Chapter 20

SELECTED MILITARY OPERATIONS IN MOUNTAIN ENVIRONMENTS: SOME MEDICAL ASPECTS

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INTRODUCTION

In war, victory often depends on skillful use of the high ground, so hills and mountains have been central to warfare for thousands of years. Gentle hills, like those at Marathon and Gettysburg, give tactical advantage with few obstacles from environment or geography. On higher mountains like the Alps or the Caucasus, the greater is the tactical advantage for offense or defense, but the problems are also greater. The mountain environment poses dangerous medical problems including frostbite, hypothermia, hypoxia, hypoglycemia, and dehydration. Of these, cold injuries (eg, frostbite and hypothermia) have been the most frequent and serious, but altitude illnesses and malnutrition have also caused many casualties (Exhibit 20-1).

Because of the obstacles to men and equipment, few military operations have taken place above 2,400 m (8,000 ft), where the environmental, geographical, and medical obstacles are more significant and often dramatic. On most mountainous terrain below 1,000 m, environment does not cause problems not encountered anywhere else, but armies that have campaigned at elevations higher than 2,500 m have sometimes suffered more casualties from the mountain environment than from enemy action. Military medicine has an obvious need to study basic altitude physiology. In 1946 the US Navy did a pioneer study of human physiological adaptations to extreme altitude, and in 1985 the US Army expanded that study: these are called Operation Everest and Operation Everest II (Exhibit 20-2).

History offers many lessons that, when heeded, can minimize military losses in mountain environments; selected examples are the theme of this chapter.

EXHIBIT 20-1

COLD-, ALTITUDE-, AND NUTRITION-RELATED CONDITIONS EXPERIENCED IN MOUNTAIN ENVIRONMENTS

Frostbite	Air temperature falls one degree Centigrade with every 100 m of altitude, and the dangers of freezing cold injury (frostbite) and hypothermia are compounded by hypoxia, hypoglycemia, and dehydration. Cold also causes problems for animals and equipment.
Hypothermia	Whenever heat is lost faster than the body can generate it, core temperature falls proportionally to the temperature difference and rate of loss, causing weakness, confusion, hallucinations, coma, and death.
Hypoxia	The available oxygen in air decreases in parallel to the decrease in barometric pressure with increasing altitude, resulting in subnormal levels of oxygen in arterial blood or tissue (short of anoxia). Hypoxia impairs judgment, slows reflexes, causes a spectrum of illnesses, and decreases work capacity and will.
Hypoglycemia	Both physical and mental exertion require fuel. Carbohydrate is the most readily available; protein and fat are used later. Owing to difficulties with transport, soldiers often do not have enough food, which may cause a debilitating decrease in blood sugar with symptoms similar to those caused by hypoxia and hypothermia. Hungry troops lose strength and weight, and are slow to respond.
Dehydration	In cold areas, water is usually scarce because it must come from melting ice, and fuel for melting is scanty. Mountain air is dry, and excessive water is lost by the increased ventilation due to work and to hypoxia. Although sweating is insensible, water is lost during strenuous work at altitude.
Injury	Higher mountains are generally more rugged, steeper, and more fraught with danger from rockfalls and avalanches, which are common causes of injuries or death. Transport for the injured or wounded is difficult, and triage is complicated by cold and altitude.
Illness	Sanitary measures are limited, and infectious diseases and malnutrition are problems.

EXHIBIT 20-2

OPERATION EVEREST AND OPERATION EVEREST II

Control of the heights has long been important in war. Two centuries ago the Montgolfier hot air balloon took this to a new dimension—high in the air. When Benjamin Franklin saw one of the first flights, he envisioned an armada of thousands of balloons carrying airborne troops to battle. France formed the first air force—the "Compagnie d'Aerostiers"—and on 2 June 1794 two French soldiers were taken high above gunshot to observe and report the disposition of the Austrian army ranged against them. For many decades such balloons did not ascend more than a few thousand feet. However, in 1875, a huge balloon carried three men to over 25,000 ft; two were dead from hypoxia when they landed. The danger of great altitude was thus dramatically proven: if men were to fight in the air, the hazards of high altitude must be overcome.

By 1920, powered aircraft could reach altitudes that incapacitated pilots if they did not breathe extra oxygen. Twenty-five years later, aircraft could go even higher, beyond the level where pure oxygen, delivered under ambient pressure, sufficed. Pressurized cabins were thought impracticable for battle; other approaches were sought.

By then it was clear that exposure to gradually increasing altitude enabled men to survive, whereas the unacclimatized soon lost consciousness. Some air forces kept pilots for weeks at moderate elevations in the mountains to enable them to fly higher than their adversaries. This was somewhat effective but impractical, and it suggested that aircrews might become acclimatized by repeated exposure to simulated altitude in decompression chambers.

Operation Everest

To examine this concept, in 1946 the US Navy authorized a study of acclimatization called Operation Everest, which was conducted at the Naval Air Station, Pensacola, Florida. Four men were taken to a simulated altitude of 8,800 m (29,000 ft) during 35 days of slow ascent. Samples of arterial and venous blood, expired air, and urine, taken at rest and after exercise, were analyzed, and subjects were examined repeatedly during the ascent. Electrocardiograms and occasional chest roentgenograms monitored cardiac function.

Finally two of the four reached a simulated altitude of 8,800 m, where they were able to do light work for 20 minutes. Next day, breathing 100% oxygen, they were taken slowly from 8,800 to 15,200 m (50,500 ft), where they were able to exercise, although only lightly. This portion of the study showed that when breathing pure oxygen, these partially acclimatized men could go much higher than could the unacclimatized; at the time, this proved that acclimatization could give a small edge to the fighting pilot at extreme altitude. Soon, however, the use of pressurized cabins made moot the issue of acclimatization. Today, for military purposes, the altitude ceiling of the aircraft, rather than the pilot's tolerance, is the limiting factor.

