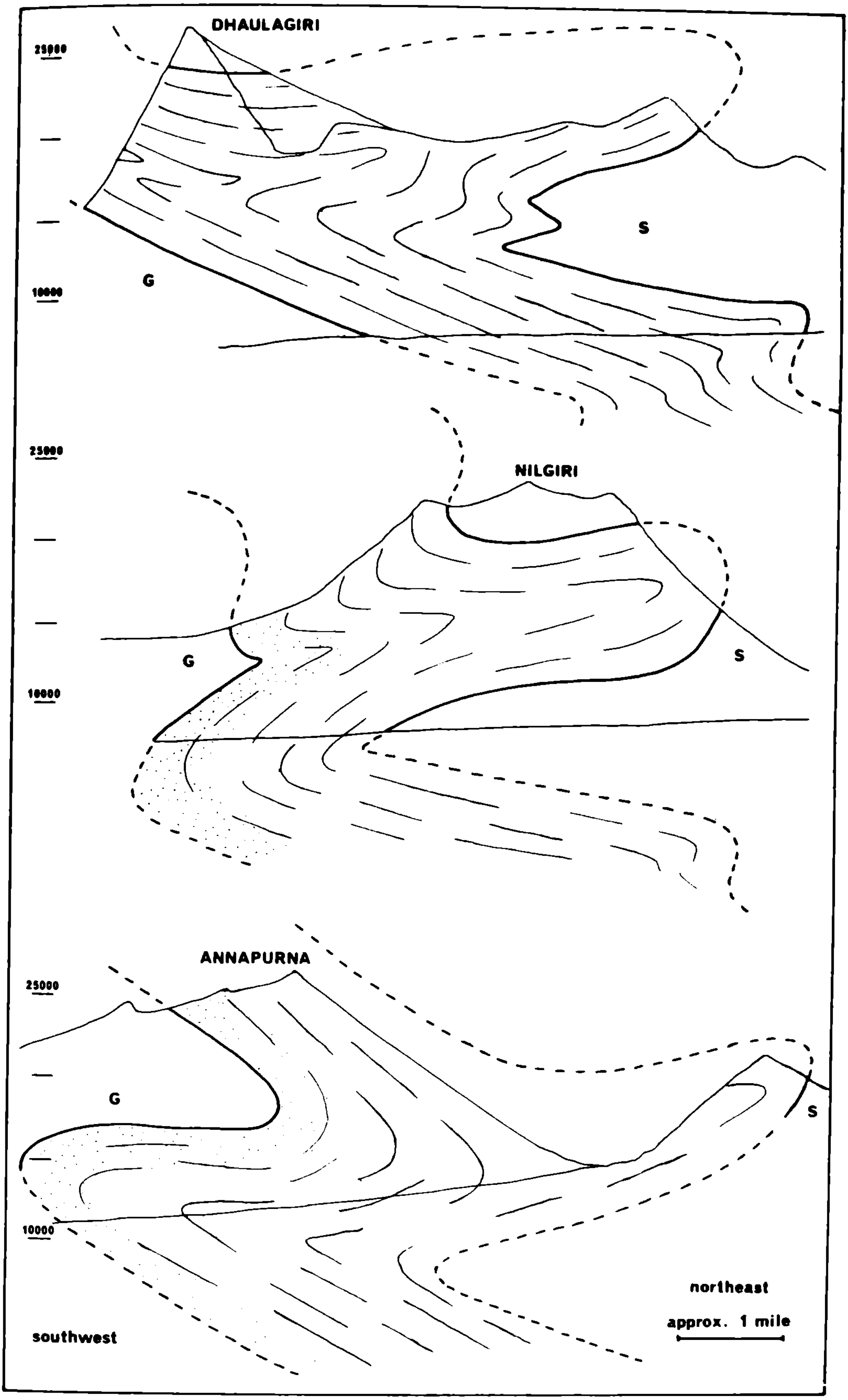


Figure 9. Diagrammatic sections of the Nilgiri Limestone forming Dhaulagiri, Nilgiri and Annapurna. Stippling shows approximate extent of Nilgiri Sandstone, lines are only form-lines. G = gneiss; S = slates etc.

Thick superficial deposits cover much of the area. In the main valleys are wide outcrops of alluvium, and spectacular terraces individually over 500 feet thick. The terraces are made mainly of coarse gravel, mostly fluvioglacial but containing horizons of unsorted till and an increasing abundance of loessic material towards the north; initial dips on the terraces are locally up to 40°, inclined downstream. Higher on the mountains, boulder clay is dominant; the Dhaulagiri Meadows include some spectacular medial and alteral moraines hundreds of feet high, and some lateral moraines reach to the floor of the Kali Gandaki Valley. The boulder clay is generally unsorted, but is locally well regraded to fine or coarse sediments. The dominance of limestone bedrock has resulted in some calcareous deposition, such as the thick tufa beds of Kursangmo (see separate report) and some local patches of cavernous calcibreccia.

Structure

The structure of the Nilgiri Limestone essentially involves a series of immense recumbent folds. Figure 9 shows the main structures of the three principle mountains, structures which are relatively easily determined when viewed from a convenient adjacent mountain. The regional structure (Hagen 1968) suggests a thrusting movement from the north, but the exaggerated inclination of the axial planes towards the north indicates an underthrusting of the main folds, and not an overthrusting of nappes as is more common in similar fold belts. Examination of the smaller scale folding shows it to be generally complex, tight and frequently disharmonious. Plastic deformation was the main result of orogenesis, and jointing is very minor though boudinage is common on a small scale. Axial planes of the folds are mostly subhorizontal, and associated with strong parallel shearing.

Though jointing is generally rare, there is considerable evidence for some widely spaced but very large faults. The levels of the limestone either side of the Dambush Khola (northwest of Tukche) suggest the existence of a large fault along the line of the river itself. However, on a much larger scale, the valleys of the Kali Gandaki, upstream of the bend just below Larjung, and of the Miristi Khola both appear to be fault guided.

The immense graben faults of the Thakkola are a famous feature of Himalayan geology, and have been mapped by Hagen (1968); however, Hagen has only very vaguely and questionably interpolated the positions of the faults across the main Himalayan chain. Figure 8 shows the suggested position of the faults based on various evidence. The Kali Gandaki fault zone may be continued from the line of Hagen's Dangarjong fault very clearly on topographical evidence. However there is also extensive mineralisation along the lower parts of the valley, due to fault guided hydrothermal activity; observed minerals include quartz, ankerite, sphalerite, pyrite, chalcopyrite, limonite and malachite and various other secondary copper minerals. Large fracture planes on the eastern flanks of White Peak suggest this fault dips at about 60° to the southeast. The fault in the Miristi Khola Valley is less easy to plot but its associated features include mineralisation, shearing and fault-drag deflection of the local strike; its attitude is very likely parallel to some very large fractures almost through the summit of Nilgiri which dip at about 50° to the northwest.

Further, quantitative, data on these major faults may be obtained by comparison of the altitudes of the main fold axes in the adjacent mountains (see figure 9). The Nilgiri block is considerably depressed in a classic graben and the throws on the faults appear to be in the order of 7000 feet on the Kali Gandaki fault and 5000 feet on the Miristi Khola fault. Finally, the suggested pattern of faulting also explains the distribution of the four known groups of thermal springs (fig. 8).

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LIMESTONE GEOMORPHOLOGY IN THE JOMSOM AREA

A. C. Waltham

Nine miles northeast of Tukche and still in the Kali Gandaki Valley, the Jomsom region provides a complete geographical contrast to the main range of the Himalayan mountains. The geology is also different, as the main beds of Lower Paleozoic limestone lie far beneath the surface on which there are outcrops of a variety of Mesozoic sedimentary rocks. In these softer strata the topography is a little more subdued; the peaks, with few rising above 20,000′ are set further back from the valley floor, itself at an altitude of about 9000′. Finally the climate is drastically different, and the very low rainfall has resulted in a barren desert landscape.

Geology

In the Jomsom region the Kali Gandaki Valley is cut into complexly folded and faulted Jurassic strata, whose outcrops and fold axes are mainly oriented WNW-ESE. The Jurassic beds are terminated to the west by the major Dangarjong fault, beyond which are Upper Paleozoic schists. Eastwards the outcrops continue beyond the watershed, but these areas are politically inaccessible to foreigners. To the north and south relatively complete sequences lead to Cretaceous and Paleozoic strata respectively, though further faulting has resulted in extensive outcrops of the Jurassic just east of Muktinath.

Thick beds of Triassic dolomite crop out near Jomsom and also on the ridges north of the Tilicho Pass, where they form extremely jagged topography due to conjugate sets of joints delimiting huge diamond shaped slabs in the almost vertical bedding.

The Liassic limestones are the only beds known to contain any karst features, and they form a number of isolated ridges immediately around Jomsom village. They are mostly thin bedded and banded, with alternating layers usually about a foot thick varying from light to dark grey depending on the content of shale and carbonaceous material. Beds of calcareous shale up to three feet thick are common and more abundant higher in the succession where they are extremely rich in fossil bivalves. The limestone has a fine grained partially recrystallised oolitic texture, and contains about 25% of patchily distributed dolomite. Fossil fragments of variable size constitute about 10% of the rock, and a 14% insoluble content consists of small, angular, well-graded quartz and chert grains uniformly distributed together with trace quantities of iron oxide and limonite. The total thickness of the Jomsom Limestone is over 1200 feet.

The remaining Jurassic strata consists of a thick series mainly of black shales, interbedded with subordinate limestones, oolitic ironstones, and yellow sandstones. Some of the dark shales are incredibly rich in fossils, with belemnites and rhynchoneilids occuring with a vast variety of mainly small lamellibranchs.

Quarternary sediments cover the valley floor and form impressive terraces hundreds of feet high. Glaciofluvial gravels are the most abundant, together with thick beds of loess and moraine, and numerous alluvial cones. Also, all but the steepest slopes, up to 2000 feet above the valley floor, are covered with a thin veneer of similar gravel deposits, and thick talus deposits have accumulated beneath the many scars.

Geomorphology

Jomsom occupies an almost classical rain shadow situation, protected from the Indian monsoons by the peaks of Dhaulagiri and Annapurna. Consequently only 8·5 inches of rainfall was recorded in a year (1969-70), most falling in the summer months with nearly three inches on a single day in June; on only 37 days in the year was any precipitation recorded. The weather station at Jomsom (altitude 9000′) recorded only snowfall for three months in the year, and the average daily minimum temperature was at or below freezing for five months. The average daily maximum ranged for the months between 50 and 78°F.

This harsh dry climate, really Tibetan in character, has permitted only the thinnest vegetation to develop in the Jomsom region. Sparse dry grass, with only little moss, together with patches of thorn dominate, though birch scrubs are scattered about and, higher up, thin stands of pine have developed in the more protected gulleys. A large proportion of the surface is bare rock, or rock fragments almost devoid of vegetation. This description really only applies to the land within a few miles of Jomsom, for the village lies in a zone of rapid climatic transition; five miles to the south the slopes of Nilgiri support thick forest, while five miles north the land is almost completely barren.

The main geomorphological effects of this harsh climate have been a considerable restriction of solutional process on the limestone, and a comparable increase in frost shattering. Only limited development of karst features was found on the ridges of the Jomsom Limestone on the west bank of the Kali Gandaki River, and this seems to be typical of the area.

Close to the valley floor, at an altitude of 9000′, the banded limestones bear two contrasting forms of solutional erosion. Small rillenkarren are formed on steep surfaces of the more massive limestone beds, while alternating with thinner bedded limestones containing only small pitting; the pits are generally 2-30mm in diameter, and of similar depth, and occur on both steeply and gently inclined surfaces. Higher above the valley, at about 9500′, shallow rundkarren have formed on some gently inclined slabs together with isolated kluftkarren, but the pitting is still dominant, and most significantly also occurs within the larger rundkarren channels, indicating that they are fossil forms. A thin brown weathered crust is locally developed on the limestone and this is very well pitted, some examples being up to 25mm in diameter and 50mm deep.

Most of the limestone outcrops above 10,000′ are very steep cliffs, the gently graded surfaces being covered by a thick regolith. The bedding plane slabs dipping at about 70° are devoid of karren forms, but some joint surfaces inclined at only 20° are scored by small rillenkarren and maanderkarren; on these slabs the karren forms are noticeably better developed at lower altitudes. Some isolated exposures at an altitude of 12,300′ bear fine examples of both pitting and rillenkarren. Most of the rillenkarren forms are modified by the development of more recent pitting, but some unmarked karren channels directly related to present surface drainage routes show that this form is not entirely fossil within the present climatic regime.

Cave development is very restricted in the Jomsom limestone. A few small phreatic openings are revealed in the cliffs just above the valley floor; they are generally guided by faults or joints and the content of large boulders in one which is isolated high up a cliff indicates its development in an older topography. Just over a mile west of Jomsom village a deep gorge cuts through one of the limestone ridges. Its course is guided by a major joint and in its walls are a number of small openings along cross fractures. Its floor is a series of potholes, scoops and smooth water-worn shutes, now almost all dry; small patches of friable clastic material are loosely cemented to the walls and dry waterfalls – remnants of a thick layer of infill – and their presence indicates the fossil nature of the gorge floor, as it can now never carry any but the minutest flows of water. There are no old sinkholes in the gorge, but a very small trickle of water flows into the top of the gorge and sinks into a rubble choke after crossing only a few yards of limestone outcrop; this is nearly 700 feet above the valley floor.

The south side of the limestone ridge directly north of the village contains two small caves at an altitude of 11,300′. One is a bedding cave about 30 feet long, 8′ wide and 3′ high, formed at the base of a relatively massive bed of limestone. An excellent vein boxwork structure on its roof indicates its phreatic origins, as do a series of small joint controlled avens; one aven has stalactites around its base though they are now completely dry. Adjacent to the cave are a number of other shallow rock shelters developed in the same bedding, particularly at intersections with thin fault breccias. A hundred yards further east, the second cave consists of a single straight passage 60′ long, mostly about two feet square in cross-section. It is very unstable being almost entirely tectonic in origin, solutional development only being evident on a very small scale in a few cross joints.

The only other indication of cavernous development is at 11,800′ where a 6′ wide bedding rift has been opened in the vertically dipping limestone. One wall of the rift is crossed by six shallow two-feet wide half-tubes plunging outwards at about 15°. One end of the rift, and the half-tubes, is exposed in a steep cliff though the other end is inaccessible. The half-tubes are crossed by recent wandkarren, and they are clearly a very old feature, probably developed within the phreatic zone before development of the present topography.

The Jomsom Springs

Three small springs emerge from the base of the limestone cliffs level with the valley alluvium immediately west of the village. A fourth spring is similarly situated about half a mile further north. Each of the three springs near the village has a flow of less than 1 c.f.s., and emerges from impenetrable fractures. The waters are warm and the temperature of each spring is different from the others, varying between about 50 and 70°F. Water from the middle spring was analysed by R. J. Bowser and gave the following concentrations (expressed as ionic p.p.m.):

Ca – 120; Mg – 60; HCO_3 – 265; Cl – 70.

This gives a total hardness expressed as $CaCO_3$ equivalent of 550 p.p.m., and tablet analyses of the other springs gave similar results.

The fourth spring, to the north, had a similar, small, flow and chemical composition, though it was cold. Furthermore it could only be seen to emerge from boulders, and its waters have constructed a low tufa dam in front of the spring holding back a shallow semi-circular pool of about 40 yards radius. The pool is now largely filled in with wind-borne loess.

Conclusion

The main factor restricting karst development in the Jomsom area appears to be the harsh arid climate. The subsequent thinness of the vegetation, and the impure, and dolomitic composition of the limestone have been additional factors. The effect of altitude is demonstrated by the variation of morphological detail between 9000′ and 12,000′, though this is a factor only subordinate to the very low rainfall. A significant proportion of fossil karst features indicates that the climate has been more favourable toward solutional erosion in past times.

The anomolously high temperature, hardness and chlorine content of the Jomsom springs indicate their essentially volcanic origins, though the possibility of meteoric karst water being added to their main source cannot be eliminated.

KARST GEOMORPHOLOGY OF THE NILGIRI LIMESTONE

A. C. Waltham

The Nilgiri Limestone forms a wide zone of outcrops across the Kali Gandaki Valley including the mountain blocks of Annapurna, Nilgiri and Dhaulagiri (see figure 8). Altitude of the outcrops therefore varies from just over 8000′ to more than 26,000′ at the summit of Annapurna.

At Marpha, a few miles northeast of Tukche at an altitude of about 8500′, a small meteorological station provided some data on climate. However, besides an obviously large climatic variation with altitude, there are also considerable changes across the axis of the main mountain range, and some climatic data from Lete (at 8000′) show some marked contrast to that from Marpha. (The following figures are from 2 years observations at Marpha and only one year at Lete, but apparently these periods were not atypical). Annual rainfall varies from 16 inches at Marpha to 42 inches at Lete, but there is considerable seasonable variation. At Marpha the three months July-September recorded 9 inches, while October-December recorded only 1 inch. At Lete the monsoon season May-September collected 33 inches while the winter months of December and January received only 0·1 inch between them. No data on temperature was obtained from Lete, but at Marpha the five summer months, May-September, had average daily mean temperatures of over 65°F and in no month did the average daily minimum fall below freezing point. Lete would tend to be even warmer in winter, and there is rarely snowfall on the floor of the Kali Gandaki Valley. However, the permanent snowline is at about 15,000′ and even in summer thick snow cover for short periods is common down to 11,000′.

The lateral variation of climate across the mountain range has resulted in comparable changes in elevation of the vegetation zones, but the following general statement applies to the mountains in the Tukche-Lete region. Below about 10,000′ is thick conifer or deciduous forest and impenetrable bamboo thicket, but above this low scrub and bush alternate with more open grassland. Any vegetation taller than grass is rare above 13,000′, and above this level mosses and only thin grass form the dominant cover. Above the average permanent snowline, at about 15,000′, only mosses are widespread, occurring in patches up to about 16,500′. Soil thickness shows considerable variation, mostly being related to the distribution of glacial till. Thick zones of rich, peaty soils are common only below 11,000′, and soils are very thin above 14,000′.

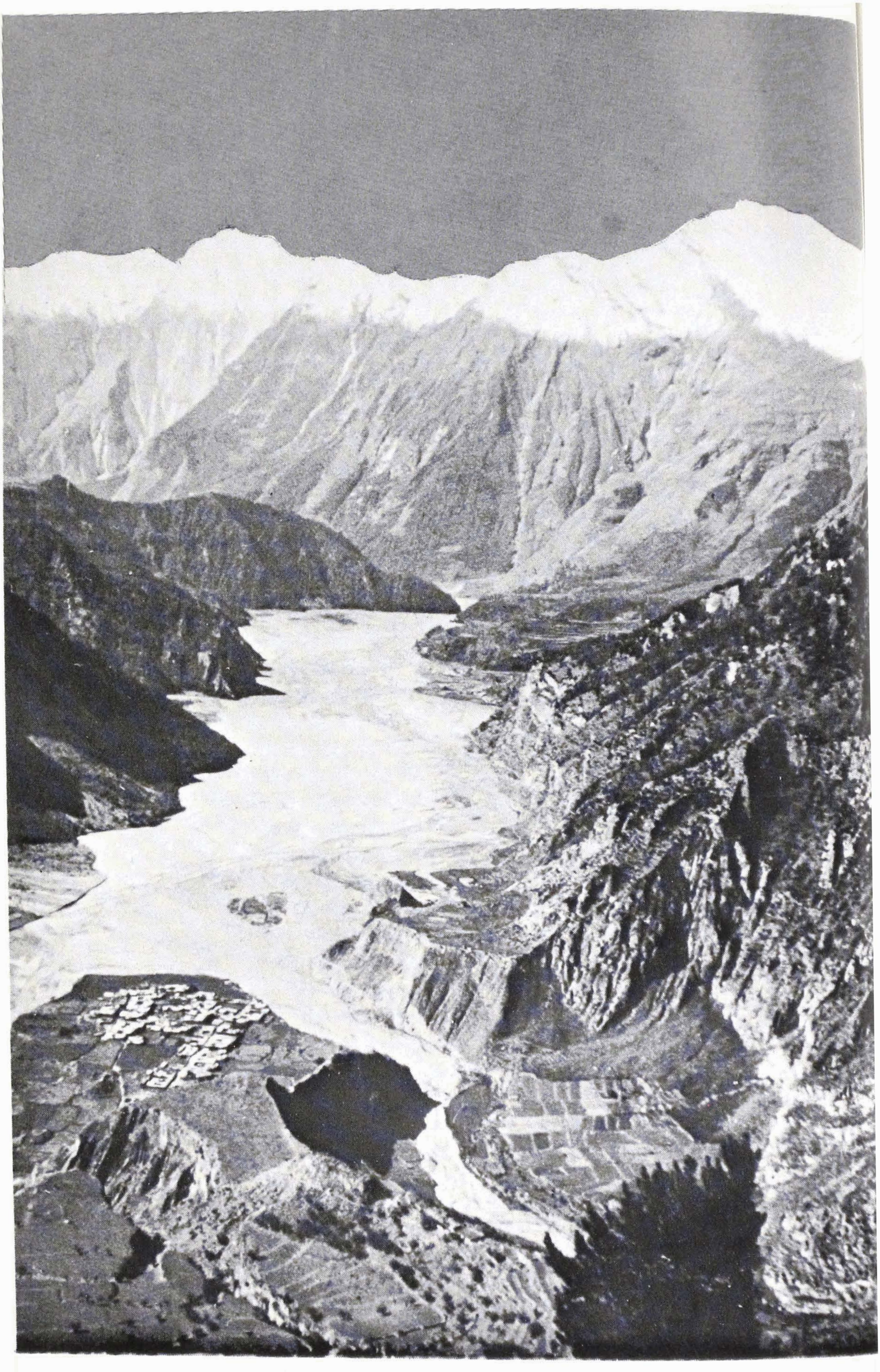
The outcrops of the Nilgiri Limestone below the snowline were examined from White Peak in the west across to the Miristi Khola Valley in the east. The descriptions of the karst features are here divided into three parts, by area, but the conclusions apply in general to the whole region studied.

Kali Gandaki Valley

The Nilgiri Limestone forms the banks of the Kali Gandaki Valley from just above Kalopani (2 miles above Lete) to just above Tukche, and along this length, there are many springs at valley floor level. A number of large springs just near the Kalopani bridge are non-karstic, but there is also one adjacent to the outcrop of the stratigraphic base of the Limestone, on the west bank, near the large bend in the river. It has a flow of about 1 c.f.s., and issues from boulders with a total hardness of 180 (measured by tablets, and expressed as p.p.m. $CaCO_3$).

Some small springs in the Larjung area appear to drain only the terrace gravels, but there are risings from the limestone near Tukche. One mile along the path up-valley of Tukche a rising of 2 c.f.s. issues from fractures in thin bedded limestone almost at river level. It has a total hardness of 390 (see table 3) and a temperature of 12°C; 2°C above the river temperature. It is close to the stratigraphic top of the Limestone and may be partly supplied from sinks in the bed of the Dambush Khola only 1½ miles to the west and about 300 feet higher; there is a small boulder choked cave above the rising but no other signs of cave development. On the northern edge of Tukche village, a small spring is used as a water supply; it rises from

Jomsom and the Kali Gandaki Valley, looking north from the mountains just north of Tukche.



The Kali Gandaki Valley seen from the north, with Tukche in the foreground and White Peak in the distance.

Location	Altitude Feet	pH	Ca^{2+} ppm	Mg^{2+} ppm	HCO_3^- ppm	Cl^- ppm	Hardness ppm $CaCO_3$
Spring on Dhaulagiri Meadows	12,100	6·5	52·2	6·37	162	–	158
Stream on Dhaulagiri Meadows	12,100	6·3	44·2	3·72	131	–	126
Spring north of Tukche	8 500	6·5	76·9	47·2	265	tr	387

Table 3. Water analyses in the Tukche region (Analyst R. J. Bowser)

the gravel, has a total hardness of 220 and is also slightly warm. In the eastern bank of the river, opposite Tukche, two small springs issue from the limestone with hardnesses of 350 and 500. The very high hardnesses and elevated temperatures of the Tukche springs suggest that they all include a proportion of juvenile water, from deep volcanic sources probably associated with the major valley fault.

There may be other smaller risings along the Kali Gandaki Valley, and a totally unknown quantity of water could flow from the limestone bedrock through the river gravels and into the river unnoticed. However, there is a distinct lack of large resurgences commensurate with the scale of the limestone hinterland and it appears that only a small proportion of the Nilgiri Limestone drainage is truly karstic along the valley.

At an elevation of 10,500′ in the Chini Ravine (east of Tukche) occurs a group of six risings with a total flow of about 3 c.f.s. and a hardness of 180. The water issues from narrow joints in thin bedded but pure limestones, and the risings are just above a zone of even thinner shaley limestone.

Any traveller passing along the Kali Gandaki Valley cannot fail to notice the huge number of open cave entrances, mostly near the valley floor. Unfortunately nearly all of these are in recent superficial deposits. The greatest numbers are near the villages of Tukche and Larjung and these are all formed in the terrace gravels; most are only "rock shelters", few are more than 50 feet long and many have been modified by man to a considerable extent – for the purpose of building temples or extracting beds of sand or clay.

A large proportion of the superficial deposits is calcareous, due to erosion of the bedrock limestone, and locally the carbonate content is so high that groundwater circulation (considerable in all the terraces) has resulted in thick deposits of tufa and calcareous cementing material. At the same time caves have formed and their development has been aided by the greater strength of the tufa and cemented sediments. The largest known tufa caves are at Kursangmo, just above Larjung (see separate description). However, some large risings (more than 5 c.f.s.) from glacial deposits at about 13,000′ on the flanks of Nilgiri opposite Larjung, may have greater associated caves. A similar cave exists in the gorge of the Dambush Khola only half a mile upstream of Tukche. A 20 feet square entrance debouches a stream of about 0·5 c.f.s. which is itself precipitating tufa on the boulders; the stream can be followed up into the cave for nearly 100 feet, up some climbs in a narrow passage to a small choked chamber, where the water pours out of interstices in the terrace conglomerate in which the entire cave is formed. On the opposite (northeast) bank two small rockshelters are developed beneath steep slopes of calcibreccia.

In this area there is only a single cave developed in the Nilgiri Limestone – situated in a gulley wall at 10,100′ due north of Tukche village. It is dry and no more than 10 feet long, and most of its walls are highly frost shattered but at the inner end, a small phreatic roof dome, developed on a thin calcite vein, has retained its solutional morphology.

Instead of forming caves the rivers draining across the Nilgiri Limestone have maintained surface courses, but have cut deep and spectacular solutional gorges. For a short distance, the Dambush Khola, just north of Tukche passes through one of these gorges. The walls are nearly vertical rising straight from an impassable river bed consisting of a series of deep rounded potholes; the proportions are impressive as the walls are no more than 20 feet apart for a height of over 200 feet. Detail on the walls is smooth and rounded due to the uniformity of corrosion, and in places scallops up to two feet long have developed. Each side of the Kursangmo basin, west of Larjung, are the lower ends of two more solutional gorges. They are even more impressive – hundreds of feet deep, twenty feet or less between vertical walls, with vast torrents roaring down their steeply graded, potholed floors. In every detail of morphology and genesis, these gorges are similar to huge unroofed vadose canyon passages in caves, but it appears that they have never had roofs even in their early stages of development.

Karren forms are very poorly developed in the Kali Gandaki Valley, though there are numerous outcrops of bare limestone. The dominant morphology of the outcrops is that of frost-shattering and mechanical breakdown. Solution has normally only resulted in small scale rounding of corners on the rock and even the few significant joints show little solutional etching. The one observed exception to this lack of karren is in the cliffs above Tukche at 9800′. Broad, shallow, rounded wandkarren are formed on a single cliff, and solutional excavation of joint traces is greater than normal. A single bedding plane in the same cliff contains a maze of anastomosing tubes, mostly elliptical about 4 x 2 inches. However, blocks falling away from the cliff show only minimal effect of solution in the deep open joints behind them.

Dhaulagiri Meadows

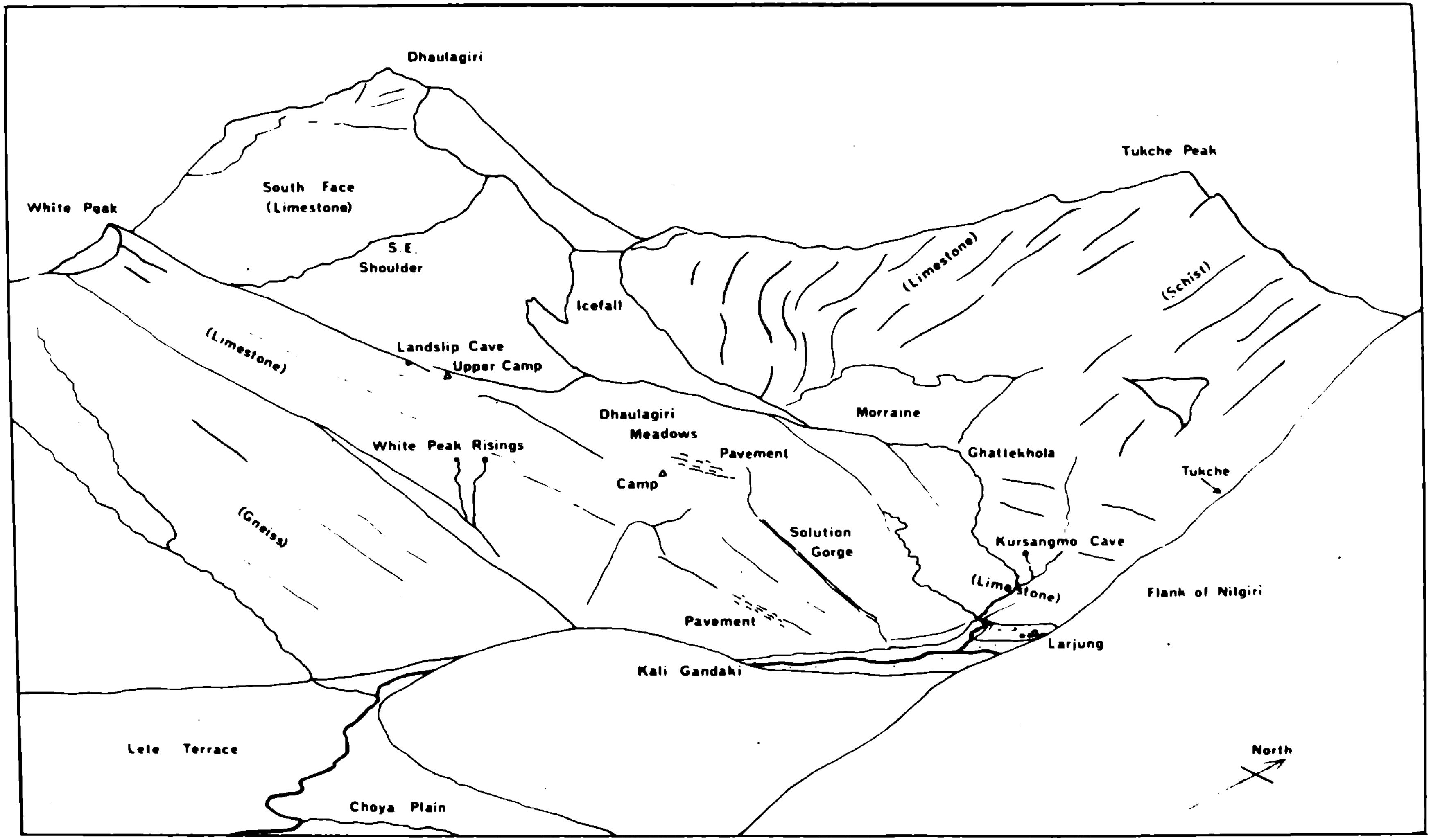
Situated on the east flank of Dhaulagiri, the Meadows is strictly the area of slightly gentler slopes used for yak grazing between 11,000′ and 13,000′ in altitude, but this description covers the wider area of study up as far as White Peak and the Icefall (see figure 10). Bedrock of the entire Meadows, and the overlooking cliffs is the Nilgiri Limestone.

The extent of karren development appears to be primarily influenced by lithology, for pavement is only well developed in isolated areas on individual beds of the limestone. One large area of pavement occurs over a thin band of limestone at about 9000′. The dominant form is rundkarren with deep rounded channels, now mostly inactive and oriented down the dip of about 25°. Jointing is poor and some slabs in more impure beds have hardly any karren development. Higher up the same slope and probably in the same stratigraphic horizon, at about 11,800′, even larger rundkarren are developed. The channels have rounded floors, but have locally enlarged and partially coalesced with adjacent channels leaving sharp aretes in between; some of the deeper grykes, maybe joint influenced, are over 3 feet deep. The importance of the soil cover, locally thick, dark and peaty, in the development of this pavement is clear, for the deepest solution channels are found on and adjacent to the yak path where a thick cover has been removed by the passage of the animals; patches of karren exposed elsewhere through thin soils are much more poorly developed. In the same area, many of the small cliffs are scored by rounded wandkarren with individual grooves up to 30 feet long.

Near the expedition's campsite on the Meadows, at an altitude of 12,200′, is a second region of pavement, though in this case rarely continuous over more than about 40 yards. A series of slabs cut by deep rundkarren occur in a region of well grassed thick soil cover, and the solutional morphology appears to be restricted to two beds of limestone each about 25 feet thick. Many of the clint blocks are partly covered with soil, peat and moss, and the vegetation commonly blocks the solution runnels. In no case do the grykes cut the entire thickness of the bed, though the fewer examples of kluftkarren are only choked with soil and gravel.

Above 13,000′, solutional karren features are almost completely absent. There is no more true pavement, and at 14,000′ the only effect of solution is the small scale rounding of corners on the rocks in the streambeds. On the flanks of White Peak, long limestone scars have broken, shattered surfaces. At 15,200′ some weak solutional etching of thin bedding is present, together with some very shallow wandkarren. At 15,500′ there is local solutional rounding and on the summit of White Peak, at 17,250′, the limestone, though quite pure, is completely shattered on all exposed surfaces.

There are no dolines in the bedrock of the Dhaulagiri Meadows. A large number of closed depressions at 14,000-15,000′ near the expedition's upper camp are formed only in



Map 2

Figure 10. Dhaulagiri Himal as seen from the Pass into the Hum Khola basin.

boulder clay. They are mainly broad and shallow, some with central holes opening between boulders for a few feet in depth, and they cannot be described with certainty as shakeholes of karstic origin. They are very likely primary hollows left during deposition of the till, and maintained since then by underground drainage within the unconsolidated sediments; how much the drainage relates to the limestone bedrock is questionable. Similarly, a group of shallow dry valleys with locally reverse gradients to their thalwegs, are not necessarily karst features.

The limestone of the Dhaulagiri Meadows is essentially non-cavernous. Some shallow rock shelters in the walls of one of the solution gorges, near the main camp, may be just meander niches or could have developed with the aid of seepage water in the joints which control their locations. Some small caves near the White Peak Risings are mere rock shelters under overhangs in slopes of calcibreccia. The landslip cave at 14,100' (see figure 10) consists of about 50 feet of narrow rift passages, formed where a great slab of limestone has slipped down the dip of the hillside, breaking away along a zone of shallow joints. Though water is now seeping through the fissures (roofed over only by thin rock slabs and soil), there is a noticeable lack of solutional morphology.

The vast majority of the water draining across the Meadows stays on the surface. The largest streams, including the Ghattekhola draining from the Icefall, flow over thick deposits of moraine and glaciofluvial gravels. However, at the change to the steeper gradients of the slopes which drop nearly 4000' to the Kali Gandaki Valley, they enter deeply incised solution gorges. These are largely inaccessible, but in places can be seen to include deep pot-holes and waterfalls, complex pinnacles and cleanly scalloped walls.

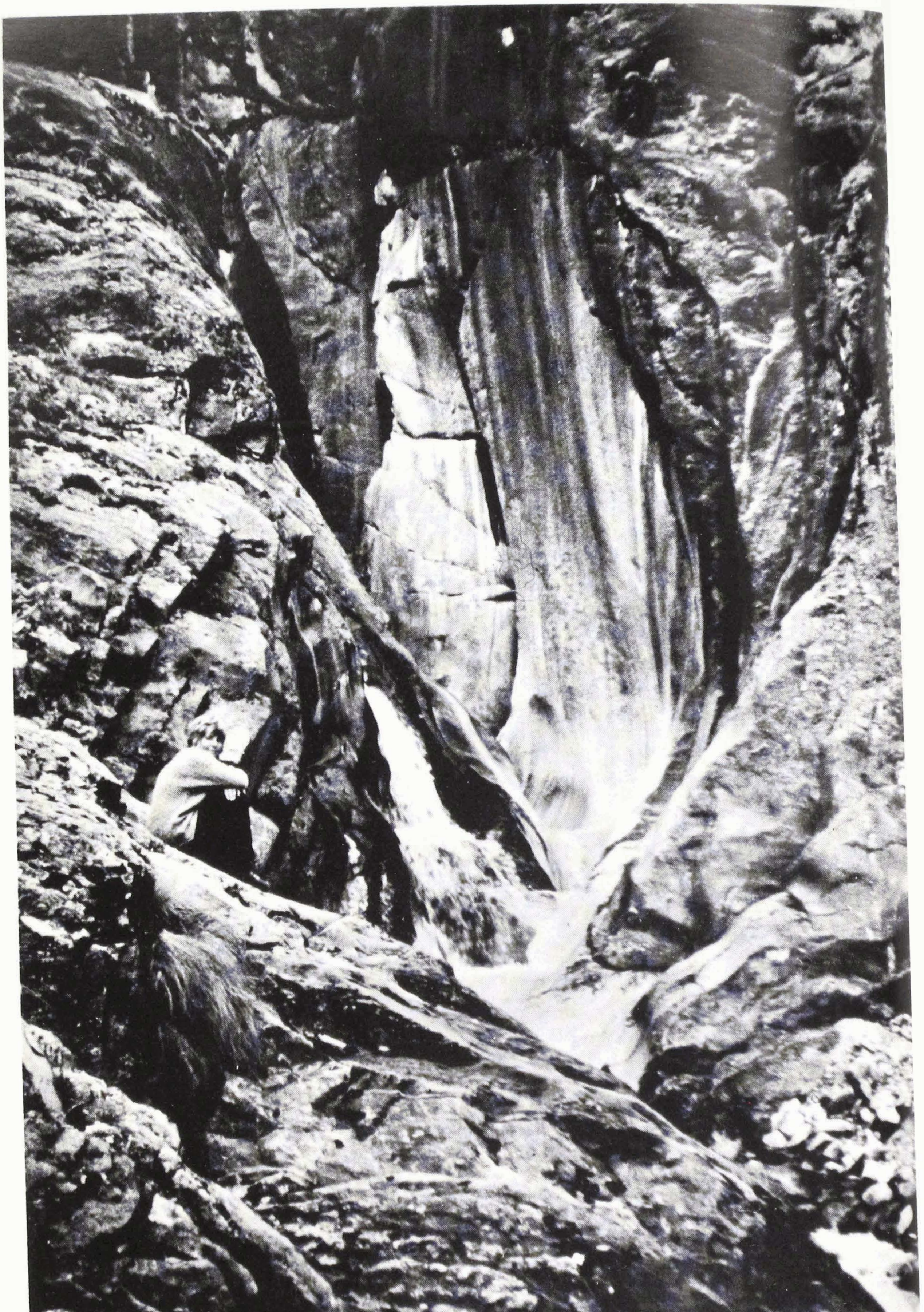
The smaller streams maintain their courses over till and bare limestone. A number, at about 12,100', have waters with a total hardness of 100-120, and flow on limestone or even through the clintfields with few solutional features in their beds, only a few solution chutes being present. A 40-feet high scar, in a single bed of limestone, forms the lower boundary to the zone of pavement near the expedition campsite, but there is no evidence of the drainage taking an underground short-cut through the scar – instead a series of small waterfalls occur along its length. Streambed morphology is similar at higher altitudes except that solutional features are even less developed. The water chemistry varies however, total hardness at 13,950' being only 70, while the glacier-derived streams at 13,000', measure only 60-90 in total hardness (all figures in p.p.m. $CaCO_3$), though the high turbidity of some of these streams indicates the considerable load of limestone carried in suspension. At 14,400', water drains directly from the side of the Icefall over bare limestone. Two streams sampled less than 100 feet from the ice had hardnesses of 50 and 60, and their courses show no sign of solution – frost shattering is everywhere dominant, even on very pure limestone beds.

Underground drainage is very limited over most of the Meadows, and most that does occur is restricted to circulation within the drift deposits. Near the lower campsite many of the small streambeds are dry over short lengths. Both sinks and risings are mostly stone ruckles or muddy pools, and in only two cases does the water sink into the limestone bedrock; even then it appears to follow very shallow courses. A number of small (less than 0·1 c.f.s.) springs nearby rise from boulder clay, with a total hardness of around 125 p.p.m., and are very likely unrelated to bedrock. At 14,000', near the expedition's upper campsite, are two more springs, similar in every respect except that water hardness was measured at only 80 p.p.m. Above this level are no springs; only some small seepages from bedding planes in the limestone scars exist and these have even lower hardnesses.