Of more general medical interest were the clinical and laboratory data obtained throughout Operation Everest. Pulmonary ventilation increased the most in the men least affected as the altitude was increased, suggesting the benefits of a strong hypoxic ventilatory drive. The alveolar–arterial oxygen pressure gradient decreased with increasing altitude but increased with exercise. The pH of arterial blood increased in parallel with increasing ventilation but leveled off and slowly fell toward normal as acclimatization matured. The increased alkalinity of blood altered the shape of the oxyhemoglobin dissociation curve, enhancing delivery of oxygen to the tissues. Although blood oxygen saturation fell, oxygen content of arterial blood did not because of the increased hemoglobin. The heart showed no sign of strain. Operation Everest confirmed earlier impressions that acclimatization was accomplished by many integrated changes that tended to restore cellular oxygen toward normal.

The data from Operation Everest also had more general clinical interest by outlining how acclimatization to hypoxia helps persons with chronic heart, lung, or blood disorders. Many such patients may live for months or years with arterial blood oxygen content almost as low as that experienced by a healthy mountaineer as high as some of the Rocky Mountains.

Operation Everest II

Troops often need to campaign in mountainous environments. The experience of armies fighting in the Himalayan Mountains has shown that unacclimatized troops taken too rapidly to altitude will suffer attrition from mountain sickness. To further study acclimatization, Operation Everest II was carried out in 1985 by the US

(**Exhibit 20-2** *continues*)

Exhibit 20-2 *continued*

Army at the US Army Research Institute of Environmental Medicine (USARIEM), Natick, Massachusetts. Like Operation Everest in 1946, this was to be a study of "pure hypoxia" absent the confounding stresses of cold, dehydration, and heavy work encountered on high mountains.

Eight healthy and athletic young men lived in a large decompression chamber for 40 days while atmospheric pressure in the chamber was slowly decreased to that found at 8,800 m. Cardiac catheterizations were done at three altitudes (sea level, 20,000 ft, and 25,000–29,000 ft) to assess heart function at rest and during and after exercise. Using special gas mixtures, pulmonary function and diffusing capacity were also measured at increasing altitude. Muscle biopsies were studied for structure, intracellular adaptations, and biochemical changes. A variety of hormone and electrolyte studies were done. Daily physical examinations, alveolar air sampling, and measurement of caloric intake and output, as well as occasional psychometric tests, were also done.

A slightly slower rate of ascent than in the first study was used, hoping that more complete acclimatization could be achieved. New technology enabled collection of far more data than had been possible 40 years earlier. During ascent, pulmonary ventilation increased, cardiac output decreased, and pulmonary artery pressure increased, but the heart functioned well. Although the alveolar–arterial oxygen gradient decreased, mixed-gas analyses of pulmonary function showed evidence of significant interstitial pulmonary edema, increasing with altitude in all subjects. This suggested that the lung, rather than the heart, may be the factor limiting tolerance for extreme altitude. Alveolar, arterial, and mixed venous blood analyses added to projections made by others. Muscle chemistry and structural analyses cast more light on cellular metabolism. Despite free choice of nutritious and appetizing food, caloric intake fell as the subjects lost appetite, and their weight decreased. Maximal work capacity decreased with altitude and did not approach that found at sea level over the period at altitude.

The findings enlarged the data obtained from the 1946 US Navy study, but suggested that the rate of ascent had been too fast to enable full acclimatization. The 1985 US Army study had special relevance to military forces that must travel, fight, and live at moderate elevations. By demonstrating the decrease in work capacity at high altitude but showing the benefits of slow ascent acclimatization, soldiers and civilians alike have benefited from this ambitious study.

RECOMMENDED READING

Jackson DD. *The Aeronuts: The Epic of Flight.* Alexandria, Va: Time Life Books; 1980.

Houston CS, Cymerman A, Sutton JR. *Operation Everest II 1985.* Natick, Mass: US Army Research Institute of Environmental Medicine; 1991.

ASIA

The vast continent of Asia, including the Middle East, contains the highest and most complicated mountains, the largest and most hostile deserts and plains, and the most difficult terrain for warfare. Yet these areas have has been arenas for battles for many thousands of years.

Ancient Greece: Xenophon

Exiled from Athens for his opposition to democracy in 397 BC, Xenophon[1] joined the army as a foot soldier. His troops elected Xenophon leader of the disorganized Greek army, later known as the Ten Thousand, when it was hard-pressed in central Armenia during the campaign against the Persians. Xenophon's detailed day-by-day account describes the hardships and dangers of warfare in the mountains and deserts of Kurdistan and Armenia and gives an intimate picture of the life of an ordinary foot soldier. In contrast to the well-balanced force that Alexander would lead in the same region many decades later, Xenophon had 10,000 foot soldiers but only 50 cavalry. This limited his mobility and his timely appraisal of the enemy and slowed the advance of his army, exposing the troops to prolonged cold, hunger, and altitude.

In a chapter of his *Anabasis,* or *Persian Expedition,* entitled "Marching Through the Snow," Xenophon describes the hardships that his soldiers encountered while crossing a high plateau in the Taurus mountains, which range from 1,800 to 4,000 m (6,000–13,000 ft) in height:

> Next came a three days' march of 45 miles over level ground and through deep snow. The third day's march was a hard one, with a north wind blowing into their faces, cutting through absolutely everything like a knife and freezing people stiff. One of the soothsayers then proposed making a sacrifice to the wind and his suggestion was carried out. It was agreed by all that there was a distinct falling off of the violence of the wind. The snow was six feet deep and many of the animals and slaves perished in it, as did about thirty of the soldiers.
>
> . . . .
>
> The whole of the next day's march from here was through the snow and a number of the soldiers suffered from bulimia. Xenophon who, as he commanded the rearguard, came upon men who had collapsed, did not know what the disease was.[1(pp196–197)]

The elevation of this plateau and the passes that Xenophon crossed are not clear from his account nor are they easily ascertainable from the maps showing his route, but the depth of snow and the cold suggest that much of the route was higher than 2,400 m (8,000 ft). Food, fuel, and water were limited in this harsh, frozen terrain. Some soldiers fell senseless to the ground from what Xenophon calls "bulimia," which was probably a combination of hunger, cold, and exhaustion. Xenophon was told that bulimia should be treated with food, so he personally went among the troops collecting and distributing food to the victims. Xenophon wrote of his troops:

> As soon as they had something to eat, they stood up and went on marching.[1(p197)]

During the day the troops suffered greatly from snow blindness, but some prevented this by holding something black before their eyes. Their feet often froze to the soles of their makeshift sandals of undressed oxen skins.

In the next chapter, entitled "They Capture a Pass by a Manoeuvre," Xenophon describes how, after traversing this difficult terrain, the troops finally reached a pass that led down to the fertile plains where the Ohasis River ran. The pass was held by a strong enemy force, and the generals disagreed how best to proceed. After a powerful address by Xenophon, the Ten Thousand surprised the enemy outposts; after several sharply fought engagements, they attacked the enemy's rear. Then, after securing the pass,

> they offered sacrifices and … descended into the plain and came among villages full of plenty of good food,[1(p206)]

where his soldiers regained their strength.

This extraordinary military campaign shows how a brilliant and determined commander can successfully lead an army through unknown territory and across mountains and deserts, facing severe weather and all the problems of a mountain environment. Xenophon's leadership places this campaign among the great military operations in history.

Ancient Greece: Alexander the Great

Sixty years after Xenophon's march through this area, Alexander of Macedon followed part of Xenophon's route during his campaign against the Persians and his subsequent invasion of India (Figure 20-1). Accounts of this long and arduous campaign (although often conflicting) describe the hardships encountered in mountainous country.[2–4]

Xenophon had shown restraint as he moved through the western part of this wild and little-known region, but Alexander, when his passage was opposed, ruthlessly destroyed cities, slaughtered inhabitants, and burned crops. Alexander felt compelled to leave only scorched earth behind him because he had insufficient troops for garrisons to protect his long and tenuous supply line. As a result, obtaining water and food was one of his worst problems.

For more than 10,000 miles from Macedonia, through Greece, Egypt, and Asia Minor, it was not unusual for Alexander's troops to march 100 or 150 miles in 4 days over ordinary terrain. Their progress was much slower in the mountains, however, which were often higher than 1,800 m (6,000 ft).[3]

In November 331 BC, driving northward from Kandahar, Alexander crossed the highlands of central Afghanistan, where his army suffered severely from altitude, cold, and snow blindness. Many soldiers died before he descended to the more hospitable environment of Kabul, at 1,800 m (6,000 ft) above sea level. Before him were the imposing Hindu Kush mountains (known in that time as the Caucasus Indicus), north of which his enemy Bessus waited, arrogant and confident that his army could whip Alexander should he attempt to cross these fearsome mountains.

Anticipating that Bessus would expect him by the lowest and easiest of the seven passes, Alexander chose the most easterly Khawak Pass (4,500 m, or 15,000 ft high), the steepest, highest, and most treacherous because of snow and avalanches. He set out from Kabul in 329 BC, too early in the spring to cross such a high pass because, although the snow was beginning to melt in Kabul, winter still raged