Exceptional to the general lack of karst drainage are the White Peak Risings (see fig. 10). The main rising has a flow of about 5 c.f.s., emerging from dozens of closely spaced bedding planes over an area of nearly 100 square feet of almost vertical rockface. There is no sign of solutional deposition or enlargement at the rising – the shallow recess in which the rising occurs owes its development to mechanical shattering – and the water appears to flow from extremely narrow openings. The nature of the cliffs around the rising made direct access

A limestone scar inclined towards the steep snow slabs of White Peak.

A block of rundkarren on the lower Dhaulagiri Meadows.



The Hum Khola gorge with a rising visible on the left.

impossible and the water could only be sampled some thousands of feet below; here it measured 100 p.p.m. total hardness, but is admixed with a roughly similar proportion of very soft gneiss drainage water, so the hardness of the actual rising is probably in the order of 180 p.p.m. The rising does not occur at the base of the limestone but only at the rather poorly defined base of the main, more massively bedded unit which forms the White Peak escarpment. The dip is about 30° parallel to the cliff face and a very minor strike fault cutting through the rising appears to be the only control over its level. There is a second rising of only about 1 c.f.s., just 100 yards to the south, but this only emerges from a scree slope. Both are at an altitude of 11,900′. No sinkholes were found associated with the risings, and the source of the water is most likely percolation meltwater beneath the snowfields of White Peak, and direct rainfall infiltration on the lower slabs.

Also at the same level, but about a quarter of a mile to the north and 200′ stratigraphically higher, is a group of 6 very small seepage risings; all are in the same horizon and have total hardnesses ranging between 115 and 125 p.p.m.

Nilgiri Himal

The footpath from Lete to the Annapurna glacier gives reasonable access to the limestone outcrops between 12,000′ and 15,000′ on the southern flanks of Nilgiri (see map 3). A number of open cave entrances visible from the path give a false impression of cave development in the area. At about 9000′, overlooking Choya Deorali (east of Lete), there is a rock shelter formed in a steep slope of calcibreccia, containing some large old fossil stalactites, and similar barren shelters are also present high on the sides of the Tangdung Khola Valley (north-east of Ghasa) at around 15,000′. The Miristi Khola valley contains a variety of small rock-shelters. All at about 13,000′, they are cut into both solid limestone and gravel terraces, but even the former are mainly formed by frost shattering. Overlooking the same valley, just above where the path descends sharply from the Hum Khola pass, is an obvious entrance in bedrock at an altitude of 14,500′; unfortunately the cave is no more than 12 feet long, formed mainly by collapse at a joint intersection.

Instead of forming caves, the majority of the surface streams have cut deep and spectacular solution gorges where they drain across the limestone outcrops. The Hum Khola, between the snout of its source glacier and where the footpath crosses it, is in a particularly impressive gorge. Other karst features are similarly rare and only a few occurrences of karren were observed. Where the path crosses the 10,000′ contour on the climb out of the Kali Gandaki Valley is a single derived block of pure limestone with its surface dissected by deep classical rundkarren formed in situ; the block now stands out of a deep soil cover supporting a luxuriant vegetation. Near the Miristi Khola rock shelter, at 14,500′, small rillenkarren are developed on some inclined limestone slabs, contrasting with the generally shattered surfaces all around. Almost on the very top of the pass between the Kali Gandaki and the Hum Khola, at 13,700′, are two perfectly formed conical dolines. About 20 feet across and 5 feet deep, they are drift dolines, or shakeholes, as their sides are entirely in fine sandy superficial sediment, and only boulders are visible at their apeces. They were both dry when observed, but their steep unstable sides suggest that they become active in the monsoon and melting seasons. Anomolously the bedrock is Nilgiri Sandstone. Nowhere else is this rock karsted and the dolines probably owe their origin to development over unusually large open fractures.

Conveniently situated where the Hum Khola crosses the footpath, at an altitude of 13,200′, are the Hum Khola Risings. Below this point the river flows in a deep ravine between cliffs of glaciofluvial sediment, while above it is in a deep solution gorge leading from the snout of the glacier at 14,800′. The gorge is mostly 100′-200′ deep and 10′-30′ wide, and slightly wider along the streambed due to a modern increase in flowrate. Rillenkarren are locally developed on small slabs. The path crosses the river precisely on the contact between the massive white, pure Nilgiri Limestone (upstream) and the red Nilgiri Sandstone, downstream. The dip is vertical and the strike perpendicular to the stream channels.

It is the geological contact that has resulted in the Hum Khola Risings – six separate springs in the rock banks of the Hum Khola itself, and two more in the banks of a tributary 200 feet to the east. When observed (late October), the total flow of the risings was about 5 c.f.s., compared to a mean flow in the surface stream of 10 c.f.s., and less than 1 c.f.s. in the tributary. No diurnal variation was detected in the flows of the risings, though the main stream doubled in flow during the afternoon (due to its glacial source), and the tributary dried up in the afternoon (probably due to a delayed flow from a snowmelt area). The two lowest risings had water spouting out under considerable pressure.

Of the eight separate sources, six emerge from vertical bedding planes, one from a joint oblique to the bedding and one from boulders. They are not all on the thalweg but range up to 15 feet above the streambed in the immediately adjacent rock walls; the total height range is about 30 feet over a distance of 200 feet. Only two sources are on the limestone/sandstone contact, while one is 20 feet stratigraphically into the sandstone (issuing from a very strong bedding plane) and the others are up to 100 feet into the limestone.

Only four of the springs could be reached for sampling. All the waters were clear and the measured total hardnesses were 100, 105, 155, 155 p.p.m. In comparison, the main Hum Khola and its tributary measured 110 and 100 respectively and the former was very turbid with rock-flour.

No trace of any sinkholes could be found between the risings and the Hum Glacier, and the thinly vegetated, very steep slopes partly covered in drift bore little sign of karst development. The source of the risings is doubtful. The obvious source is the Hum Glacier of sinks in the gorge immediately below it, but unless some underground filtration and settling takes place, the clarity of the spring water indicates an origin from percolation water over a wider area. Certainly the huge catchment area to this karst drainage system is quantitatively adequate to account for the flow without the inclusion of the Glacier drainage.

Distribution of karst landforms

Unfortunately, the extent of karst development of the Nilgiri Limestone is rather limited. This is not due to climatic conditions or restrictions imposed by the altitude, but is a function of the geological environment. The limestone is exceptionally impure with insoluble contents ranging 15-34·5%, and this must hinder solutional process. The dolomite content is low enough to be ignored in this respect (magnesium carbonate content is generally 2-4%), but the regional low grade metamorphism has further reduced the limestone's solubility.

The lack of caves in the area is almost entirely due to the plastic deformation and consequent lack of significant jointing in the limestone. Though water may flow over the surface of the rock and corrode it, there are inadequate joint or bedding plane fractures capable of providing the initial underground routes from which caves may subsequently develop by solutional enlargement. As run-off water cannot enter the rock, it flows on the surface but the rivers have still cut spectacular vadose canyons down the mountainsides – the solution gorges. Though here called "solution gorges", it is quite clear that mechanical abrasion must have been an important process in their development – in the same way that cave passages elsewhere in the world are formed by both corrosion and abrasion. However, their morphology indicates the relative importance of the solutional process, and they give some indication of the size of cave systems which may have formed had the limestone been initially jointed.

The impurity of the limestone limits the value of conclusions relating to the distribution of karst-types with respect to altitude. However, there seems to be little trace of the three karst zones postulated in other parts of the world – doline karst, karren fields and then non-solutional shattered surfaces, with successive increase in altitude. Rillenkarren is more common towards the snow-line but is scarcely abundant enough to designate a rillenkarren zone. Instead rundkarren fields occur from near the valley floors to over 12,000', and shortly above this, frost shattering is entirely dominant. The spatial distribution of rundkarren is largely a function of the occurrence of thick humic soil cover at lower levels. At the higher levels, the thick layer of felsenmeer restricts sinkhole formation by diffusion of the solution effort, but there is a similar lack of closed depressions at lower altitudes.

Certainly karst drainage does exist at high levels. The risings of two large, but admittedly youthful, systems occur at 11,900′ (White Peak Risings) and 13,200′ (Hum Khola Risings). The latter is particularly high – among the most elevated of observed karst forms. It is classically situated at the topographically lowest point on the immediate limestone outcrop, thereby suggesting an overflow of an integrated drainage network within the phreatic zone. It is in phase with the present topography and there is no indication of flow channelling through established cave passages. The clarity of the water suggests percolation feed, as most streams in the area are turbid with glacial-flour. Furthermore no sinks were found. Both these karst systems are high, but the possible existence of similar systems lower down, with their risings buried by the gravel infill of the Kali Gandaki Valley floor, cannot be ruled out.

A glacial climate does restrict the karst processes, and the Himalayan mountains show evidence of an extensive recent glacial retreat. Any such retreat of the glaciers in the area would undoubtedly have been upwards over a period of time. Consequently, if the extent of karstification was a function of the duration of the present climatic regime, there would be more extensive development of karst features at lower levels. However, the largest known underground karst features – the feeders to the risings – are among the highest. It is therefore very unlikely that the general scarcity of karst and caves in the area is significantly due to the shortness of time since the recent glaciations.

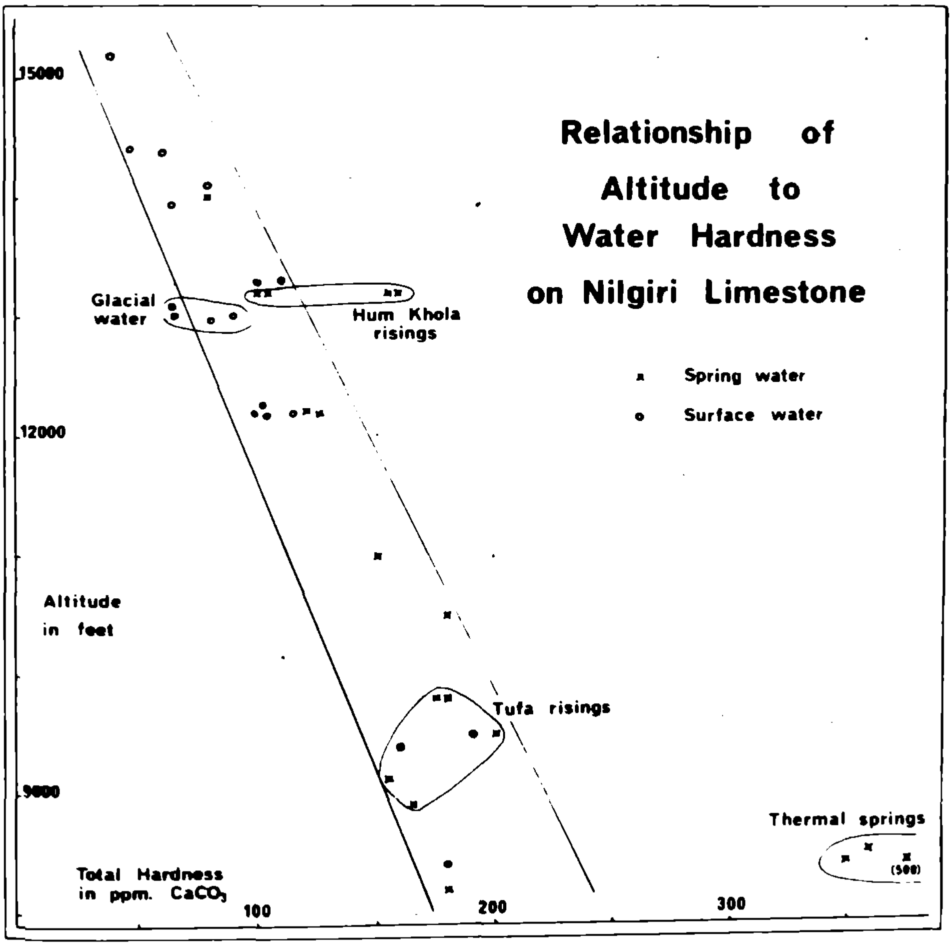


Figure 11.

Pattern of limestone solution

An exploratory programme of water analyses revealed a distinct decrease of solution rate with respect to altitude. The graph (fig. 11) is based on 36 total hardness analyses. Measurements were made at the points of collection by the Palintest tablet method, and comparison with full chemical analyses shows that the tablet measurements are all about 10% low, due at least in part to an operator error from adding water to the tablets instead of vice-versa. This error is constant, so the relative significance of the results is still valid. Also all measured waters were holokarstic. Over the period of the expedition, the regional hydrology was subject to a steady decrease in stage. However, there was a random relationship between altitude and date of sampling, so the results should not be influenced by an expected increase of water hardness with decrease of stage.

The highest water sampled was at 15,200′ (on White Peak). No flowing water was found at higher levels on the mainly snow covered slopes which were traversed. Solution should be taking place even at considerably higher levels due to melting in the strong radiation heat of the sun, but this would be restricted to the more inaccessible steeper rock faces.

The measured water hardnesses at high altitude are well below the solubility of $CaCO_3$ in water in contact with normal atmosphere under equilibrium conditions. Above about 14,000′ there is no need to invoke the presence of soil and vegetation CO_2 to permit the solution levels recorded. Similarly the water hardnesses measured nearer to the valley floor (about 8000′) are well below those to be found in other temperate vegetated areas. Therefore one may conclude that, in the Himalayan region, the solubility of limestone is a function of the three interdependent variables, altitude, climate and vegetation, from well below 8000′ to around 14,000′.

On figure 11, there are recorded three groups of chemically anomolous waters. Three springs (around Tukche) are excessively hard due to their partly juvenile origins. Not surprisingly the waters draining from the Dhaulagiri Glacier are relatively low in solute, probably due to squeezing of the carbon dioxide from the glacier ice. Two of the Hum Khola Risings (and probably the White Peak Risings – see above) are atypically hard – they appear to be nearer to a saturated state due to a longer time spent in a phreas. Field measurements were inadequate to determine saturation indices, and the Hum Khola Risings analyses indicate that saturation has probably not been generally reached. However, the relative narrowness of the zone on the graph suggests some form of maximum limit to the extent of solution.

Measured magnesium carbonate contents of some of the limestone waters (see table 3) merely reflect the slightly dolomitic composition of the bedrock. Analyses were too few to indicate any differences in the effect of altitude on the relative solubilities of calcite and dolomite.

THE TUFA CAVES OF KURSANGMO

A. C. Waltham

Where the Ghattekhola river pours off the flanks of Dhaulagiri, it has cut a deep basin just west of the village of Larjung. High in the slopes of this basin, at an altitude of 9800', a group of springs and waterfalls is locally known as Kursangmo. The spot is reached by a very overgrown track winding up from the foot of the basin, 1100 feet below, and many other springs can be seen from the path. Kursangmo is set into a nearly vertical cliff, which rises about a hundred feet above the springs to the edge of a gentler slope, which itself rises for thousands of feet to the rock towers of Tukche Peak.

Around Kursangmo nearly all the surface exposures are of boulder clay, though some of the deeper ravines have cut down into the Paleozoic limestones. The Kursangmo cliff reveals a thickness of well over 100 feet of very coarse glacial deposits, but this thickness is not maintained as the contact between the till and the limestone is itself irregular and locally nearly vertical. This veneer of glacial sediment, with initial dips of up to 40°, is stable on these steep slopes largely because of its fairly high degree of calcareous cementation. Most of the till appears to be calcareous, though the composition varies vertically and some horizons are highly tufaceous.

The Kursangmo springs and caves are formed in a single tufaceous layer of till, and are accessible only because the same bed is topographically weak and therefore forms a notch and ledge in the cliff. This ledge, about 25 feet wide, is formed on tufa covered boulders and is very thickly overgrown; even denser bamboo jungle makes it impossible to see what is just below the platform. At the back of the ledge there are dozens of spouts of water pouring out of the cliff and cascading onto the tufa floor. Some of the water springs from small fissures in the boulder clay cliff, other spouts pour from small caves in the tufa layers and still more flow down the insides of great hollow tufa stalactites.

The tufa is pure white, solid calcite with a considerable variation in porosity, though the outside layers are soft, dirty grey and mossy. Over a length of about 200 feet the cliff face is liberally covered with a variety of large but dirty tufa stalactites, columns, bosses and flowstone; the formations are up to twenty feet high and are nearly all active.

At the back of the ledge, nearly all the water flowing out of the cliff sinks back into it, and at, at least, three points entry can be gained to an active cave streamway. Though nowhere more than about eight feet square in cross section, the Kursangmo cave is extremely beautiful as its entire walls, floor and ceiling are pure tufa; furthermore this is all white except at one point where it is bright orange due to staining by an iron-rich inlet. The stream cascades over flowstone covered boulders for a distance of about 80 feet to where it enters a lake which sumps after 20 feet. Its total flow is about 2 c.f.s., derived from a whole series of inlets, as the cave runs parallel to the cliff, just below ledge level, collecting the waters of the various springs. Depth of the cave is about 30 feet and the water returns to daylight from a talus slope at a level about 20 feet below the sump. Just above the active cave, and again parallel to the cliff face, is a short dry cave passage, now open at both ends, of similar cross section to the active passages and again cut entirely in tufa.

There are many other risings and waterfalls in and on the tufa beds of the Ghattekhola basin, but none of those accessible is associated with cave development as at Kursangmo.

Water hardness measurements (using standard tablet methods) of the various tufa spring waters in the Ghattekhola basin showed a range of 155 to 200 p.p.m. total hardness (expressed as $CaCO_3$) with a majority at about 175 p.p.m. A full analysis of one sample (by R. Bowser) gave the following result:— (as ionic p.p.m.)

Ca – 44·2; Mg – 20·7; CO_3 – 9·6; HCO_3 – 146

Altitude of the springs ranges from 8900' to 9800', and the water hardness contrasts with that of streams which flow entirely on the surface, either over the tufa, or in gorges incised through it into the limestone, which average 120 p.p.m. The Mg/Ca ratio in the water is very much higher than in the bedrock limestone from which most of the till is derived. It would appear that the till has been considerably leached of calcium, in an older climatic phase, and only now is the magnesium significantly entering into solution.

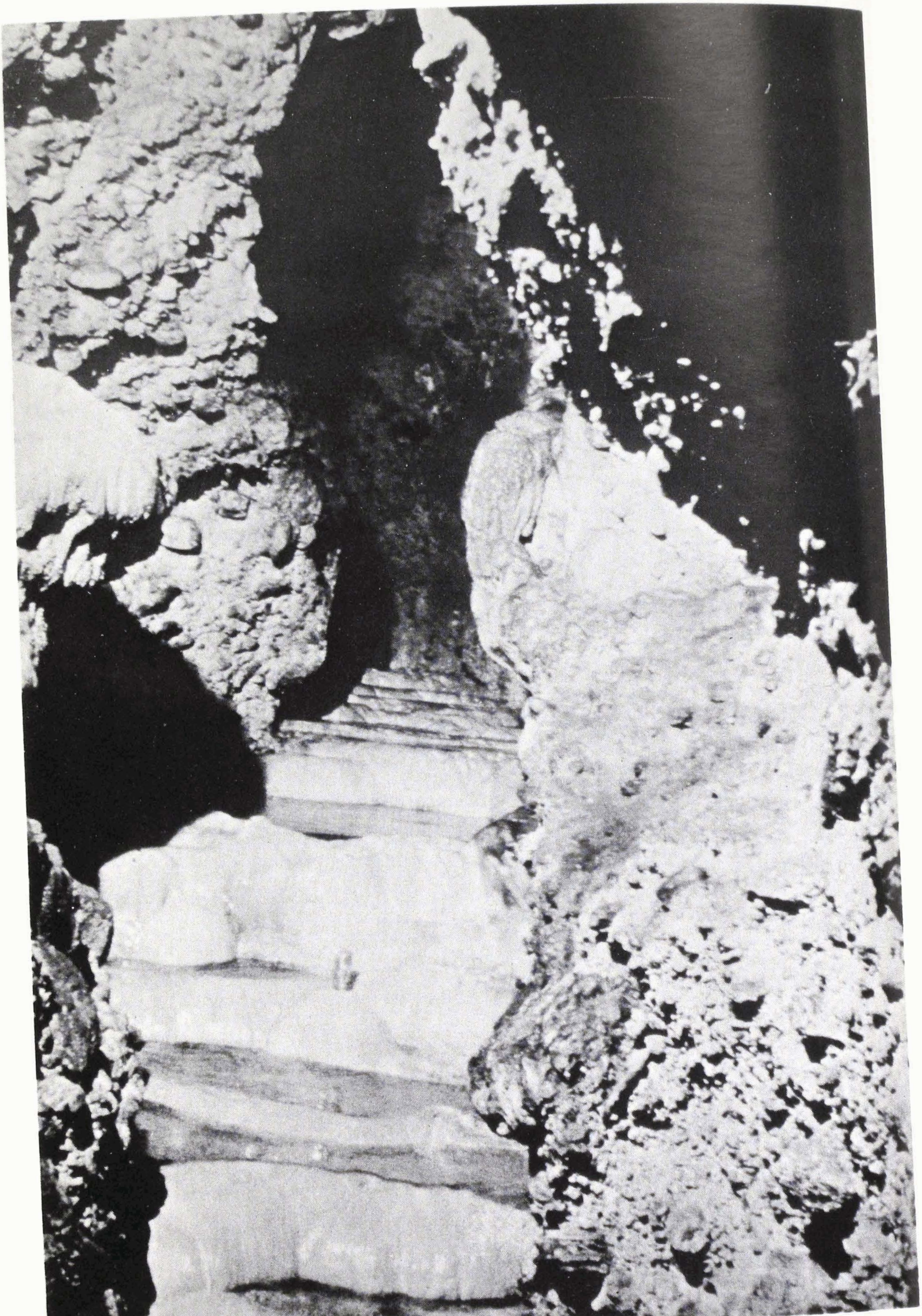
The source of the tufa springs appears to be percolation water passing down through the boulder clay. There are no sinkholes as allogenic streams maintain their surface courses. The percolation water passes down and along through the boulder clay and reappears on the surface where the cliffs of the Ghattekhola basin are retreating headward through both limestone and till. The greatest concentration of risings, Kursangmo, is at the head of a deep subsidiary cwm-like basin.