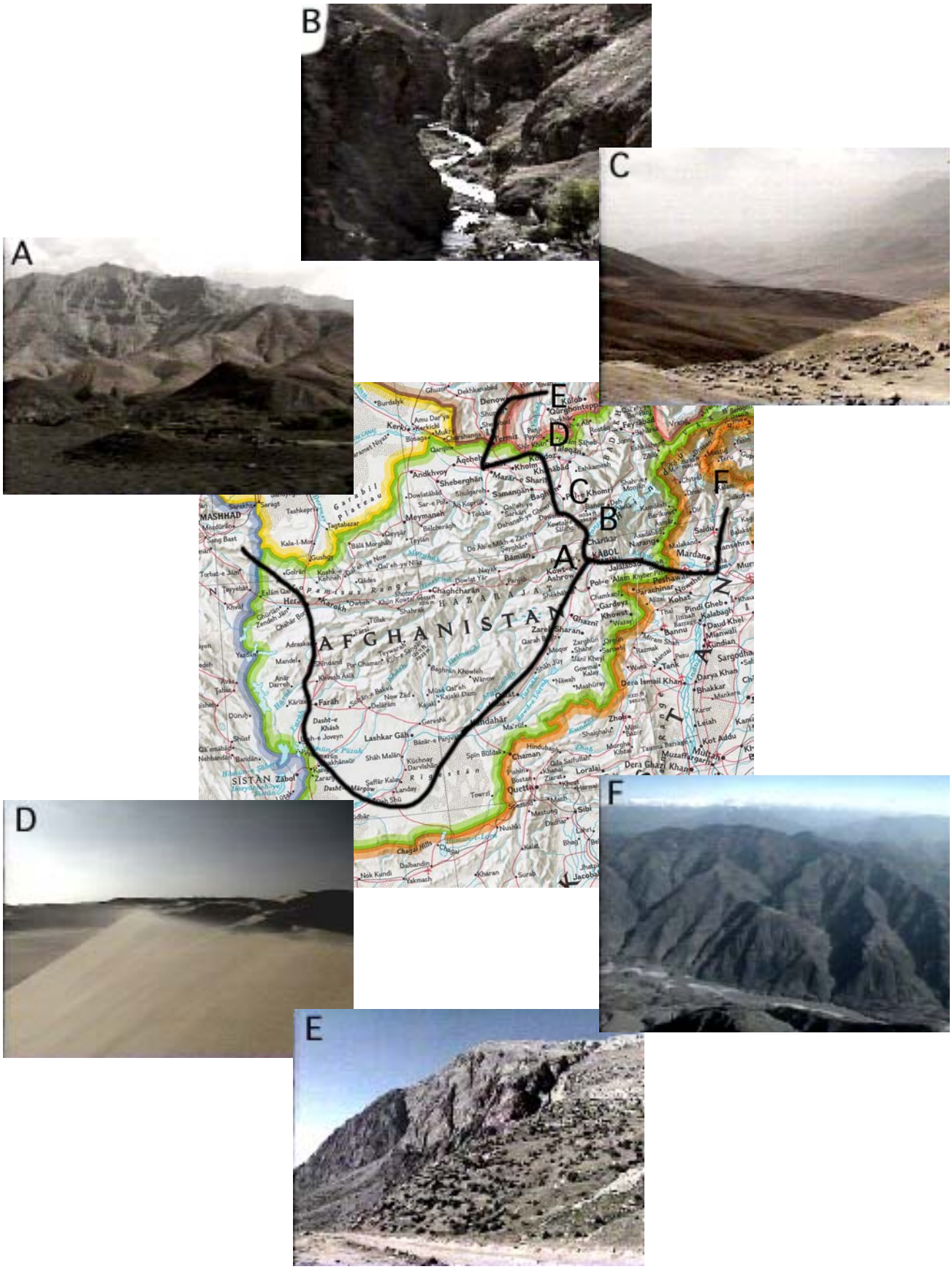
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Fig. 20-1. When Alexander's route through central Asia is superimposed on a map of modern Afghanistan, his army is seen to have marched through many populated locations that have recently assumed great importance: Herat, Kandahar, Kabul, and Mazar-e Sharif, to mention a few. The geographical sites that Alexander is renown for traversing are equally impressive. (**a**) A view of the Hindu Kush Mountains from north of Kabul; this range had to be crossed if Alexander were to reach central Asia. (**b**) The Panjshir Valley is seen at a point before the entrance to the Khawak Pass is reached. (**c**) The view looking north from the summit of Khawak Pass (11,000 ft); Alexander's army of approximately 50,000 crossed here in the spring, before the snows had melted. (**d**) The desert that Alexander had to cross before reaching the Oxus River (now, the Amu Darya) and present-day Tajikistan. (**e**) The likely Sogdian Rock in Tajikistan; Alexander's mountain troops are believed to have scaled the rock face to the left. (**f**) The probable site of the last of Alexander's great mountain warfare campaigns, the Aornos Rock in modern northwestern Pakistan. Alexander's mountain troops scaled the deep couloir on the extreme left and traversed the ridge line to his enemy's base camp on the extreme right. Map: Adapted from National Geographic Society, Washington, DC. Video frames: Reproduced with permission from Dobbs R, producer. *In the Footsteps of Alexander the Great.* Maya Vision International, London, England.

in the mountains.

The snow line began 20 miles before the actual pass, and the snow drifts became deeper the higher his army climbed. The weather was severe. (There are several different versions of the story, but they all describe extreme difficulty.) Hundreds of men froze to death, others became snow-blind and wandered away. Altitude illnesses had not been recognized in that era, but it is probable that Alexander's losses were a classic example of the synergism of hypoxia, cold, hunger, and dehydration. After reaching the summit of the pass, the long baggage train, including Alexander's full court, and the surviving thousands of camp followers labored another 40 miles down the northern side to below the snow line. The army was starving and exhausted as it reached a desolated land: Bessus had destroyed everything.

That 60 miles took 15 days and cost Alexander an unknown number of lives, unknown because only battle deaths were recorded.[2] Some reports say that half of Alexander's fighting men died from the altitude and cold, the effects of which were increased by inadequate food and water. This famous campaign is one of the most costly and difficult in the history of mountain warfare.

Many historians describe Alexander's assault on a famous mountain citadel, the Sogdian (or Ariamazes) Rock. (Quintus Curtius Rufus's version is slightly different from that of other historians. He writes that the soldiers drove their wedges into cracks between the rocks, as modern climbers do, and states that the rock was 30 furlongs [2,000 m] high.[5]) Although altitude was not a factor, the rock was said to be at least 1,000 m (3,300 ft) high and precipitously steep on all sides. Its exact location is hard to trace but it is probably in modern Tajikistan, near the Oxus River (now called Amu Darya). It is said to have had persistent snow on the flat summit, which gave the 35,000 inhabitants ample water. Confident of their impregnable position, the Sogdians scoffed at Alexander's demand for their surrender. "To reach us your men will have to fly like birds," they replied. According to Arrian, Alexander was furious and determined to capture and sack the castle. So at night, in midwinter, he asked for volunteers:

> There were some 300 men who in previous sieges had had experience in rock-climbing. These now assembled. They had provided themselves with small iron tent-pegs, which they proposed to drive into the snow, where it was frozen hard, or into any bit of bare earth they might come across, and they attached to the pegs strong flaxen lines ...; then, driving their pegs either into bare ground or into such patches of snow as seemed most likely to hold under the strain, they hauled themselves up, wherever each could find a way. About thirty lost their lives during the ascent—falling in various places into the snow, their bodies were never recovered … —but the rest reached the top just as dawn was breaking.[2(pp233–234)]

The awestruck defenders, seeing this small band on the high cliffs across from but overlooking their town, believed that Alexander's men had indeed "flown like birds" and immediately surrendered. This must be among the first records of such direct aid climbing in warfare; much later it would become part of the training for troops intended for fighting in the mountains. Alexander killed most of the people; spared their king, Oxyartes; and married the king's beautiful daughter, Roxana.[4]

As was the case with his predecessor, Xenophon, strong leadership inspired Alexander's army to fight its way through uncharted hostile lands despite inadequate supplies, and across high mountains despite extreme cold and altitude. Much later, when Alexander's leadership faltered, the campaign fell apart; after his death, disaster followed.