Once initiated, percolation drainage is most efficient through the more calcareous layers of till, and a large proportion of the carbonate dissolved by this water is redeposited at the surface springs to form the tufa banks. The process of chemical deposition appears to be taking place simultaneously with mechanical erosion of the finer fractions of the boulder clay. At present deposition of tufa is dominant outside the cave, and, in the cave, is taking place without any erosion by the stream. However, exposures of bevelled surfaces in banded tufa, and the existence of the abandoned dry cave above the present streamway, indicate that erosion has been the dominant process during more than one stage in the past.

The formation of massive tufa is clearly restricted to a very narrow zone adjacent to the exposed surface, and it appears that the balance between erosion and chemical deposition is a very fine one, probably controlled largely by climatic variation, as indicated by recent changes of process.

Streams rising from the tufa covered till slopes at Kursangmo.

The west entrance to Kursangmo Cave.



Gour Passage in Gupteswary Cave.

GUPTESWARY CAVE, KUSMA

J. M. H. Coward

The village of Kusma is situated on the bank of the Kali Gandaki River, at 28°12'N, 83°39'W, about 18 miles west of Pokhara. The village lies at an altitude of about 3000' on a half-mile wide terrace, 700 feet above the Kali Gandaki River. Paleozoic quartzites and phyllites crop out on the hillside and many ripple marked quartzites are used decoratively as flagstones for the paths in the region. The terrace upon which the village is situated is composed of boulder clays, loosely consolidated and in places with a calcareous cement; these are interbedded with horizons of glaciofluvial material of similar composition. Gupteswary Cave is well known in Nepal as a Hindu shrine, and enquiries in the village soon produce a guide who knows the way to the cave. It lies about 1000 yards west of the town in the side of a dry gulley (see survey), which is tributary to the Kali Gandaki.

Cave Description

The cave is a resurgence discharging a small stream (about 10 galls/min on November 8th, 1970). It is developed on two main levels – an active streamway, and, along most of the cave, an abandoned higher level, generally 10-30 feet above the stream. A few feet from the entrance a ledge leads up to a small chamber, containing some fine formations. A difficult traverse continues in the roof for about 100 feet to more decorated chambers containing a number of bats, though it is easier to walk along the streamway. One hundred feet from the entrance a number of rimstone pools are developed across the passage. The first ten of these are about three feet wide and six inches high, but are followed by a series with each one up to four feet high. Several pebbles, mostly about one inch across, which must have fallen from the conglomerate roof and walls, are cemented in the rimstone dams.

The streamway continues up to the Temple Chamber. A steep scree slope leads up to a group of stalagmites, the largest of which is almost 20 feet high and is known to the pilgrim visitors as the shrine. At the end of Temple Chamber, the passage closes down but a small crawlway about six feet above the floor leads to a tight canyon passage and further on to a boulder strewn chamber. The water emerges from an impassable boulder choke, but a short passage leads back to the Top Chamber. This chamber contains a few formations, although the floor is generally of mud and breakdown; a few bats were also observed here.

Cave Morphology and Genesis

The cave is developed in the loosely cemented boulder clays. This material is extremely soft and pieces of the wall may be easily broken off by hand. In many places along the cave, pebbles, up to six inches across, stick out from the softer matrix of the walls. A sample of the boulder clay taken from the cave wall above the rimstone pools, gave a porosity of 32% and a vertical permeability of 2·5 gals/day/ft^2 (at 20°C). The permeability value puts the material in a "poor aquifer" class, but it is still capable of transmitting large quantities of water, and the permeability is many orders of magnitude larger than the primary permeability of a typical cave-bearing limestone (10^{-6} gals/day/ft^2). The section exposed in the cave is not homogeneous, and several lenses of finer and coarser conglomerate are visible in the walls, presumably having somewhat differing permeabilities. There is no direct evidence of a more permeable layer near the roof, nor of a less permeable layer near the floor, though the roof of the Top Chamber does appear to be stratigraphically controlled.

The cave has developed entirely from a vadose stream, with the water probably originating from seepage through the boulder clays of the terrace. The cave is formed nearly underneath a dry gulley, which itself probably follows a line of weakness, but the reason for the vertical position of the cave is not proven; it may relate to either a previous level of the Kali Gandaki River or to a broad lithological variation in the terrace sediments.

It appears that solution was not the only factor in the formation of the cave. A test on the sample shows that only 27% by weight is acid soluble (mainly calcium carbonate), 36% is siliceous cemented sandstone, 18% is phyllite, 1% white quartzite and 18% fines of less than 1mm diameter including mica, quartz and clay minerals. The calcareous cement was dissolved out along the length of the cave, leaving the unconsolidated sediment which was then mechanically removed from the cave.

The rimstone pools near the entrance are now showing some signs of resolution, as some small notches are visible in some of the dams. Consequently the cave has gone through at least five major stages of development. The first genetic stage was erosional when the large high level chambers and roof sections of the passages were formed. This was followed by a stage of clastic infilling, which was then largely removed during a third, erosional, stage when the present vadose stream canyon was formed; isolated patches of sediment are now found adhering to the walls of the high level passages but are absent in the lower canyon passage. A fourth stage resulted in deposition of the flowstone and rimstone barriers, and the contemporaneous fifth stage is re-eroding the latter.

The present average rainfall in the area is about 50 inches a year, with a marked seasonal distribution (25 inches fall in the July and August monsoons, but only about ¼ inch falls in November). The heaviest rains fall in the hottest season, and, in spite of the lowered solubility of CO_2 in water at elevated temperatures, the high CO_2 content of the soil air (due to plant activity) will result in very aggressive water, making solution of carbonates rapid.

It is possible that during the first erosional stages of the cave development the climate was cooler and wetter than now, resulting in a lowered soil CO_2 content, lowered water hardness and slower cavern development but with less possibility of the water depositing flowstone in the cave. The uneven distribution of rainfall, resulting in periods of high water and flooding, would allow the released fragmental material to be washed out of the cave quickly.

During the fourth, depositional, stage, the water must have become over saturated to deposit the calcite. Water seeping through the soil becomes enriched with CO_2 due to the higher partial pressure of carbon dioxide (pCO_2) in the soil air, and is then capable of dissolving larger amounts of carbonates than if in contact with the atmosphere where pCO_2 is about 3×10^{-4} atms. As the water seeps down, it dissolves calcite, and probably reaches the cave somewhat undersaturated but at a higher pCO_2 than atmospheric. When the water comes in contact with cave air it will lose (or possibly gain) CO_2 until finally the pCO_2 in the water is equal to that in the cave air, and, as it loses CO_2 the water will become relatively more saturated, until if it becomes oversaturated, deposition of flowstone will start.

In Gupteswary Cave, there is very little flowstone in the stream above Temple Chamber. The restricted ventilation above the crawl could well result in fairly high pCO_2 in the air around Top Chamber, which limits the amount of CO_2 that the water can lose, and prevents oversaturation. The stream was found to have a total hardness of 135 p.p.m. (as $CaCO_3$) in Temple Chamber, which, at 15°C, at saturation is in equilibrium with a pCO_2 of about 3×10^{-3} atm. (Thrailkill, 1968). Thus the air in Top chamber may have such an enrichment of CO_2. However in Temple Chamber and below the better ventilation can result in loss of CO_2 by the stream, supersaturation of the water, and deposition of calcite.

Extensive flowstone occurs on the floor of Temple Chamber and further down the streamway. Some is also present on the walls near Top Chamber, but this is caused by percolation water which could initially have a higher pCO_2 and contain more carbonates, so be more liable to deposit calcite. Another possibility is that the stream flows under Top Chamber quickly and in a relatively deep channel, so equilibrium may take some time and distance to be reached, while the percolation water on flowstone will have more opportunity to approach equilibrium.

Some formations occur in Temple Chamber and all appear to be still active, although the rimstone dams further down the cave are being eroded. Five drips in Temple Chamber gave hardnesses of 130, 190, 110, 160, and 155 p.p.m. as $CaCO_3$. Three of these drips are harder than the stream and may be expected to be depositing calcite, but the two with the lower

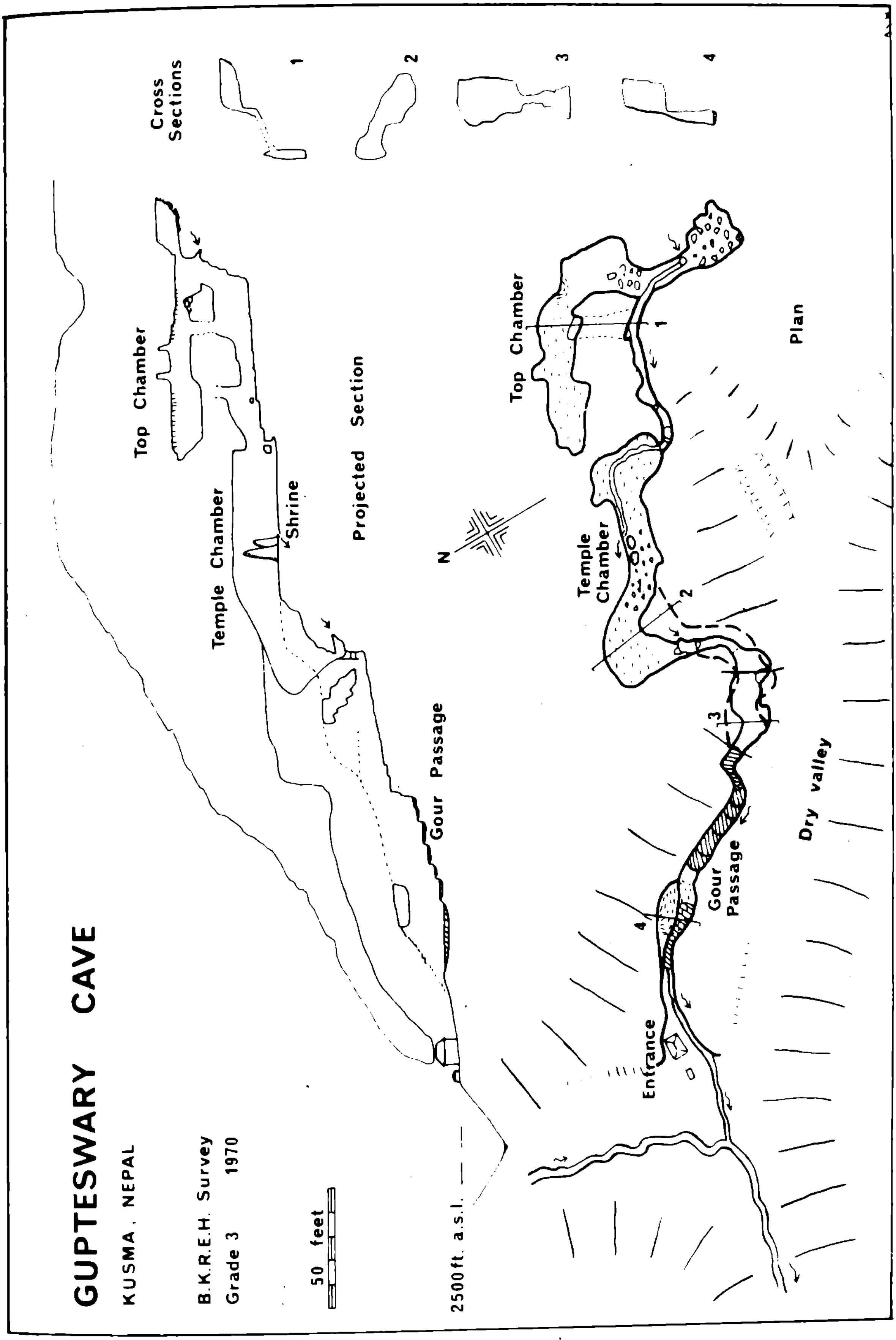

GUPTESWARY CAVE
KUSMA, NEPAL
B.K.R.E.H. Survey
Grade 3 1970
50 feet
2500 ft. a.s.l.
Cross Sections
1
2
3
4
Top Chamber
Temple Chamber
Shrine
Projected Section
Gour Passage
N
Top Chamber
Plan
Temple Chamber
Dry valley
Gour Passage
Entrance

Figure 12.

hardnesses could both be depositing calcite if the pCO_2 in the air is small.

A stream near the entrance of the cave, running down an adjacent gully had a total hardness of just 15 p.p.m., which would be quite aggressive.

At present the rimstone dams near the entrance are being eroded. A possible explanation for the resolution is that in winter, when the soil CO_2 will be less due to the reduction in plant activity, the water will become less hard, and near the entrance the water will cool down, and due to the greater solubility of calcite at lower temperatures might become aggressive. The tendency for the cool winter air to move into a resurgence would help to cool the water fairly deep inside the cave. Of course, in summer the opposite effect will take place and deposition could occur, but the balance between stream deposition and erosion is small and several factors, such as floods, evaporation, or air movements can effect the stream saturation. An overall cooling of the recent climate, or the recent cultivation of the terraces above the cave could also result in the stream becoming aggressive.

Conclusion

Although in size Gupteswary cave is insignificant compared to many European or American caves, it has some interesting features. It is formed entirely in the lightly consolidated boulder clays, in contrast to the more usual limestone caves. The cave has developed in at least five phases, and some tentative predictions about former climatic conditions can be drawn. One can assume that the climate was cooler and wetter during cave formation and probably warmer and drier during the deposition of the flowstone, than at present. However, further work in the cave would have to be carried out in order to confirm these ideas.

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CAVES AND KARST OF THE POKHARA VALLEY

A. C. Waltham

Extending over about 50 square miles the Pokhara Valley is a well cultivated, relatively densely populated region economically centered on the town of Pokhara situated near its western margin. Most of the area is almost perfectly flat, being interrupted only by a few isolated monadnocks and the deeply incised gorges of the many rivers which traverse the plain and converge to drain out as the Seti Khola river. The altitude of the plain is about 2500' (see figure 13).

The main geological structure of the valley is a thick accumulation of almost undisturbed Pleistocene sediments which have built up to a depth of at least 200 feet, though their base is nowhere visible. Underlying the Pleistocene sediments and also forming the monadnocks and surrounding hills is a highly folded, faulted and sheared series consisting mainly of phyllites, impure quartzites and basic metavolcanics, locally covered by talus and lateritic soils.

The uppermost bed in the Pleistocene succession is a 50 feet thick unit of conglomerate, whose relative resistance has resulted in the preservation of the largely undissected stratimorphic form of the Pokhara Plain. It is a coarse badly sorted conglomerate with many cobbles up to 6 inches across, consisting dominantly of sandstone, though pebbles of phyllite, garnet gneiss, basalt and limestone are present together with many fragments of non-calcareous organic remains. The matrix cement is made up of about 50% of calcite with an equal proportion of quartz of fine sand grain size.

Beneath the conglomerate, the dominant lithology is limestone. This is a generally thin-bedded, yellow, friable, calcilutite which appears under the microscope as an extremely fine-grained, almost featureless mass of calcite. Carbonates form about 55-80% of the rock, the remainder being mostly angular grains, about 0·05mm across, of clear yellow quartz, together with accessory micas and organic fragments; the dolomite content is low, only 6% in the sample analysed. The only fossils present are delicate and unidentified non-calcareous insect remains. There is no chert present, though foreign pebbles are widely and randomly scattered through the rock; some bedding planes contain an abundance of ripple marks and swirl structures. The limestone must be largely detrital in origin.

Distributed through the limestone are thin horizons of conglomerate and sandstone. Rarely more than about five feet thick (except the conglomerate caprock) they rapidly thin out at various places. The sandstone varies considerably in grain size and even contains a few scattered cobbles; graded bedding, variously oriented current bedding, ripple marks and quicksand structures are all common, and it has a significant iron content colouring it pale red or, more commonly, yellow. By volume it consists of about 50% rounded quartz grains, mostly about 0·15mm across, with small amounts of biotite, muscovite, magnetite, epidote and organic fragments and a large proportion of limonitic clay and calcareous cement.

All the Pleistocene rocks are barely lithified, being friable and still highly porous. They clearly represent a phase of deltaic and lacustrine infilling of the Valley and have since been hardly disturbed; there is no appreciable dip and joints are only widely dispersed even though the area is in an active earthquake zone.

Karst Features

The main feature of the topography is the level plain, now forming a wide terrace, developed on the top of the conglomerate caprock, which being only partly calcareous is rather poorly karsted. However its resistance to erosion has resulted in the spectacular nature of the series of river channels which cut across the valley floor.

At the southern margin of the terrace the drainage all collects to form a large surface river flowing along the contact of the Pleistocene and the basement rocks, for most of its length about 200 feet below the general level of the plain. Tributary to this watercourse are at least six major rivers which cut right across the plain and have incised deep, narrow gorges. These have vertical or overhanging sides, due to the resistance of the caprock, and the floors of some are covered by huge blocks of conglomerate. Clearly much of their development has been due to underground erosion of the limestones and subsequent collapse of the conglomerate roofs into quite sizeable caverns. Further evidence of this process is provided by the fact that much of the present drainage is underground for short distances, e.g. in the Harpan River Cave, and many of the present resurgences are at or near the heads of upstream retreating gorge sections. Various stages of development have been reached by the different rivers; the Harpan Khola river goes entirely underground beneath only a very shallow surface channel, while the upper part of the Seti Khola (near Pokhara) maintains a long surface course on the floor of a relatively wide gorge. Downstream the Seti Khola also goes underground, leaving dry a spectacular ravine about 150 feet deep and only a few feet wide; clearly, in this case initial downward incision of the surface stream took place far more rapidly than underground development, and the caprock's resistance has prevented any valley widening by normal processes of slumping. The river resurges at the downstream end of the ravine and then flows down a wide gravel floored gorge — a normal fluviatile feature which cannot owe its development to cavern collapse, as in the case of the Harpan River gorge. Between the Harpan and Seti rivers, a group of large springs feed into the Phusre Khola; they are located at the foot of the backwall of an impressive cove, and there is only a shallow dry gulley above this. Morphology of the river valleys east of the Seti Khola has not been shown on figure 13 as it was not examined in detail; however, brief observation from an aeroplane showed that they are similar to, but less spectacular than, the gorges in the west.

The limestone is rarely seen on the surface in the Pokhara Valley, the main outcrops being on various minor terraces within the gorges, owing their origin to a combination of lithological controls and variations in erosion processes. Well developed but vegetated pavement occurs around Mahendra's Cave, though in the Harpan River area the pavement is very degraded.

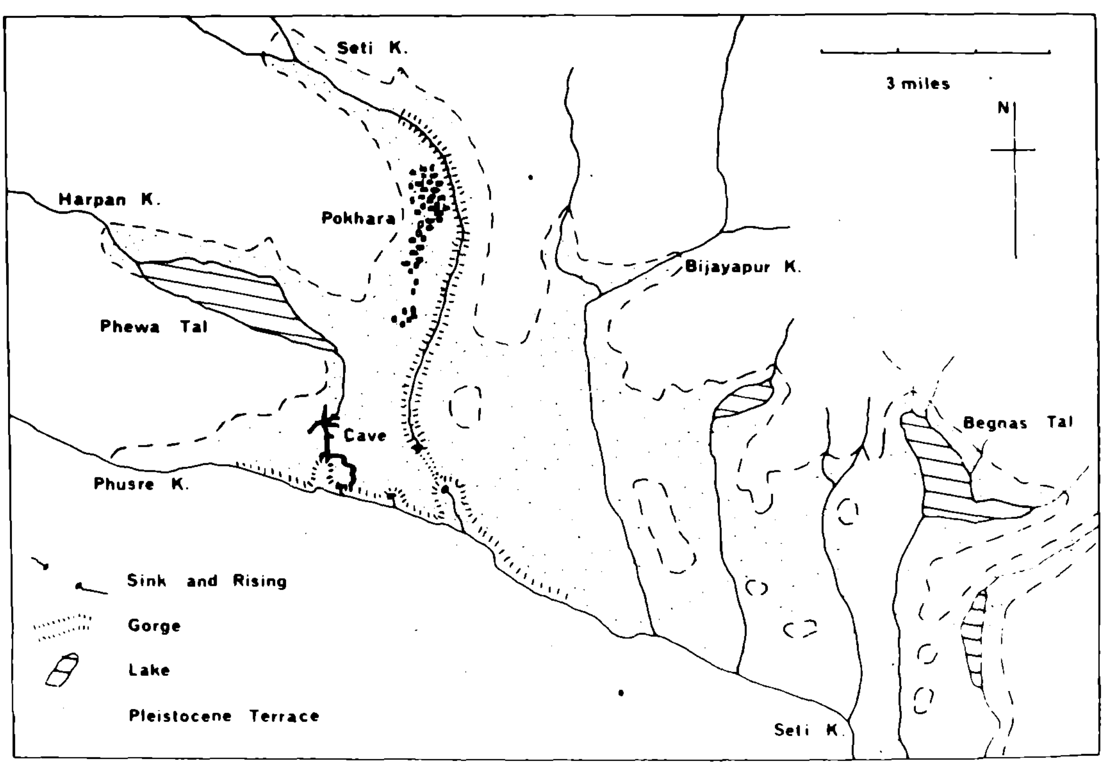


Figure 13. Sketch map of the Pokhara Valley. Morphological details not shown to the east of the Seti Khola.

Dolines are rare and small and mainly occur near the edges of the gorges where there is some concentration of seepage due to the steep hydraulic gradients. A noticeable exception is the large collapse doline which leads into the Harpan River Cave (see below). A number of open rifts also occur near the gorges but are formed by progressive collapse and bear little evidence of solution.

There are numerous caves in the limestones, but due to the presence of the conglomerate caprock nearly all the entrances occur in the floors and sides of the gorges. Mahendra's Cave is only one of a number in the side of the Seti Khola gorge north of Pokhara. Though their passages are generally large in cross section, none of these is longer than about 300 feet. Undoubtedly many long and large caves exist in the Pokhara Valley, but at present the only important explored one is on the Harpan River.

The Harpan River Cave

Located about three miles southwest of the town of Pokhara, the Harpan River Cave is easily found as it passes directly under the main road. The river flows out of the Phewa Tal lake in a broad, shallow, gently graded valley, within which the river has now incised a more restricted gulley rarely more than 30 feet deep. Just above the road-crossing, the entire flow of the river is engulfed by a long deep rift, the Main Sink of the Harpan River Cave, which lies across the gulley. Below this, the dry gully continues (see survey on fold-out before end paper) and so does the form of the shallow valley (one side marked as terrace on survey). The resurgences are at the foot of the cliffs marking the southern margin of the Pleistocene terrace, where all the Pokhara Valley drainage collects. Cut back into the cliffs is a deep boulder-strewn gorge, which the dry gulley enters at its head.

The fairly simple system of cave passages is clearly shown on the survey. The Main Sink consists of a series of pitches, totalling 150 feet in depth, which carry the river into the high Main Rift, and the quantity of water makes entry here impossible without tedious and difficult traversing above the cascades. At the first junction the water all turns into the impressive Terminal Lake, 30 feet wide and of unknown depth and yet still bearing a strong current toward the sump at its end.

Further west along the Main Rift there is another junction. From the North, Dripping Inlet carries a small stream down a low, wide, muddy passage which contains a shallow pool along most of its length and sumps after about 400 feet. To the West, a roomy high level passage continues the line of the Main Rift. Its size is interrupted by a short bedding plane section, after which it opens up into a classical collapse passage, increasing further in size till it is over 50 feet wide. The cross section (no. 6) shows how the roof is steadily collapsing along closely spaced bedding planes and a corresponding pile of rubble is accumulating on the floor. At its present explorable end the collapse has worked through to the surface, where a perfect doline has formed in the rice-paddies – Collapse Entrance, which is the easiest way into the system.

South from the main junction is Canals Passage, for most of its length having a cross section of about 15 feet square, and containing long pools of standing water, of varying depth and in places with deep potholes in the floor. All the water is remarkably clear and the entire passage is devoid of any sediment or stalactitic formations. The profile is broken by two roomy collapse chambers, the southerly one being distinctive for its large blocks of flowstone of unknown origin distributed through the boulder pile on the floor.

The canals terminate abruptly at a fork in the passage. To the west a smaller dry passage divides again and a number of loops lead up boulder and sand piles into West Chamber. There are two large passages leaving the chamber, one choked after a few yards by more collapse and the other leading into daylight in the floor of the gorge. Directly opposite is another much larger entrance leading straight into Bat Chamber. This is another high collapse chamber with a block-strewn floor, and part way along it a ladder is needed to descend an overhanging step. Back underneath the ladder, a boulder slope leads to the fork at the end of Canals Passage, while ahead daylight is again seen at Pool Entrance, where swimming is the only way into the open air, again in the floor of the gorge.

An opening in the eastern corner of Bat Chamber leads into South Passage, of similar proportions to Canals Passage. However there is much less water in it and the first part has a gravel floor; there is also a profusion of generally small stalactities decorating the bedding roof. The only aven in the system carries a small trickle of water, not far before Boulder Hall – another large collapse chamber. Beyond here a stream flows out of a choked side passage and sinks into a sump after a short distance, just before a large choke. Daylight is visible and an easy climb up through the blocks leads to Jungle Exit, situated on a ledge overlooking a boulder slope covered in dense vegetation; it is almost impossible to find this entrance from the outside.

The gorge is floored by a chaos of huge boulders which make walking very difficult. The sides are mostly vertical or overhanging and contain at least two small caves. Just above Pool Entrance a vertical step in the floor can fortunately be climbed via a boulder pile, to gain access to the other two entrances to the main cave. Above these the gulley floor contains some deep, dry potholes, but exploration was restricted by the resident population of snakes.

The progressive upward collapse which is taking place in the cave chambers makes the position of the Pokhara to Tansing road – just half of Nepal's present system of main roads – somewhat unusual. Above Road Chamber, there is nearly 80 feet of rock supporting the road, and half of this is conglomerate, so the road is perfectly safe at present; however the rate of collapse is an unknown factor and considering the seasonal flooding and susceptibility of the area to earthquakes, the future of the road is by no means certain. The other place where the road crosses the cave is supported by just over 100 feet of rock.

Hydrology

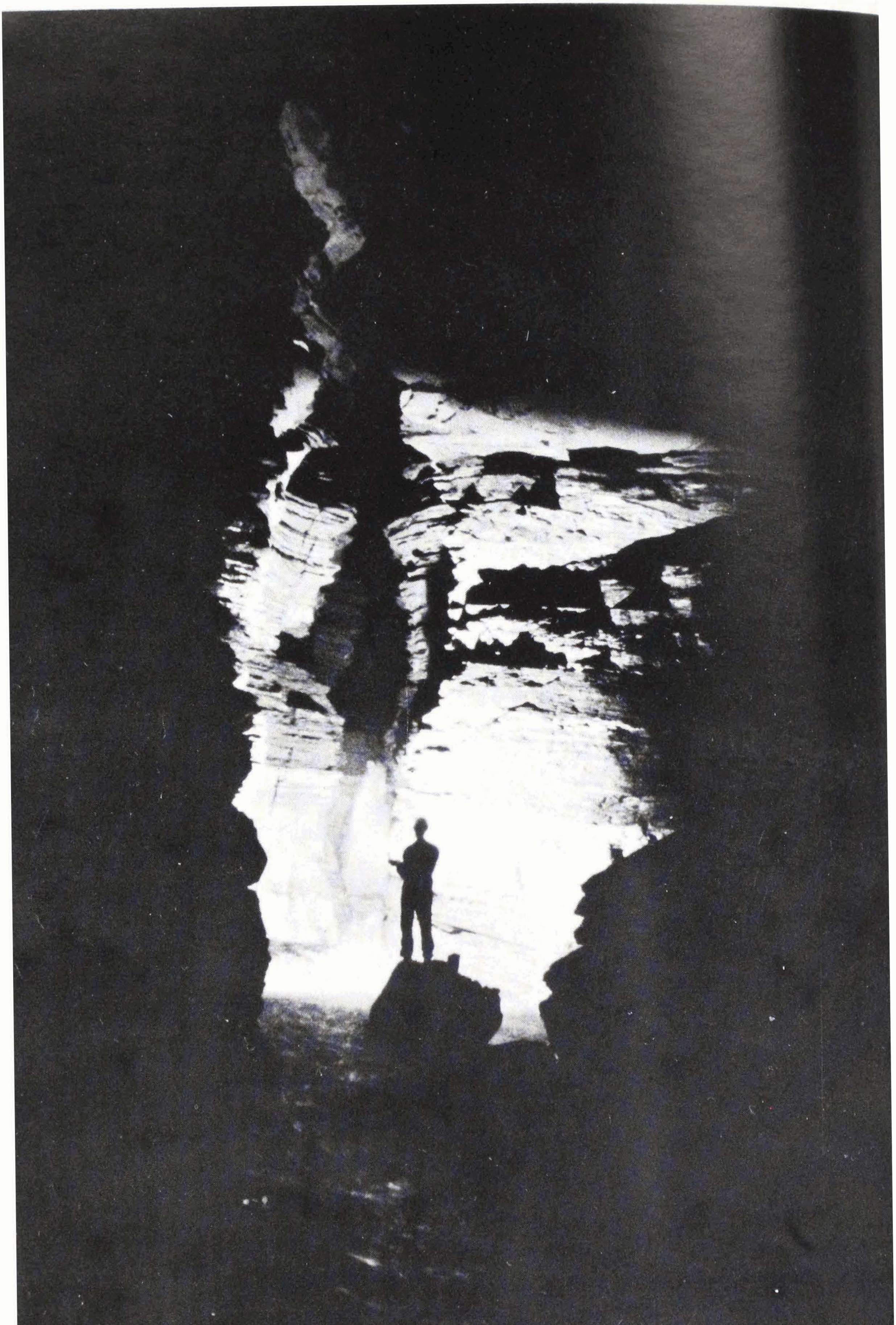
Normal base flow of the Harpan River is between 10 and 15 c.f.s. where it enters the Main Sink, and its underground course can only be followed into the Terminal Lake. Rhodamine B was inserted at the sink and reappeared at the risings a third of a mile to the south. After 90 minutes the dye emerged strongly from the Main Risings, with about a third of the input flow of water. Ten minutes later the dye appeared, though rather weaker, from the risings below Jungle Exit, these having about the same flow. After 115 minutes dye also appeared at a number of other risings up to 400 feet further downstream. No dye was seen at the risings in the gorge.

It is debateable how much the divergence of flow is due to separation and filtering through the boulder piles behind the risings, or due to development of branching discrete cave passages. The dye flow-through times suggest that the Main Risings have a separate feeder from well into the solid limestone, while the other risings are probably only separated by boulders.

The source of the water entering Dripping Passage (about 1 c.f.s.) is unknown but it would be unlikely if at least some of it is not derived from seepage through the river bed upstream of the sinkhole. Similarly it is unknown how the 1 c.f.s. flow seen for a short distance near the end of South Passage relates to the main river's underground course, though it is most likely derived from a separate source to the east.

All the above flow figures must be drastically altered when considering flood conditions which are brought about during each monsoon season, and also when the sluice gates are opened on the small dam across the Phewa Tal lake. Under these conditions, the flow of the Harpan River rises to around 1000 c.f.s. The sink still manages to engulf the entire river – an incredibly impressive sight – but almost the whole cave fills to the roof with rushing water. Testimony of this is provided by the massive logs found at the extremities of all the passages, and also by the roaring noise heard, in flood conditions, at Collapse Entrance. Only rarely does the sink overflow, but almost every monsoon water can be seen spouting out of numerous fissures in the gulley downstream of the road. The gorge itself floods to an average depth of about 30 feet, and the then submerged Pool Entrance becomes a major resurgence with water bursting up

The Main Sink of the Harpan River Cave.



The main rift in Harpan River Cave.

under considerable pressure into the "gorge lake". As the floods recede, large amounts of standing water are left in the cave, most noticeably in Canals Passage. There is no surface outlet to the water, and it is only added to by a few minor drips, but it does somehow seep away, as the level was observed to fall about five feet in two weeks in November 1970; possibly it dries out almost completely further into the dry winter season.

Development of the Harpan River Cave

There are two distinctive environmental aspects which must have strongly influenced the processes of cave development – the barely lithified nature of the limestone and the exceptional seasonal variation of hydrologic stage.

The limestone has an extremely high primary porosity and permeability, as it has never been overlain by thicknesses of other rock and is still a rather friable sediment. For the same reason it has few well developed joints in it. The rate and pattern of percolation of water through the rock appears to vary, but in general is highly diffuse; there are very few drips of water entering the cave, yet the water in Canals Passage is able to drain away quite rapidly, presumably via a series of micro-fissures.

Erosion of the conglomerate contrasts sharply with that of the limestone. Many of the cave passages are roofed by conglomerate (see surveyed sections), suggesting that it may have had a greater initial permeability, so that groundwater flowed along the base of the conglomerate beds and only cut the cave passages into the limestone as a subsequent process. Further evidence of this development is provided by some roof half-tubes cut in the conglomerate. However, the overall erosional resistance of the conglomerate has been of utmost significance where it has acted as a firm caprock to the Pleistocene sediments; without its presence the Harpan River Cave would never have developed, as the gorge would have cut back at a greater rate than caves could develop in the soft limestone.

Bedding plane development has been important throughout the geological succession and the stratigraphic position of the Terminal Lake (see section 7) must be due to lithological variation within the limestone, locally of greater influence than the conglomerate contact. Jointing is generally minor, with the one exception of the single fracture zone in which the Main Rift is developed; this has been essential to the cave development as it has provided an easy and efficient route for the water through the conglomerate and into the limestone.

Under the present hydrologic regime, most of the cave is clearly epiphreatic. However, it is difficult to distinguish the past environments of development as the profiles of most of the cave passages are strongly influenced by collapse. There are no roof pendants and floor relicts are only present in Dripping Inlet; fluting is absent and scallops are very poorly developed. In some parts of Canals Passage the preservation of half-tubes in the roof indicates the dominance of downward vadose erosion after an initial phreatic phase, and this seems to apply to most of the main passages. But in addition to the surveyed passages, there are a number of small unexplored, but enterable, openings, the majority of which are perfectly developed phreatic tubes.

Clearly, the height of the phreas must have been controlled by the level of the surface drainage to the south. Initial hydraulic gradients are difficult to estimate but must have been considerable, though the influence of the conglomerate bands would have made the aquifer far from uniform. The fact that dolines are present only near the gorges or southern margin of the Pleistocene, and their total absence over most of the Pokhara Valley, indicates the necessity of steep hydraulic gradients to initiate efficient karstic drainage. The presence of the Main Rift joint at just the suitable distance back from the southern marginal cliffs was an overriding factor in the cave's initiation. The influence of base-level, as opposed to stratigraphic control, is difficult to estimate in the case of development of the main low level passages in the cave.

An additional problem is posed by the location of the chambers in the cave. Their present forms are almost entirely dictated by patterns of roof collapse, but this collapse must have taken place, over time, into an initial, lower, even larger cavity. There seems to be no geological structure controlling the positions of these initial erosional chambers, excepting the presence of the joints through the Main Rift and possibly also through the Collapse Entrance chamber. All the other chambers, however, are on bends in the passages, and it appears that normal accentuation of sideways erosion of water channel bends may have formed an initial low wide chamber; the low strength of the roof would then have resulted in rapid upward collapse over a wide span.

In conclusion it is possible only to suggest a broad outline of speleogenetic development of the Harpan River Cave. The high rates of erosion and collapse seem to suggest rapid formation of the cave, particularly when it is appreciated that the limestone was only formed during the Pleistocene. However, the diversity of passages indicate a reasonably long and complex history, but one which cannot be absolutely dated without further geomorphological work.

Undoubtedly, the first passage to form was from the Main Sink along the Main Rift to Collapse Entrance. This entrance itself is a younger development, and the passage must continue beyond here, probably to the choked passage leading into the west end of West Chamber. From here the initial route is into Bat Chamber, and then through Pool Entrance, and along the line of the Gorge where all trace has now been lost. The age of South Passage is debateable; it may have formed as a distributary of this initial system, or may have developed later simultaneously with Canals Passage.

Massive collapse into these earliest passages would then have formed the Gorge, the erosion of which must have been aided by water pouring down the gulley. The gulley itself was probably only formed during a period of periglacial conditions, and its youthfulness is indicated by the way it has cut down into the passage between Bat and West Chambers.

Canals Passage appears to represent a second major phase of cave erosion and Dripping Inlet was probably developed at the same time. The main resurgence at this time would have been Pool Entrance, and this would only have been relegated to a flood course by the later development of the present permanently active passages, most of which are still inaccessible. A second climatically influenced interphase, during or after the period of formation of Canals Passage, may be indicated by the blocks of stalagmite in Flowstone Chamber, as calcite speleothems do not appear to be forming on this scale at the present time.

This sequence can only be postulated as an outline and it is to be hoped that further exploration of this and other similar caves in the Pokhara Valley will lead to a fuller understanding of their rather unusual morphology. The surface geomorphology also warrants further attention as the weakness of the rocks has permitted rapid erosion and relict features provide a good record of past stages of development.

BATS AND THEIR PARASITES FROM SOME CAVES IN KASHMIR AND NEPAL

G. N. J. le Patourel

With the expedition working in two contrasting areas of the Himalaya, the initial hope was to study the adaption of cave insect populations in relation to the altitude and climatic conditions, since extremes of both factors may be found in the Himalayan region, and large differences in both the size and composition of insect populations would be expected as a consequence. In the event, however, few caves were found – certainly not enough to make such a comparative study feasible – and while a certain amount of collecting was undertaken where this was possible, the results were, on the whole, disappointing. Consequently, most effort was devoted to a study of ecto- and endo-parasites of bats living in the caves of the regions studied.

Bats were caught with mist nets, anaesthetised with chloroform, and ectoparasites found by searching the fur. Blood smears were taken, and the animal perfused with 10% formal-saline. A small sample of liver was cut out and preserved, together with the ecto-parasites, in 10% formal-saline. The bat carcase was similarly preserved in formal-saline. Specimens of bats and ecto-parasites were identified at the Natural History Museum, London, and the ectoparasites and blood and liver samples were examined by Professor P. Garnham at the Dept. of Parasitology, Imperial College, London for malarial parasites. The collection has been presented to the Natural History Museum where it is available for study.

Kashmir

Three species of *Myotis* were captured in Kashmir. A single specimen of *Myotis myftacinus hipalensis* was caught in the open at Kukarnag, near Achhabal, soon after dusk. This specimen did not appear to harbour external parasites and the blood smear showed no obvious endoparasites.

A large colony of *Myotis longipes,* estimated at about 2000 individuals, was found in the Bhamajo Bat Cave, near Achhabal, at an altitude of 5470′. The temperature in the cave was 18°C with a diurnal variation of about 2°C (September). Small quantities of guano on the cave floor yielded a few insects (not yet identified), but there were no animal remains under the colony and it seemed probable that rats (one of which was seen in the cave) removed any carcases.

The bats were observed to move around the cave during the day, being found predominantly in the furthest chambers during the morning, but congregating on a broad slab of rock, from where dim light from the entrance was visible, towards dusk. Very soon after sunset one or two bats could be seen flying towards the cave entrance and then looping back. This process continued, with the bats getting nearer and nearer to the entrance until, about quarter of an hour after the first movement was seen, the bats began to emerge from the cave, first in ones and twos, and finally as a continuous stream.

Nineteen specimens of this species were taken. Typical dimensions were:

Forearm: 38mm   Head and body: 47mm

Most of these bats harboured external parasites, both fleas and Nycteribiid flies (not yet identified).

Two Protozoa have been found in blood specimens of this species. The first, *Polychromophilus melaniferus,* is a malaria - like parasite, and is known to be associated with *Myotis.* This identification extends the known geographical range of the parasite. The second parasite has been tentatively identified as a species of *Achromatus.* The liver samples and ectoparasites are at present under investigation to find other stages of the life-cycle of these parasites.