EUROPE: THE ALPS AND THE CAUCASUS

During the centuries of the Roman Empire, hundreds of roads were built across several dozen passes over 2,000 m (6,500 ft) high through the Alps north of Italy. Some roads were paved and their traces remain today. Some were trade routes, but most were originally military roads over which the Roman armies marched to conquer northern tribes and to police their vast empire. The passes were easily defended, and the Alps provided a strong barrier to invading barbarians from the north. Gibbon, the comprehensive historian, does not describe the environmental problems that Roman soldiers

Fig. 20-2. This classic 1869 map drawn by Charles Joseph Minard, Inspector General of Bridges and Roads, depicts the successive losses of men from Hannibal's army as he crossed from Spain to Italy, through Gaul (according to Polybe). Translated, the legend reads, in part:

> The number of men accompanying Hannibal is represented by the thickness of the colored line (1 mm = 10,000 men [at the start, Hannibal's army numbered about 50,000 men]). Geographical landmarks are also shown on or near the colored line. Because it is uncertain where Hannibal crossed the Alps, I have adopted the opinion of Larosa without attempting to defend it.[1]

Confusion still reigns over the exact route that Hannibal took, but it is known that his men and animals suffered greatly from hunger and the cold, wintry conditions. For example, according to the Greek statesman and historian Polybius (ca 200–118 BC),

> [the] conditions were so unusual as to be almost freakish. The new snow lying on top of the old, which had remained there from the previous winter, gave way easily, both because it was soft, having only just fallen, and because it was not yet deep. But when men and beasts had trodden through it and penetrated to the frozen snow underneath, they no longer sank into it, but found both their feet slipping from under them, as happens when people walk on ground which is covered with a coating of mud. What followed made the situation even more desperate. In the case of the men, when they found they could not get a foothold on the lower layer of snow they fell, and then, as they struggled to rise by using their hands and knees, slid downwards even faster on these, no matter what they clutched on the way, since the angle of the slope was so deep.
> As for the animals, when they fell and struggled to rise they broke through the lower layer of snow, and there they stayed with their loads, as though frozen to the earth, because of their weight and the congealed state of the old snow.[2(pp227–228)]

1. Lounsbury D, trans. Colonel, Medical Corps, US Army; Director, Borden Institute, Office of The Surgeon General, Walter Reed Army Medical Center, Washington, DC; March 2002.
2. Polybius; Scott-Kilvert I, trans. *The Rise of the Roman Empire.* New York, NY: Penguin Books; 1979: Book III: The Second Punic War.
Map: Reproduced from Minard CJ. *Tableaux Graphiques et Cartes Figuratives de M. Minard, 1845–1869.* Held at Bibliothèque de l'École Nationale des Ponts et Chaussées, Paris, France.

faced while crossing these mountains.

The Caucasus ranges were quite different from the Alps: scarcely settled, larger in scale, and with only primitive tracks or trails. Until recently, few armies had attempted to cross or to fight on them.

Second Punic War: Hannibal

Among the many battles for these passes, Hannibal's crossing of the Alps is the best known (Figure 20-2). There are many different versions of this feat and the details differ. What is clear is that Hannibal was an imaginative and charismatic leader who had many tricks up his sleeve. Although much of the story may be myth, it is clear that the critical part of the invasion took less than 3 weeks and included all the elements that make fighting in the mountains so perilous.[6] Few Roman mountain campaigns are so well described.

At the age of 28, in 221 BC, Hannibal was elected by the army to head the forces of Carthage. Within 3 years he had consolidated an amphibious attack from Carthage on the Gulf of Tunis in North Africa across the Straits of Gibraltar into Spain. During the summer of 218 BC, Hannibal marched his army of about 50,000 men across Spain, along the Mediterranean coast and over the foothills of the Pyrenees, and on to the Alps of southern France, fighting most of the way. Next, he led the army over small hills and across a plain, from which they would have to find a pass over which they could climb before descending into Italy.

There is little agreement over which pass Hannibal crossed. This, and what hazards he encountered, have been debated for centuries. The most reliable information is from Polybius, who wrote 60 years after the fact, but the contemporary place names have been lost in myth. Recently De Beer[6] examined all the available evidence and concluded that the most likely crossing place is the Col de la Traversette, which is over 3,000 m (10,000 ft) high. Its northern approach is through a narrow gorge, very steep and difficult. Hannibal's army spent 15 days fighting its way up through this gorge, hemmed in by almost vertical cliffs, along narrow trails, and over large boulders. The elephants found the boulders insurmountable. Legend has it that Hannibal built huge bonfires around these boulders, and when they were red hot, poured red wine on the boulders to split them into fragments. Improbable though this may seem, it had already been described by Pliny and Vitruvius. Much later, in the early 19th century, this practice (but using water) was carried out on rocky New England farms. Today's armies would use explosives.

The army was constantly attacked by hostile tribes, who rolled great rocks down the cliffs to block the way. But the tribes attacked only by daylight and returned to their homes at night so that Hannibal was then able to restore the passage. The men suffered terribly from the cold, but the effect of altitude hypoxia probably was slight because the men had gained altitude gradually. The elephants and horses had a dreadful time on the steep, broken tracks, which were often ice-covered. Above the tree line they came onto fresh snow lying treacherously over deep slush near the top of the pass, and this gave them great trouble. From the pass Hannibal showed his men the plains of Italy, although they would still confront problems while making the steep descent.[6]

Hannibal's army crossed the Alps in October or November 218 BC, and descended on Italy with 20,000 infantry and 6,000 cavalry (of his original army of 50,000). Although many elephants may have survived the passage, historians believe they did not tolerate the lower Apennine hills, and most died. Although Hannibal's daring passage through the mountains caught the Romans by surprise, they rallied and—with their much larger armies—forced Hannibal to maneuver around Turin for many months. During this period, Hannibal twice scored significant victories over the much stronger Roman army, crushing it in 216 BC at the decisive Battle of Cannae.