A second species of *Myotis* was found in this cave, now identified as *Myotis blythi.* This bat remained in the cave after emergence of *M. longipes.* About fifteen specimens were observed and one was taken by netting. No parasites, either internal or external, were found on this specimen. The dimensions were:

Forearm: 55mm — Head and body: 75mm

Nepal

Although many species of bat were observed in this semi-tropical region, ranging from fruit bats with wing spans of over five feet to small vespertilionids at an altitude of 14,000', only two species of bat were caught in the caves. These were *Hipposideros armiger armiger*, and *Rousettus leschenaulti leschenaulti*, (Photos). Both were found in the Harpan River Cave, south of Pokhara.

The fruit bats (R. leschenaulti) had a very large colony in Bat Chamber (see survey). They were quite active during the day, a small number continually flying about the chamber and fighting for roosting sites with a shrill squawking which was audible some distance from the cave. Most of the specimens captured were parasitised to some extent. The following external parasites have been identified so far:

Thaumapsylla breviceps orientalis Smit	(Syphonaptera; Ischnopsyllidae)
Eucampsipoda latisterna Schurmans-Stekhoven	(Diptera; Nycteribiidae)
Nycteribosca pygialis Jobling	(Diptera; Streblidae)
Acari;	
Argas sp. (larvae)	(Argasidae) – tick
Ancystropus indicus	(Spinturnicidae)
Meristapsis lateralis Kolenati	(Spinturnicidae)
Bechsteinia sp.	(Anystidae) – probably predatory

The dimensions of a typical bat were:

Forearm: 75mm — Head and body: 95mm

Several specimens of the Indian Horseshoe bat *(Hipposideros armiger armiger)* were captured on emergence from the main sink of the Harpan River Cave. The colony was located in the roof of Road Chamber close to the entrance. The bats were difficult to catch because their acute echo-location enables all but the stragglers to easily avoid the net. The dimensions of a typical specimen were:

Forearm: 90mm — Head and body: 90mm

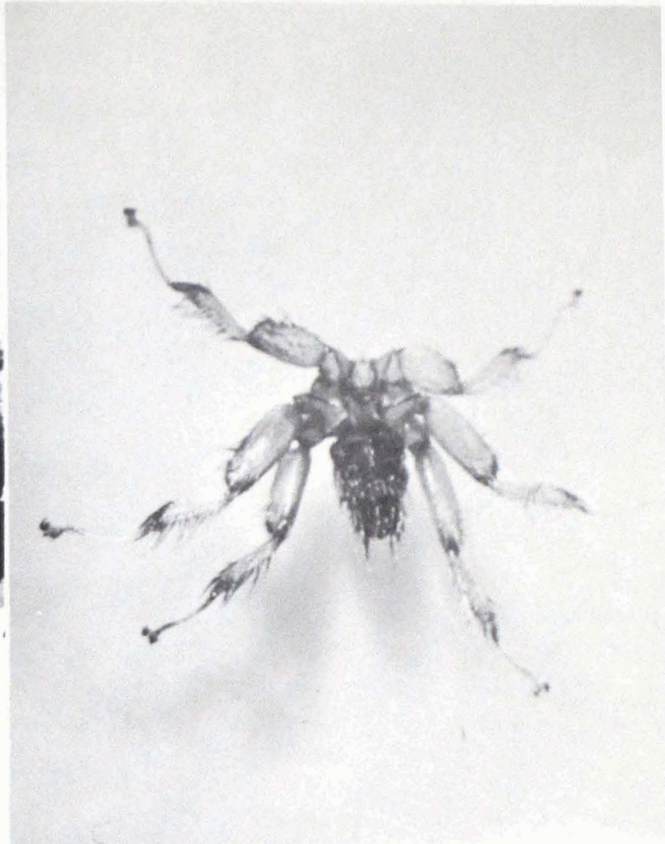
The following ectoparasites have been identified so far:

Whartonia spp., probably *brennani* Hiregander and Bal, (larva)	(Trombiculidae) – chiggers
Nicteribosca pygialis Jobling	(Diptera; Streblidae)

Blood smears from both species of bat are still under investigation. It is interesting that the colonies of *H. armiger* and *R. leschenaulti*, though separated by several hundred yards of passages which sumped during the monsoons, were both parasitised by the same (winged) Streblid.

Unfortunately, both colonies were situated directly above the flood stream routes in the cave and no appreciable guano deposits could develop. Some hunting spiders (not yet identified) and small flies were also caught in the cave.

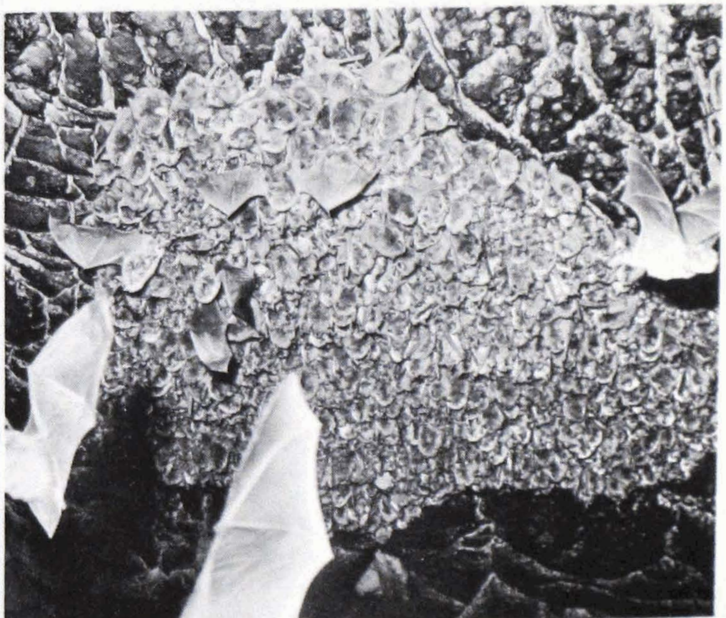
Hipposideros armiger armiger.

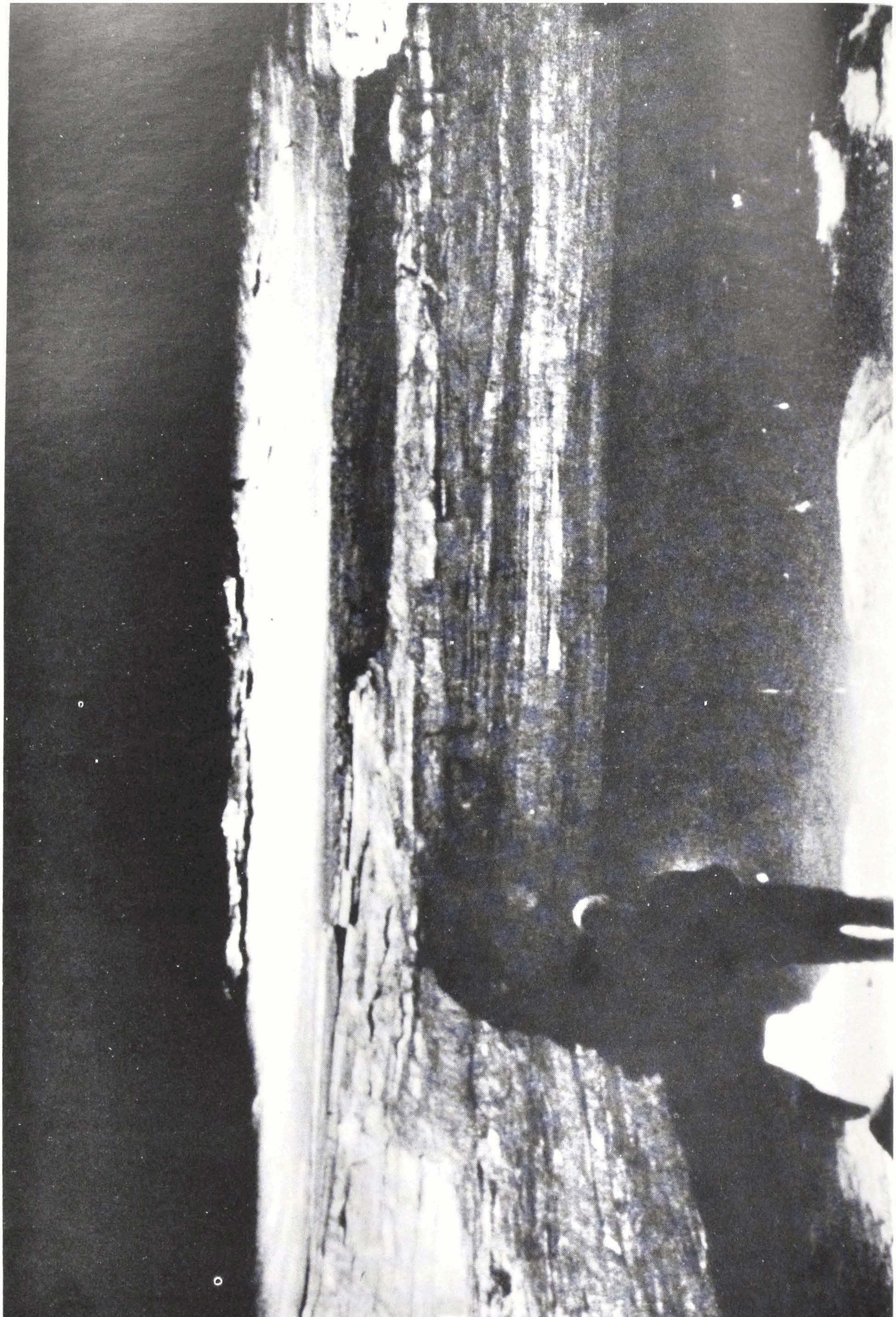


Nycteribosca pygialis Jobling from *Rousettus* sp. Body length = 3 mm.

Rousettus leschenaulti leschenaulti.

Myotis longipes colony in Bhamajo Bat Cave.





THE FUTURE OF HIMALAYAN SPELEOLOGY

A. C. Waltham

Two British expeditions looking for caves in the Himalaya during 1970 have considerably increased our knowledge of the karst of this immense mountain range. While the bulk of the Himalayan mountains consists of metapelites, there is considerable variation in the geology, perhaps most noticeably due to the existence of a number of granitic intrusions and a variety of limestone sequences. At present, however, there appears to be a disappointing lack of well developed cavernous karst on a scale which is found, for example, in parts of Europe. The following assessment of the situation and prospects is based upon our own observations, together with numerous personal communications, including discussions with the members of the British Speleological Expedition to the Himalayas 1970, and two particularly useful references – a literature survey of Indian caves by S. A. Craven (India Underground, Himalayan Journal v.29, 1969) and the geological volume by A. Gansser (Geology of the Himalayas, 1964, Wiley). Locations of the known Himalayan karst features are shown on the map (figure 14).

It is difficutl to delimit the western end of the Himalayan Ranges, but it is possible to include the Band-i-Amir valley in Northeast Afghanistan. This valley is famous for its five beautiful lakes situated in an area of barren desert, and the lakes are confined behind massive natural calcite dams, so they resemble huge gours miles long and hundreds of yards wide. The surrounding rocks are very impure muddy limestones and no streams enter the lakes, though water does flow out over the lowest dam only to sink in a broad gravel plain. It is most likely that the dams owe their origin to calcium saturated thermal springs rising in the lake floors, and the existence of no more than small fissures in the surrounding limestones holds little promise for the discovery of significant caves.

South of Afghanistan, the mountain ranges of West Pakistan, continuing through Baluchistan to Iran consist dominantly of limestone. The Sulaiman area is one of the highest parts and is built of impressive thick-bedded Mesozoic limestones which have, however, never been seached for caves.

In the far north of Pakistan, the village of Chitral is surrounded by massive limestone plateaux. The valley floor stands at an altitude of about 5000' and the nearby mountains are over 20,000', though this is by no means all limestone. The geology of the area appears complicated with both Devonian and Cretaceous limestones occurring, but separated by faults. There are various dubious and conflicting reports about caves in the area, some even claimed to penetrate the hillsides for hundreds of feet. Though nothing conclusive is known, the Chitral area looks quite promising speleologically and might repay investigation.

Further east, the famous mountain of Nanga Parbat contains a record breaking cave. Explored in 1963, the Rakhoit Peak Cave is only 240 feet long, but is situated at an altitude of just over 21,800'. It appears to be formed in one of a number of marble bands no more than 100 feet thick in a region of migmatitic gneisses, and at present it is more than twice as high as any other known cave in the world.

Over the border into India, the limestones and dolomites of the Vale of Kashmir were investigated by our own expedition and are described in this report. Numerous short caves are known, the one at Amarnath being the most famous, and the karst risings at the head of the Vale are evidence of spectacular underground drainage. However, the prospects for finding major cave systems in the area seem very poor, probably the best hope being offered by a chance entry into the caves behind the main risings.

The Simla and Chakrata regions have been the objectives of the earliest and most prolonged speleological investigations anywhere in the Himalaya. This is probably because of their proximity to Delhi and Dehra Dun, though the altitudes of the limestones are proportionately low – the highest are at only 10,000'. A number of different calcareous beds are known, of varying age, and scattered outcrops are found along the foothills as far as Jammu.

Around Simla there are many outcrops of rather impure dolomites and these were

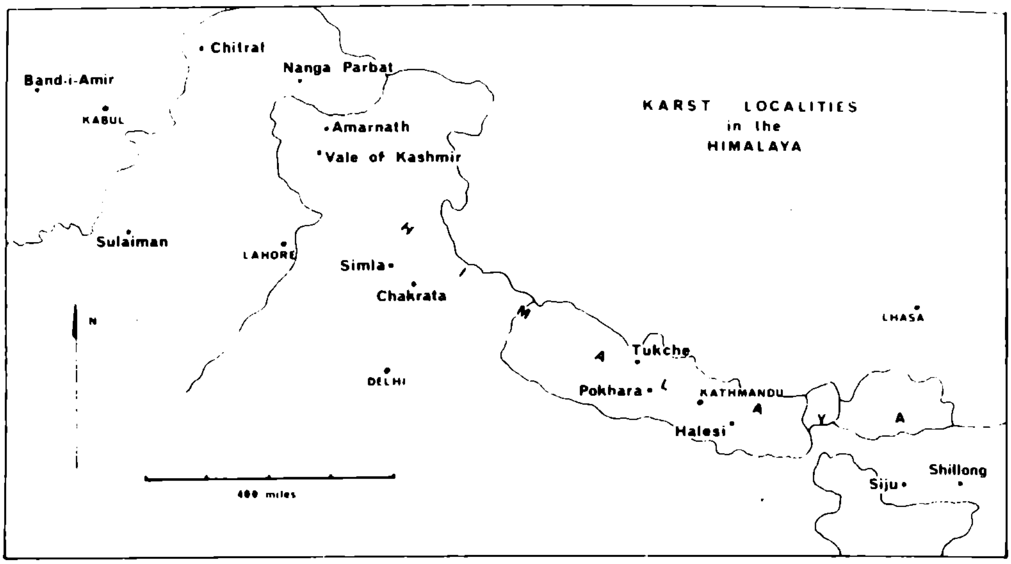


Figure 14.

examined in 1970 by the British Speleological Expedition to the Himalayas. However, few caves were found. West of the town, near Arki, only a few inactive, but decorated, chambers were discovered, but another region 20 miles north of Simla was more interesting. There, a number of very well decorated tectonic caves were found, though all are small, and solutional erosion had been minimal; one cave containing an abandoned streamway was followed to a depth of 200 feet, about 300 feet from the entrance, and, like all the other caves in the area, huge numbers of bats live in the chambers.

The Deoban Limestone, lower Paleozoic in age and highly dolomite and cherty, occurs in the area just north of Chakrata. Glennie and Leakey explored most of the potholes in the region and their work is well summarised by Craven (op. cit). Vertical shafts are commoner than horizontal cave development, and the deepest pothole is Lower Swift Hole at an altitude of 8575', consisting of a fine 243' ladder pitch into a large chamber. It appears that the full caving potential has not yet been reached in the Chakrata region.

Further east these same limestones continue in outcrop and become progressively thicker and reach a maximum in the Tejam area. Here the lower Paleozoic limestone is over 17,000' thick, mostly thick bedded but locally dolomitic or siliceous and containing interbedded phyllites. There appears to be no record of geomorphological work here and the possibility of cave development cannot be ignored.

Not surprisingly, Nepal contains the highest limestones in the world. The most spectacular outcrops are of the Nilgiri Limestone in the Tukche region, which are described elsewhere in this report, though their lack of significant cave development is disappointing. The Nilgiri limestone does continue in outcrop both east and west of Dhaulagiri and Annapurna, but is at its thickest and purest in the Kali Gandaki region, so offers little speleological prospect in the other areas.

The scant geological literature on Tibet reveals an abundance of limestone. There, political barriers will deter the most enthusiastic cave searcher, but in a few places the geological boundaries have overlapped the political boundaries. One such place is at Jomsom just north of Tukche, but there the Jurassic limestones are well karsted but almost completely non-cavernous (see this report). A similar but more famous locality is the summit of Mount Everest — as yet unvisited by cavers — but even here the Everest limestone is described as 1500' thick, arenaceous, schistose and dolomitic — three properties which should ensure a complete lack of karst features, beside the doubts concerning cave development at such altitudes.

At Pokhara, the Harpan River Cave with its length of 4850 feet is now the longest cave in the Himalaya (see this report). Formed, together with a number of other caves, in Pleistocene limestone flooring the Pokhara Valley, there are most likely numerous other cave systems of similar magnitude in the Valley and in other geologically similar ones nearby. Even Harpan River Cave could easily be extended, probably to well over a mile, by a little digging, or more exploration of the smaller passages which our expedition did not have time to examine.

Outside the Pokhara region, the only large cave known in Nepal is situated at Halesi, about 7000′ above sea level high on the east bank of the junction of the Dudh Kosi and Sun Kosi rivers. Famed for its religious festival during the birthday of Ram, the Halesi cave consists of a large passage 100 feet long leading to a chamber 150 feet in height, width and length illuminated by an opening in the apex of its roof. The cave is now isolated in the crest of a ridge, and so completely inactive, as is another single chamber cave further along the ridge. The country rock appears to be a dolomitic limestone and the potential of the area is unknown.

Again it is difficult to delimit the eastern end of the Himalaya, but it is worth mentioning the caves in the jungle clad hills of Assam, though strictly they are geologically more related to the karst regions of Burma (see also Craven, op. cit.) The Khasi and Jaintia Hills around Shillong abound in karst features and include the Mawsmai Cave, at least 1000 feet long containing a large amount of water and not yet fully explored. Further west the Siju Cave contains at least 3900 feet of large passage, some still active.

In conclusion the Himalaya do not offer as good prospects to the speleologist as might be hoped. The world's deepest block of limestone – the Nilgiri Limestone on Dhaulagiri – is almost completely non-cavernous, and, without the rather unlikely event of a completely new limestone area being discovered sometime in the future, the best hopes for deep caves probably now lie in the Chitral area. Undoubtedly many miles of cave passage await discovery in Assam and the Pokhara Valley regions, but these will not include deep caves on a scale appropriate to the grandeur of the Himalayan mountains.

EXPEDITION LOGISTICS

EQUIPMENT

The expedition equipment was by necessity a combination of that normally used for caving, camping and high-altitude mountaineering. Much of the equipment was of a type familiar to cavers and climbers, though more than usual attention was paid to weight with regard to the caving gear. This report only mentions some of the most useful or interesting items of our equipment.

With a long overland journey followed by marches with porters, packaging was of prime significance. We were fortunate to be able to pack everything in fibreboard boxes, 28" x 18" x 12", supplied by Bowater Stevenson. These were excellent, standing up to four months use when normally loaded with 60-70lbs, though some took much more weight. Their size permitted convenient attachment to a pack frame, and they were easily assembled with adhesive tape which also rendered them waterproof.

Spending four months under canvas made us appreciate our tents and the 2-3 man Vango Force Ten proved excellent. The large zip-up bell to the flysheet in front of the tent door was invaluable in hard weather conditions; the tents are very spacious and yet still light enough to carry long distances. However, we did also have one Peter Hutchinson nylon tent, weighing only 5lbs – complete. Its incredible weight made it unbeatable in the mountains, where it stood up to the weather well, though it is small and indeed not intended for long-period camping.

We did most of our cooking on Optimus petrol stoves which served us admirably, and petrol was more obtainable than paraffin on parts of the journey. In Nepal, however, we mainly used wood fires – our sherpas were expert with them – but firewood normally has to be purchased or carried long distances, so stoves were still useful, especially above the tree-line.