Despite Hannibal's bold and brilliant crossing into Italy, the privations of the mountain environment left him barely enough power to win at Cannae. Thereafter, in a strange and hostile land he faced attrition from the continuously reinforced Roman armies. He had no secure supply line through the Alps or from the sea. Nor could he adequately replenish his supplies from the countryside, which was protected by the Romans. After the Battle of Cannae, Hannibal's leadership weakened. He left Italy several times only to return for years of skirmishing against stronger Roman armies, which slowly exhausted the Carthaginians. Hannibal took poison and died in 183 BC.

Here again, strong and daring leadership enabled a small army to prevail against the difficult barriers of high mountains and, initially, to defeat a much larger force. Owing to increasing problems with supplies and reinforcements during many years of fighting, Hannibal's leadership failed and the decades of war ended in defeat for Carthage.

Two thousand years later, when the French were challenging all of Europe, in May 1800 Napoleon led some 40,000 troops across the Great Saint Bernard Pass (2,500 m, or 8,200 ft, in the Alps between Switzerland and Italy), along an ancient Roman

road that Napoleon rebuilt—and which is the major highway in use today. Few altitude-related problems have been recorded. The monks and their huge rescue dogs in the 800-year-old monastery on the summit of the pass received him with impartial hospitality, and in return, Napoleon promised the monks perpetual custody of monasteries there and on the neighboring Simplon Pass.

World War I

Although the years of slaughter and stalemate on the western front are the best-known part of World War I, some of the most desperate battles were fought elsewhere, in mountain environments.

In December 1914, Enver Pasha led a strong Turkish army against a smaller Russian army in the high Caucasus Mountains. His first attack surprised and overwhelmed the Russians but the following counterattack defeated the Turks, who lost 78,000 of Enver's original 90,000 men. Bitter winter cold and altitude contributed heavily to this month-long debacle. Troops on both sides came close to starvation, and scurvy disabled many.[7]

Between 1915 and 1917, many major battles were fought in the Alps between the Italians, who sided with the Allies, and the Austrians, who sided with the Germans. Much of the fighting took place on the frontier mountains at 2,000 m (6,500 ft), and many troops lived for weeks and months at much higher altitudes.[8] More than half a million men were engaged along a 600-mile front but concentrated within 20 miles along the crests or slopes of the steep Italian Alps and the Dolomites (a subsidiary Alpine range in northern Italy), in terrain consisting of steep mountains, ravines, waterfalls, and turbulent streams (Figure 20-3). Ten thousand soldiers fell at the Col di Lano, the most fought-over pass in the Dolomites. Troops fought at an altitude of 3,000 m (10,000 ft), and some 600 injured soldiers arrived daily in Milan, most suffering from frozen feet and hands.[9]

This was terribly difficult terrain, even for the experienced mountaineers who had been professional guides in civilian life and needed only a little military training. Food, ammunition, arms, and supplies of all kinds had to be carried from the roadhead in the foothills to the front line, often on men's backs. Only occasionally could mountain