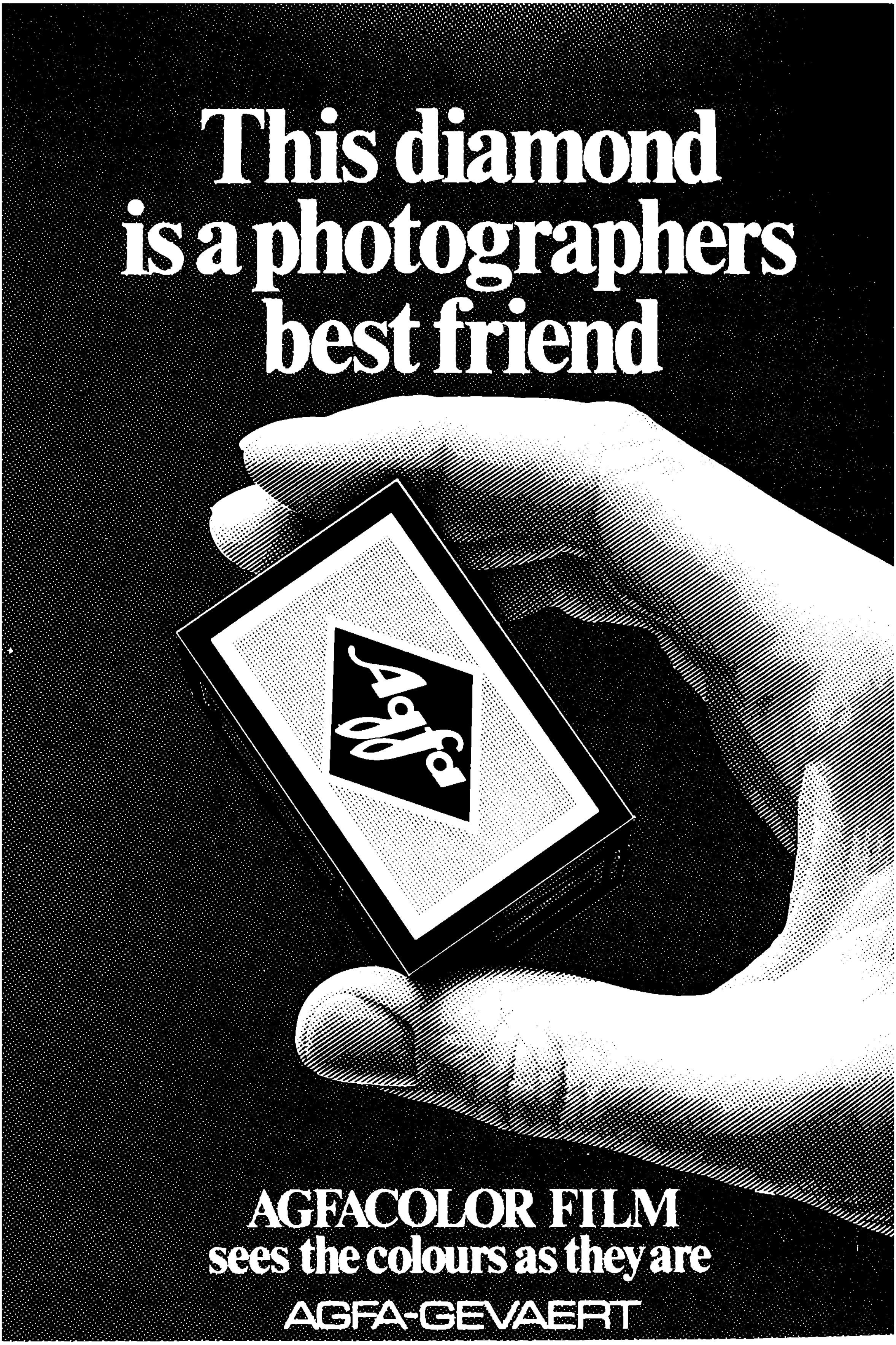
Among our mass of camping equipment, two items which were noteably successful were the Plysu plastic containers and the Morfed tin openers; both were very adaptable and proved very popular as "backsheesh" on a number of occasions.

Undoubtedly our most successful equipment were our Damart Thermawear garments. Made of P.V.C. and designed as underwear, we wore them nearly all the time, the vests often on their own so that they almost became an expedition uniform. They were incredibly warm and, being made of synthetic fibre, didn't absorb water; furthermore their fleecy lining was more comfortable than many natural fibres. The vests and mittens were particularly popular and the socks were unbeatable for mountain walking which involved repeated immersions through fording streams.

Beside the Thermawear, our main means of combating the cold were exceptionally warm Peter Hutchinson duvets, Pick sweaters and Hutchinson sleeping bags; for outer garments most of us wore Helly Hansen anoraks and Levi jeans. All of these were excellent and none of us suffered from the cold, either high in the mountains or on the very cold return journey.

Old clothes and ladders would not have been adequate for caving, and we had plenty of experience to guide us over selection of our underground equipment. The clothing problem was simply solved – Damart Thermawear long sleeved vests, long johns and socks are unbeatable. Over these we wore goon suits when necessary, and Lawtex nylon boilersuits which would be almost indestructable as long as they are stitched with nylon and not cotton. Our rope was all polypropelene, and our ladders came from Caving Gear, made by the pin and araldite method and proving most successful. We economised on slings and belay by taking Tiger Web tape which is far more adaptable, besides being stronger when weight is considered.

Our survey instruments, suitable for high speed mapping in hard conditions above and below ground, were selected with great care. Compasses and clinometers by Suunto are without equal, being strong, light and, with their built-in lamps, by far the easiest instruments to use in caves. The hole in the centre of the dial, which is liable to let in mud and water, was easily


This diamond
is a photographers
best friend
Agfa
AGFACOLOR FILM
sees the colours as they are
AGFA-GEVAERT

sealed with canada balsam; however, this is no longer a problem as the 1971 Suunto instruments have a holeless one-piece dial, with the option of improved sealing round its edges, and these new versions must be the ultimate in cave surveying equipment. Rabone Chesterman fibron tapes proved indestructable, and, for wet caves, waterproof notepads were made at home from Permatrace and Fablon. For water tracing we used, with some spectacular results, Fluorescein and Rhodamine B supplied by Canadian Industries.

We had a variety of cameras, as the expedition did not buy new ones but each member brought his own. In the end most photographs were taken on a Pentax, a couple of Zeniths and a Praktica; having interchangeable lenses, some weight-saving was possible when a pair of photographers went on a long trek together. Nearly all our photography was on colour reversal film, and on the surface we used Agfa stock, the results from which were excellent and pleased every expedition member. Underground we used Ansco 500, the greater speed saving complicated multiple-flash techniques in large chambers. Ilford monochrome film was successfully used for some of the scientific photography, and some of it was processed in the field. The unusual lighting conditions, in the mountains especially, made exposure meters almost essential; most of us had them on our cameras, but Phil found a Weston meter excellent for his cine and still photography. (A.C.W.)

FOOD

It is perhaps appropriate that the task of organising an expedition's food should fall to the expedition member displaying the greatest tendency to corpulence. It is also immensely useful if he has a wife willing to type several hundred letters to those firms on whose generosity expeditions so heavily rely. Such, at least, was our experience. Having to organise the two tons of rations required for about 1500 man days is quite a considerable job in itself. What is more, it would have proved an extremely expensive one had it not been for the assistance of some forty British companies whose gifts accounted for about two-thirds of the total cost of our food.

From the very beginning, the expedition decided to take virtually all the food it would require both on the journey and in the mountains rather than have to buy any locally. This decision was reached for a variety of reasons, the main one being to ensure the health and fitness of the expedition members by providing a well balanced and adequate diet and, hopefully, avoiding some of the more esoteric local bugs. Other equally practical reasons included convenience and the fact that sufficient quantities of food for a group our size would not always be available in some areas.

Naturally, our food requirements varied somewhat according to our level of activity and the temperature, moreso the latter. On the whole, though, the daily quantity of food actually consumed did not vary very much.

The main difference in our requirements was more in the form of the food we took than the absolute quantity. For about half of the expedition the weight of the food was of comparatively little consequence as we were near our vehicle, but while away from the vehicle, i.e. in Nepal, the weight of our food was by far the most important consideration. Thus, on the journey and for most of the time in Kashmir we used mainly canned foods which are more convenient, frequently cheaper and offer a greater variety than dried food, whereas in Nepal we used dried foods almost exclusively. What limited canned foods were taken into Nepal were just 'luxury' items to add variety.

The planning of our diet was carried out on a highly pragmatic basis. The basic guidelines were to make sure there was enough – in quantity and variety – and, thus, we decided what we liked, how much we liked and, checking this against cost and against sample diet sheets prepared by past caving and mountaineering expeditions, arrived at the following breakdown of food required per man day.

ITEM	*Ozs/Man/Day*	
	Journey & Kashmir	*Nepal*
Cereals	1·0	1·0
Dried Egg	1·3	1·3
Canned Fish/Sausages/Ravioli/Beans/Tomatoes	5·0	–
Margarine	2·0	2·0
Jam/Honey/Marmalade/Syrup/Cheese etc.	2·0	2·0
Crispbreads	0·5	1·5
Biscuits and Cake	2·0	2·0
Chocolate/Sweets/Nuts & Sultanas	1·0	2·5
Soup	1·0	1·0
Dried Potato	1·5	1·5
Pasta/Rice	2·5	2·5
Canned Meat/Fish	6·7	–
Dried Meat/Fish	–	1·6
Canned Vegetables	4·0	–
Dried Vegetables	–	1·0
Canned Fruit	5·0	–
Dried Fruit	–	2·0
Instant Whips etc.	1·0	1·0
Dried Milk	1·5	1·5
Coffee/Tea/Chocolate etc.	0·4	0·4
Lemonade Powder	1·0	–
Sugar	4·0	7·0
Salt	0·2	0·2

NOTES i) On average, dried meats reconstitute to about 3 or 4 times their dry weight and dried vegetables and fruits to about 4 to 5 times their dry weight.

ii) The second and third items on the list which were breakfast foods were not eaten every day.

iii) Naturally, we had a fair selection of condiments and also flour, Complan and some Horlicks rations.

These quantities proved to be reasonably generous – which was appreciated by most people – our only serious errors being in having about twice as much margarine as we required and too little sugar in the mountains where sugar consumption can easily rise to 10-12 ozs. per day.

The dominant pattern was for us to eat two meals a day, breakfast and supper. On the journey, and particularly when it was hot, breakfast often consisted of just 'spreadies' – jams, marmalade, honey, syrup, meat pastes, cheese, etc. While travelling, we generally bought local bread which, east of Turkey, is more like chapattis, but in the mountains we used crispbreads exclusively. When it was colder, and particularly in the mountains, porage frequently featured on the breakfast menu and there was sometimes other cooked food. We used dried egg quite a lot in Nepal and although there is quite a knack in preparing it successfully, the results can be very good.

In the course of the day, it was usually just sweets and sweet biscuits, of which we had an excellent selection. In the mountains we also had chocolate and our own mix of sultanas, peanuts and walnuts. These rations were sometimes supplemented by more spreadies and cans of sardines or meat by those out for fairly long days.

Supper was the main meal of the day and almost invariably consisted of soup, a main course of potato, pasta or rice, meat and vegetables (both either dried or canned) and a dessert of

The expedition was supplied with

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table dispenser.
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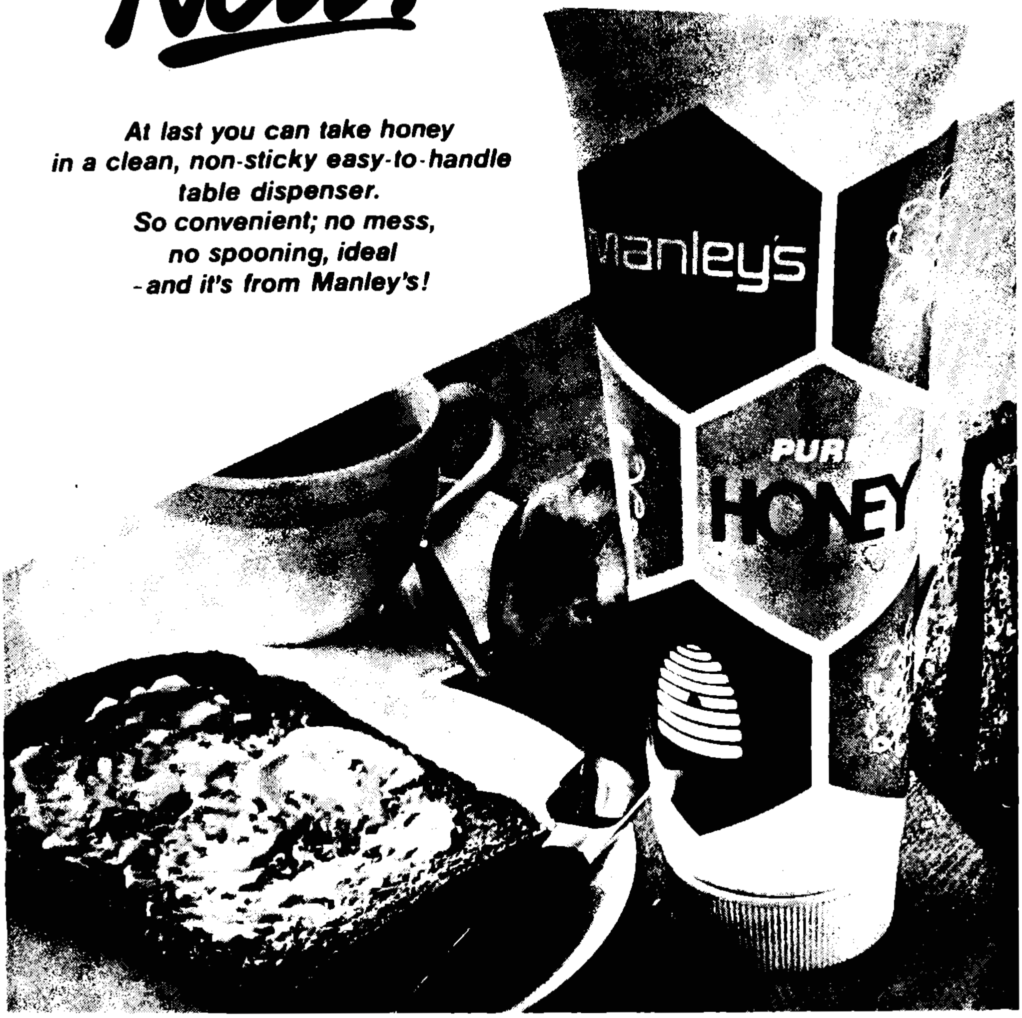
no spooning, ideal
-and it's from Manley's!



THE NEW TUBES ARE READY FOR FUTURE ENDEAVOURS –

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BERINSFIELD, OXFORD.

canned or dried fruit (often with custard) or instant whips.

As for drinks, the expedition had a good selection of hot drinks including tea (both instant and in tea bags), coffee, chocolate and Ovaltine. We also had some canned beer (which did not last too long), whisky and lemonade powder, the latter being particularly good on the hot outward journey when it was most important to drink quite a lot.

Some of the products that proved extremely popular included:

– Meusli and Weetabix

– The 2½ oz. packets of A.F.D. beef and mutton which make up to approximately ½ lb. of meat – expensive but extremely good (Batchelors Catering Supplies)

– A.F.D. Smoked Fish Dish and Dried Cabbage (Heinz-Erin)

– Buttery potato, A.F.D. egg and instant custard (Ranks Hovis MacDougall)

– Canned fruit cakes (Park Cake Bakeries)

– Morton's Pie Fillings (Beecham Foods)

– Penguin biscuits - which travelled very well (United Biscuits)

– Dried fruit salads

– Chicken dinners (Yorkshire Egg Producers)

As far as packaging goes, we left most of the foods we had in their original containers. Some items like salt, sugar, dried milk and custard we transferred to polythene jars with either screw-on or snap top lids. These, particularly the latter, were most effective. Also we packed some items like flour, sugar, milk and dried egg, whose original wrappings were not very strong, into large metal tins until they were required.

In spite of the length of time we were away and the extremes of temperature we experienced, all the food remained perfectly good. The only items that suffered at all in fact, were the canned margarine and the chocolate we had with us. Even so, these were perfectly edible and what damage they suffered did little to affect the members' rate of consumption.

Future expeditions to Nepal might be interested to note that:

i) Beef and margarine should not officially be taken into Nepal. This rule is not always strictly applied, however, and it may be possible for expeditions to get permission to take these foods into Nepal if the members undertake that they alone will consume them.

ii) When this expedition was in the Tukche area, potatoes and parota flour were available at reasonable prices. Sugar, however, is of low quality and comparatively expensive as it has to be carried up from Pokhara. (J.S.C.)

MEDICAL

The medical supplies for expeditions to relatively isolated parts of the world are inevitably the results of compromise. The medical officer is frequently, as in the present case, not medically qualified, and there is no point in taking drugs for conditions which he is unable to diagnose; on the other hand, one must be equipped to deal with contingencies which one knows beforehand are unlikely to occur. The medical kit was based on that suggested in "Exploration Medicine", by E. G. Edholm and A. L. Bacharach, and met these conditions reasonably well; for the walk in to the Kali Gandaki Valley the quantities of some of the items could be reduced on the basis of the experience of the previous few weeks and the resulting medical kit could be carried by one porter. This was further broken down into two-man kits for people to take on reconnaissance trips.

Before leaving England everyone was vaccinated against cholera, tetanus, smallpox, typhoid, paratyphoid, and polio, and in addition we received gamma-globulin injections shortly before departure. Those members likely to be handling animals were also vaccinated against rabies.

On the drive to India, the commonest ailment was diarrhoea (usually non-infective) and for this Kaopectate and Lomotil (with or without Neomycin) were given. Occasionally Streptotriad, Thalazole or Imperacin were necessary. Headaches were treated with Calpol or

Nembudeine, stomach-ache with Mylanta. Hibitane ointment or iodine solution were useful for minor cuts and burst blisters, and more serious wounds were treated with Synalar-N or Myciguent ointment. Ephedrine ointment was used on bee-stings. Sore eyes caused by the dust were bathed in 1% Boric Acid solution, and sore throats were countered by Hibitane tablets, which, however, were not very effective – a more soothing blackcurrant-flavoured lozenge would probably have been more suitable. Constipation was treated with Cascara Evacuent, and we took Paludrine as an anti-malarial.

Once in the mountains most people required sleeping tablets and one or two Doriden were usually adequate. Redoxon and Dayamin or Abidec were taken to maintain vitamin requirements. Contac was found to be very effective for colds, and together with Calpol was very popular with the porters. Occasional bouts of toothache usually responded to oil of cloves. We used Uvistat Cream and Uvistat-L for protection against ultraviolet radiation at high altitudes. Nivea cream was useful for minor sunburn.

There were several instances of lack of acclimatisation, but none was serious and all symptoms disappeared when the sufferer descended a few thousand feet. One member fainted while running uphill after a large meal at the end of a hard day. The most serious cases were not in fact expedition members. We heard of a case of broncho-pneumonia and another of typhoid in a village near Tukche and for these gave courses of Imperacin and Compocillin respectively. On the return journey we came across a road accident in Iran in which the driver was trapped in his lorry with a broken leg; the medical officer injected Fortral and supplied Fortral tablets to last until the victim could be taken to hospital.

The problem of sanitation was more easily dealt with when we were camping well away from human habitation as in the Sind Valley. There we could use trench latrines, whereas in Tukche this was not possible, if only because it would have attracted so much attention from the villagers. Consequently there was a greater risk of transmission of infectious diseases. This unsatisfactory situation was partly remedied by the use of Savlon Hospital Concentrate in the water used for washing purposes. Water for drinking was sterilised by filtration using a Berkefeld Filter Pump, which was much more convenient than halazone tablets, which were used only by people away from base-camp.

Generally we were well able to cope with the medical situation. I think that both John and myself may take as a compliment the observation that no-one had been on an expedition before on which they had so much food and so few pills. And it only remains for me to apologise to Tony for not noticing that he had a broken back. (K.W.T.)

TRANSPORT

The expedition had originally planned to use an ex-Army Bedford RL. However, those available were in very bad condition, and so it was decided to buy a Civil Defence RL fire tender chassis and fit this with a body from a breakers.

In April 1970 Tony and Phil went to Raydon airfield to find a suitable fire tender chassis. There were in the same hanger two complete RLHZ fire tenders. As these seemed better suited to our needs, they decided to buy one, and for £440 at the auction room in Colchester the expedition became the proud owner of Lot 743, Bedford RLHZ fire tender PGW 376.