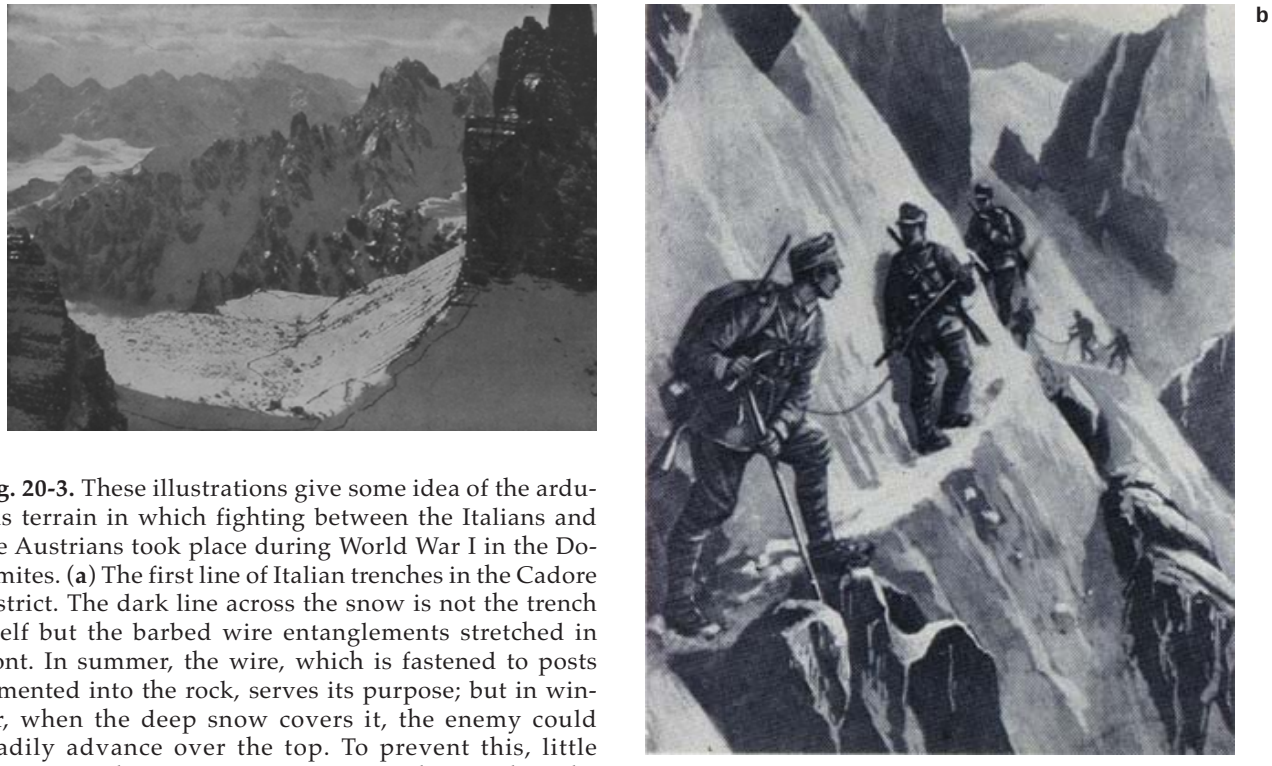

Fig. 20-3. These illustrations give some idea of the arduous terrain in which fighting between the Italians and the Austrians took place during World War I in the Dolomites. (**a**) The first line of Italian trenches in the Cadore district. The dark line across the snow is not the trench itself but the barbed wire entanglements stretched in front. In summer, the wire, which is fastened to posts cemented into the rock, serves its purpose; but in winter, when the deep snow covers it, the enemy could readily advance over the top. To prevent this, little wooden sawhorses are constructed in the trenches, the wire attached, and the portable entanglements pushed out on the hard snow surface. (**b**) An Austro-Hungarian night patrol makes its way cautiously along a ledge in the Dolomite Alps. Photographs and legends: (a) Reproduced from Bagg EM. Letters from the Italian front. *National Geographic.* 1917;32(1):47. (b) Reproduced from Gregory B. *Mountain and Arctic Warfare*. Wellingborough, Northamptonshire, England: Patrick Stephens Ltd. Thorsons Pub Group; 1989: 18.

mules be used. In places, long ropeways were constructed up which loads were hauled.

Most of the engagements were fought between specially trained mountain troops—the brigades or divisions of the Austrian Bersaglieri and the Italian Alpini. Both sides were equipped with white camouflage clothing, skis, and machine guns mounted on skis. The Alpini on Monte Ciove were under continuous attack for 3 weeks, losing 4,000 of their 6,000 men. Frequently the fighting was hand to hand, with bayonets. These elite mountain troops used advanced rock techniques to scale steep cliffs, establish ropeways, and fortify almost impregnable summits. The strong points were vulnerable to long-range artillery so the soldiers lived in snow caves and tunnels, inadequately protected and provisioned.[9,10]

This was the first time that two great armies had faced each other on extended mountainous terrain. Artillery barrages, machine gun attacks, and hand-to-hand bayonet battles caused less damage to both sides than did injuries from rockfalls, avalanches, and cold. The mountains were rugged and access very difficult; blizzards often dumped many feet of snow on slopes too steep to hold it, and avalanches buried many men. At night the great cold froze rocks in place, but as the sun melted the ice, there were dangerous rockfalls. The climbing was difficult, and falls by men and equipment caused many casualties. Some of the fiercest battles took place on skis, often hand to hand.

Fig. 20-4. Transporting Italian casualties in the Alps. The teliferica car provided the most comfortable vehicle for the men wounded at the front, and this stage was said to be the easiest of their long journey back to the base hospitals. The teliferica car was also used to carry bodies of Italy's Alpine soldiers to their snowy graves. If time and opportunity permitted, the dead were sent back whence they came, but more often they were buried with full military honors in the ice and snow of the glaciers. Photograph: Reproduced from Bagg EM. Letters from the Italian front. *National Geographic.* 1917;32(1):55.

Food was poor and scanty, and malnutrition and abominable sanitary conditions weakened the soldiers. The effects of altitude hypoxia are not recorded but were probably minimal owing to the acclimatization the men developed. Although casualties could usually be evacuated to a hospital, many were lost (Figure 20-4). Between the mountaineers on both sides a certain chivalry prevailed (what climbers call "the fellowship of the rope"), unlike on any other front. But disputes among the leaders decreased morale, and the years of fighting ended in stalemate when the two huge armies disengaged—except for small battles fought from summit to summit in the Dolomites.

Such campaigns in World War I convinced many countries that special training was important for troops who would fight in the mountains (Figure 20-5). Not so much altitude sickness but steep, broken, and dangerous terrain, and storms, snow, ice, and cold posed then and will always pose major problems for fighting in the mountains, despite advances in supplies and equipment of modern times. Strong, united leadership would be particularly important in such harsh environments; however, not all countries acted on these lessons.

World War II

In 1938 the German mountain troops, or *Gebirgsjäger*, were reconstituted into three divisions, but except for their battles in Italy and the Caucasus, most of the fighting was not in mountains, although their mountain training was invaluable in winter conditions.

The Gebirgsjäger fought in Norway for 8 weeks in 1940, facing bitter cold, deep snow, and long darkness with little food and shelter. Finally they prevailed and drove the British from Narvik. Other Gebirgsjäger fought in the Balkans and Macedonia and captured Athens.[10,11]

After the terrible winter of 1941/42 outside of Moscow, the German Army was slow to recover but in August 1942 began a drive into the Caucasus ranges, the first chance the Gebirgsjäger had to fight in terrain for which they had been specially trained. The southern prong of the 1942 German offensive would cut southward across the Caucasus to the Black Sea to seize the seaport city of Batum, near the Turkish border, and the oil-rich south. (The

Fig. 20-5. The skirmish line of Italian skimen advancing in attack. These troops, mounted on skis, can descend on an enemy position like a flock of great white birds, bringing a message of disaster to their foe. In this photograph, they are creeping forward in skirmish formation, firing as they go. Photograph and figure legend: Reproduced from Bagg EM. Letters from the Italian front. *National Geographic.* 1917;32(1):61.

northern prong was directed toward Stalingrad.) They fought their way over many passes 2,000 to 3,200 m (6,500–10,500 ft) high, in bitter summer blizzards and cold, and on into the fall and winter.[7]

Throughout the Caucasus campaign the Gebirgsjäger were extremely short of food and adequate winter clothing. They were harassed by thousands of native men and women, who had improvised fortifications in the mountains. German casualties were heavy, but the natives were inured to the mountain environment and suffered less. Here once again, more casualties were due to cold, hunger, and privation than to enemy action. Although trained for mountain warfare, the German Army was inadequately equipped; they had little knowledge of the geography or climate in the Caucasus and were forced to gather information hastily, from 15-year-old sources in Moscow, just as the campaign started.