A few days later the vehicle was collected and taken to Kingston-on-Thames for fitting out. Little mechanical work had to be done, as although the vehicle was 16 years old, it had only done 420 miles. Several changes were made to the body. The cab was extended back into a cross locker to make room for eleven seats. The new section of the cab had a soft top, which could be rolled forward in fine weather to give access to a sun deck, where passengers could ride on top of the vehicle. In the centre of the vehicle was a 400 gallon water tank. Our efforts at lifting this out failed, which was probably due to its weight of over half a ton. A local scrap dealer lifted it out by crane and we put in a floor to give a luggage hold. At the back was

a very large pump. This became a major non-ferrous metal mine, which yielded nearly £100, and then a further floor was put in to give even more space.

At departure luggage overflowed the holds and side lockers and was stacked on large roofracks. The vehicle was then so heavy that there was less than an eighth of an inch clearance between the rear springs and the bump stops.

In Germany two rear tyres disintegrated within a few miles of each other. We decided that the combination of load and old tyres was dangerous and £250 later we were on our way with four new tyres. These gave very good service, and only one puncture was experienced during the remainder of the trip.

We experienced trouble with vapour lock which made climbing hills difficult, with frequent stops to cool the engine. The cooling system was not really adequate for the 115°F shade temperatures experienced, especially as there was no shade and the actual temperature was off the top of the thermometer. Cooling was improved by fitting a locally made aluminium six blade fan, and fitting various cooling ducts made from Duckhams tins; these tactics successfully eliminated the fuel problems.

The only mechanical trouble was that in Iran the vehicle started jumping out of third gear. We had the necessary parts flown to Nepal where they were kindly fitted at the British Ghurka Centre, Paklihawa.

On the return journey the vehicle ran beautifully. The only delay was in Afghanistan when the engine froze solid overnight, and took some time to thaw out. Antifreeze bought in Kabul solved the problem of the sub-zero temperatures.

The route we took from England to India is nowadays fairly well known as an increasing number of travellers use it. The roads are continually being improved, so that four-wheel drive is no longer a necessity; we even noticed that over a hundred miles of new road were opened in the time between our outward and return journeys.

As far as Ankara the road is perfectly good except for some very rough stretches on the Zagreb-Belgrade motorway. From just beyond Ankara, there is a choice of routes – north along the Black Sea coast to Trabzon and then inland, or straight through the mountains to Erzerum. The former route is perhaps more interesting and involves some long climbs just after Trabzon, while the inland route is now much improved and undoubtedly quicker. From Erzerum is a good road to the frontier, and then an excellent fast, tar road across Iran to Tehran. Either of these routes through Turkey at present involves about 200 miles of untarred road, but there is a 100% tarred road from Ankara to Tehran via Damascus and Bagdhad, though this is longer and crosses three extra frontiers.

From Tehran there is again a choice of routes – north over the Elberz Mountains to the Caspian Sea, then east to Mashhad along tarred and gravel roads, or direct to Mashhad along the edge of the Great Salt Desert. The latter route contains over 200 miles of very bad corrugated sand road, and all the improvements are at present being made to the northern route, though both roads have their own attractions.

The once notorious road from Mashhad to the Afghanistan frontier is now completely tarred and then the famous wide, fast, empty Afghan roads give an easy drive to Kabul. Beyond here a spectacular new road leads down the Tangi Gharu gorge to the Pakistan frontier, immediately after which is the Khyber Pass. The Pass is poorly surfaced with tar but it is only short (it is closed at night), and the remaining roads across Pakistan are very good.

Lahore is the end of another loop, from Tehran via Isfahan and Quetta. This crosses the deserts of southern Iran and is really a four-wheel drive road, besides being excessively hot in the summer; also the roads in southern Pakistan are rather slower than those in the north.

There is only one open crossing point on the Pakistan-India frontier and this necessitates slow by-roads from Lahore to Ludhiana. From here we turned north on good fast roads to Jammu, but beyond Jammu the road to Srinagar and Kashmir is very slow. It crosses two high passes, is rarely straight for more than about 20 yards and speed is dictated by the ceaseless stream of loaded lorries, even though the surface is generally good. Once in the Vale of

Kashmir we were surprised by the high quality of the roads – narrow but nearly all tarred even to very remote villages.

Continuing towards Nepal from Ludhiana is an excellent road to Delhi and then a choice as far as Lucknow. Probably the best runs direct to Kanpur, but we were drawn by the Taj Mahal onto an alternative route via Agra. This is very good as far as Agra but then only narrow from there to Kanpur, though well surfaced and generally fast, and almost devoid of traffic.

From Lucknow to the Nepal frontier, via Gorakhpur, is on typical second class Indian roads. These are well tarred and quite fast, except for the numerous cyclists and ox-carts; however, they are only single lane and all passing and overtaking is only possible with the use of the dry-earth hard shoulders, which are perfectly good except in the monsoon when they are often deep mud.

Within Nepal the road to Pokhara is new and very good, though very winding to avoid steep gradients. However, nearly every year it is blocked during and just after the monsoon by landslides. 1970 was a bad year; it took a couple of months to clear over 40 landslips, and the ferry was also washed away at Ramdi Ghat – a new bridge will be opened in 1972. (P.J.C.)

ACCOUNTS

The expedition finances are summarised in the balance sheet with this report. Added into the balance sheet are the retail values of the goods donated and the discounts received from manufacturers. This is to give some indication of what such an expedition would cost if it received no support. We did, in fact, receive approximately 70% of the cost of food, 66% of the cost of equipment, 80% of the photographic costs and 12% of the total transport costs. Virtually all the medical supplies were donated.

The total equipment costs are made up of 52% personal equipment (including all items of clothing), 28% camping equipment, 18% caving and scientific equipment and 2% packaging.

Included in the organisational expenses are the cost of a printed leaflet, stationery, postage to manufacturers, etc. We have included only the costs of the reports given to sponsors, as these are a necessary expedition expense; the cost of those on sale are not included, but it is intended that their sales will just cover their cost.

The expedition account was handled by The Chartered Bank Limited, Manchester, who were very helpful. (S.E.C.)

MAINLY POLITICAL

Not surprisingly, one of the most awe-inspiring aspects of planning an expedition like this is the problem of formalities and political regulations. In fact, however, the path through the red tape is quite smooth once the right route is found, and so some of our experiences are related here in the hope that subsequent travellers may more easily find the short cuts.

The bulk of the Himalayan regions are close to some politically sensitive frontiers and so permits are needed to visit most areas. It took us just twelve months to obtain the expedition permit necessary to work in the Kali Gandaki Valley of Nepal. Though the permit can be obtained direct from the Nepalese Ministry of Foreign Affairs, it is much better to work through the British Embassy in Kathmandu. The Embassy staff are familiar with the routine, are willing to help any genuine expedition, and certainly gave us an immense amount of assistance.

Contrary to any information provided by the Indian High Commission in London, a visit to the Vale of Kashmir requires no special permission, though we were just inside a restricted military zone at Baltal and Amarnath. To go into the remoter parts of Kashmir one has to get a special permit which must be obtained through the British High Commission in Delhi.

BALANCE SHEET

INCOME

	£
Expedition Members' Contributions	1170
Winston Churchill Memorial Trust	1490
Mount Everest Foundation	400
Royal Geographical Society	100
Other Cash Donations	60
Value of Manufacturers' Gifts and Discounts	2562
Sale of Lorry	400
Sale of Equipment	448
Miscellaneous	32
	£6662

EXPENDITURE

	£
Food	919
Equipment	2496
Medical Supplies	170
Photography	267
Lorry (inc. modifications and parts etc.)	998
Lorry Insurance	101
Petrol and Oil	433
Ferries	95
Visas	38
Other Transport Costs	228
Porters and Sherpas	401
Personal Insurance	130
Report	146
Import Duty (Nepal)	10
Organisational Expenses	178
	6610
In hand	52
	£6662

10 May 1971

Frontier crossings on the journey out to the Himalaya gave us a variety of problems. Iranian visas are easily obtained at the Embassy in London. However the Afghanistan Embassy in London must be the world's most unreasonable, putting almost prohibitive restrictions on the granting of visas. Fortunately Afghan transit visas are freely available at the embassies in Tehran and Delhi, involving no more than 24-hour delays. We only heard vague and conflicting reports about obtaining these visas in Mashhad and Peshawar, and so avoided the issue for safety.

British nationals do not require visas for India and Pakistan, though everyone needs a road permit to cross the India-Pakistan frontier at Hussainiwala (the only open crossing point). Regulations concerning these have been relaxed recently but we still could not obtain ours from the incredibly inefficient Pakistan High Commission in London. We therefore had to apply to the Pakistan Embassies in Kabul and Delhi, but in each case had to wait only a few hours.

For entry to Nepal two-week visas are freely available in their London Embassy. Similarly long-period visas are no problem as long as one has already a suitable expedition permit; furthermore with such a permit, short visas are easily converted to long visas in Kathmandu.

Customs presented surprisingly few problems, though each frontier crossing took about two hours (once beyond Europe). A carnet is essential for the vehicle, and the person whose name is on this in particular needs a fairly empty passport to take all the rubber stamps. The Nepal customs were the only ones to charge us any duty – on our food – and also charged us a returnable deposit on much of our temporarily imported camping and caving equipment. Keith had some delays importing his gun into Nepal (no other country had provided any difficulty) and we also met two special Nepali customs rules – we were not allowed to take in any beef or margarine.

The only other difficulty we met was with regard to insurance – and only the vehicle provided problems. A Green Card works all over Europe and Turkey, but excludes Bulgaria where insurance is easily obtained at the frontier. No British company will insure for driving in the Middle and Far East, and only in Afghanistan is insurance available at the frontiers. For Iran, Pakistan and India we had to go to an English broker who laboriously fixed up individual policies for each country (though the Indian company covered Nepal), which proved not too expensive but a very long drawn-out procedure. However, it is certainly the most reliable way of obtaining insurance. (A.C.W.)

EXPEDITION MEMBERS

Roger J. Bowser
John S. Carney
Susan E. Carney
Philip J. Collett
Julian M. H. Coward
Mary J. Coward
Geoffrey N. J. Le Patourel
Keith W. Turnbull
Roy G. Turnbull
Antony C. Waltham — *leader*
Janet M. Waltham

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We are especially grateful to the following who made cash donations to the expedition:
The Winston Churchill Memorial Trust, who granted a most generous fellowship to the expedition leader;
The Mount Everest Foundation and the Royal Geographical Society;
British Petroleum Ltd. and T. Bailey Forman Ltd.

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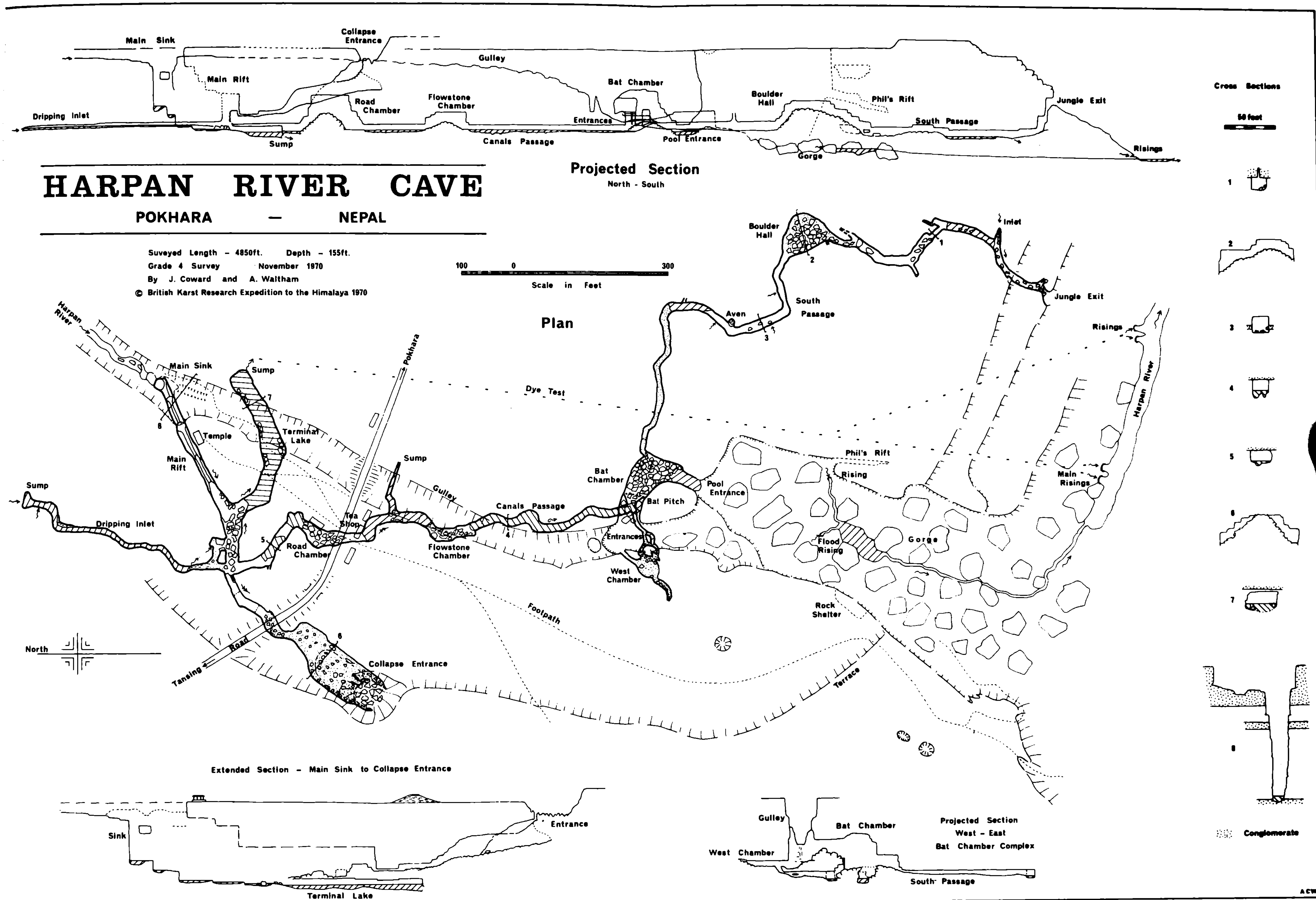
Abbott Laboratories Ltd.
Advance Tapes (Industrial) Ltd.
Agfa – Geveart Ltd.
Allen and Hanburys Ltd.
George Angus and Co. Ltd.
Austin Reed Ltd.
Baird and Tatlock Ltd.
John Bartholomew and Son Ltd.
Geo. Bassett Ltd.
Batchelors Catering Supplies Ltd.
Batchelors Foods Ltd.
Beechams Foods.
Birmetals Ltd.
Black and Edginton Ltd.
Peter Blake Ltd.
Bowater Stevenson Containers Ltd.
G. & T. Bridgwater Ltd.
British American Tobacco Co. Ltd.
British Berkefeld Filters.
B.D.H. Pharmaceuticals Ltd.
British Egg Marketing Board.
British Sugar Corporation Ltd.
Britton of U.K. Ltd.
Brooke Bond Oxo Ltd.
Brown and Polson Ltd.
Bruntons (Musselburgh) Ltd.
Calmic Ltd.
Malcolm Campbell Plastics Ltd.
Canadian Industries Ltd.
Canadian Pacific Railway
James Carr & Sons Ltd.
Alexander Carus & Sons Ltd.
Caving Gear
Chiltern Honey Farms Ltd.
CIBA (A.R.L.) Ltd.
CIBA (Laboratories) Ltd.
Colgate Palmolive Ltd.
Colibri Lighters.
Cooperative Wholesale Society Ltd.
G. Costa & Co. Ltd.
Barry Cottle & Co.
P. B. Cow (Li-Lo) Ltd.
C. Z. Scientific Instruments Ltd.
Dale Products (Plastics) Ltd.
Damart Thermawear (Bradford) Ltd.
E. B. Dive & Co. Ltd.
Dornay Foods Ltd.
Alexander Duckham & Co. Ltd.
A. Gallenkamp and Co. Ltd.
General Aniline and Filme Corporation
General Foods Ltd.
Glaxo Laboratories Ltd.

Grabiner Ltd.
William Grant & Sons Ltd.
Green Giant of Canada Ltd.
Grout & Co.
C. & T. Harris (Calne) Ltd.
Joseph Heap and Sons Ltd.
H. T. Heinz Co. Ltd.
Heinz - Erin Ltd.
Helly Hansen (U.K.) Ltd.
Holborn Surgical Instrument Co. Ltd.
P. M. Hutchinson Mountain Equipment.
Ilford Ltd.
I.C.I. (Dyestuffs Division) Ltd.
I.C.I. (Pharmaceuticals Division) Ltd.
Ind Coope (Scotland) Ltd.
Johnsons of Hendon Ltd.
James A. Jobling & Co. Ltd.
Kavli Ltd.
William Kenyon & Sons.
The Kiwi Polish Co.
J. Langdon & Sons Ltd.
Langston Jones & S. Smith Ltd.
Lawtex Ltd.
Levi Strauss (Jeans) Ltd.
Lipton Ltd.
Littlewoods Ltd.
The Lord Rank Research Centre.
Marshall & Co. (Aberdeen) Ltd.
Mattesons Meats Ltd.
May and Baker Ltd.
Menley and James Ltd.
Metal Box Co. Ltd.
Minnesota Mining & Manufacturing Co. Ltd.
Morfed (South Wales) Ltd.
Mountainsports (Nottingham).
The Nestle Co. Ltd.
Newtime Foods Ltd.
Optimus (London) Ltd.
Pakistan Tabacco Co. Ltd.
Park Cake Bakeries Ltd.
Parke Davis & Co.
Petty Wood & Co. Ltd.
Philips Electrical Ltd.
J. Pick & Sons Ltd.
John Player & Sons Ltd.
Plus Gas Co. Ltd.
Plysu Houseware Ltd.
Premier Lamp & Engineering Co. Ltd.
Prestige Group Ltd.
Price Patent Candles Co.
Quaker Oats Ltd.
Rabone Chesterman Ltd.
Ranks Hovis McDougall Ltd.
Rawlplug Ltd.
Reckitt and Coleman Ltd.
Ripolin Ltd.
James Robertson & Sons Ltd.
Robinson & Sons Ltd.
Roche Products Ltd.
Ronson Ltd.
Rupla Sales Ltd.
The Ryvita Co. Ltd.
Sams Brothers Ltd.
Sangamo Weston Ltd.
G. D. Searle & Co. Ltd.
C. Shippam Ltd.
T. J. Smith and Nephew Ltd.
T. W. Spear & Sons Ltd.
Speedry Products Ltd.
Spillers Ltd.
Standards Brands Ltd.
Suunto Oy.
Tate & Lyle Refineries Ltd.
Tavener Rutledge Ltd.
Tecalemit Ltd.
Thermos Ltd.
Thorn Electrical Ltd.
T. G. Tickler Ltd.
Timex Ltd.
Graham Tiso.
Trebor Sharps Ltd.
Unilever Export Ltd.
United Biscuits Ltd.
Upjohn Ltd.
Vango (Scotland) Ltd.
Vauxhall Motors Ltd.
B. J. Waltham Son & Kitchingman
A. Wander Ltd.
Ward Blenkinsop & Co. Ltd.
Weetabix Ltd.
The Welconstruct Co. Ltd.
White Horse Distilleries Ltd.
Wrights Biscuits Ltd.
The Wrigley Co. Ltd.
Yorkshire Egg Producers Ltd.


HARPAN RIVER CAVE
POKHARA — NEPAL
Suveyed Length - 4850ft. Depth - 155ft.
Grade 4 Survey November 1970
By J. Coward and A. Waltham
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Projected Section
North - South
Main Sink
Collapse Entrance
Gulley
Main Rift
Bat Chamber
Road Chamber
Flowstone Chamber
Boulder Hall
Phil's Rift
Jungle Exit
Dripping Inlet
Entrances
South Passage
Sump
Canals Passage
Pool Entrance
Gorge
Risings
100 0 300
Scale in Feet
Plan
Harpan River
Main Sink
Sump
Pokhara
Dye Test
Boulder Hall
Inlet
South Passage
Aven
Jungle Exit
Risings
Harpan River
Temple
Terminal Lake
Main Rift
Sump
Gulley
Tea Shop
Canals Passage
Bat Chamber
Bat Pitch
Pool Entrance
Phil's Rift
Rising
Main Risings
Dripping Inlet
Road Chamber
Flowstone Chamber
Entrances
West Chamber
Flood Rising
Gorge
Footpath
Rock Shelter
North
Tansing Road
Collapse Entrance
Terrace
Extended Section - Main Sink to Collapse Entrance
Sink
Entrance
Terminal Lake
Gulley
Bat Chamber
West Chamber
South Passage
Projected Section
West - East
Bat Chamber Complex
Cross Sections
50 feet
1
2
3
4
5
6
7
8
Conglomerate
ACW