In both world wars, which were largely European and Middle Eastern wars, too little forethought was given to the problems that troops would face in the mountain environment: extreme cold, lack of oxygen, insufficient food, and the difficulties of providing timely medical care. Some of these lessons of the past were not entirely ignored in the United States as the storm clouds gathered over Europe in the 1930s. In 1939 several groups of American mountaineers and skiers pressed for the formation of a special Mountain Division. After months of planning, the 10th Mountain Division was commissioned in 1942 and composed of volunteer mountain climbers and skiers. Training began in early 1943 at Camp Hale, Colorado, at 2,700 m (9,000 ft) and included rock and ice climbing, survival in cold weather, ski combat, avoidance of rockfalls and avalanches, and travel in dangerous terrain. The division was originally intended to attack the Germans, who had survived difficult winter months in Denmark and controlled the country. But it was soon apparent that their effort would be too late and inadequate against the large, entrenched German armies.

After 8 months of training at Camp Hale, detachments moved to Camp Swift, Texas, or to the Aleutian Islands, southwest of mainland Alaska, awaiting the invasion of Italy, where they were expected to be most valuable. They arrived in Italy in early 1945, 18 months after the invasion had started, fought notably at Riva Ridge, and moved north-

ward until the war ended.

The main Allied forces had already landed and were fighting north toward Rome. In January 1944 these forces confronted a formidable barrier, Monte Cassino, the center of the Gustav line, which the Germans held across Italy.[12,13] The monastery of Monte Cassino had been built in AD 524 by Saint Benedict, on a high, steep mountain chosen to be impregnable against assault from any side. Although destroyed several times over the centuries, the monastery was always rebuilt more strongly; in 1944 Monte Cassino, rising 500 m (1,600 ft) from the plains, dominated the road to Rome. Although the elite German *Jaegergebirge*, the specially trained and highly experienced mountain troops, had stockpiled armaments and other supplies to repel repeated attacks or a long siege, Monte Cassino was defended by paratroopers of the German 1st Parachute Division. Trained mountain troops from France, Morocco, Turkey, and India, along with regular infantry from England and the United States, attacked again and again, forcing routes up the steep cliffs almost to the summit before falling back with heavy losses from firepower above them. Winter conditions prevailed: mud, slush, snow, and sleet caused casualties comparable to some of the terrible injuries received by troops in the trenches of France in World War I.

The US Quartermaster Corps had been developing a special boot for cold weather warfare, and a few hundred were field-tested in Italy in the closing months of that campaign. The troops who did not have this special boot suffered a special type of cold injury—immersion foot—that caused thousands of casualties and necessitated many amputations. This boot would be nicknamed the Korean boot (or, affectionately, the Mickey Mouse boot) after it was used in the Korean War 5 years later, although it arrived too late to prevent many amputations for frostbite.

The Italian campaign was bitter. Some German troops said that the winter of 1944 on Monte Cassino was as bad as anything on the Russian front. Allied troops fought four major battles in the next 5 months before the Germans retreated from the monastery, which was by then almost totally destroyed.[12,14]

Monte Cassino fell in May 1944 and Rome was taken 10 days later. In 1945, the 10th Mountain Division had its baptism of fire in an assault on a series of strong points on Riva Ridge and surrounding peaks. The trained mountain division forced routes up steep cliffs, fixing ropes much as Curtius[5] says that Alexander's men had done in Sogdiana. Casualties were heavy, but the mountain training paid off and the German line was broken. The 10th Mountain Division moved northward.

Many of the lessons from World War I had been ignored or forgotten in the following decades and mistakes were repeated in the Italian campaign of 1944–1945. Some top leaders disliked each other and failed to cooperate at important times. They disagreed over tactics at critical times. They led troops who came from many countries and therefore had language problems as well as different cultures and military traditions. The US Army 10th Mountain Division trained for 2 years to fight in the mountains but did not arrive until the bitterest fighting (at Monte Cassino) was over. The military leadership and the US mountain troops, too, had not expected a long winter campaign, and their clothing, footwear, shelter, and even food were inadequate. New commanders for all troops repeated the mistakes of those they replaced. In many respects it was déjà vu all over again, at least in Italy and in the Caucasus.

TRAVELERS' TALES

Most military operations in Europe and the Middle East were conducted below 3,000 m (10,000 ft), where altitude hypoxia is seldom a problem because most troops acclimatize rapidly to these elevations. However, Asian mountain ranges (including the Hindu Kush, Caucasus, Karakoram, and Himalaya) and the South American Andes are high enough to cause serious altitude problems for troops, especially since supply problems limit the time that can be spent on acclimatization. The first reports of altitude or mountain sickness came from travelers in Asia and the Andes, and at least a few military campaigns in Asia have also experienced these problems.

Asia

Some of the earliest accounts of the dangers of high mountains come from the mountains of Asia. For example, in 156 BC, General Du Qin advised Chinese Emperor Wudi not to send envoys to Kashmir because the mountains along the way were too perilous. The general described the dangers of the journey in terms suggesting altitude illness (he and others also mentioned the risks from dragons among the mountains):

> [T]ravellers have to climb over Mount Greater Headache, Mount Lesser Headache, and the Fever Hills. … [T]hey must support each other by ropes.[15(p10)]

An early example of a serious altitude problem was described in the 5th century AD. After crossing the Safed Koh, a subsidiary range of the Hindu Kush, on the way to the higher Kohat Pass near Peshawar, in modern Pakistan,

> Fa Hsien and the two others proceeding southwards, crossed the Little Snowy Mountains. On them the snow lies accumulated both winter and summer. On the north side of the mountains, in the shade they suddenly encountered a cold wind which made them shiver and unable to speak. Hwuy Kung could not go any farther. A white froth came from his mouth and he said to Fa Hsien, "I cannot live any longer. Do you immediately go away, that we do not all die here"; and with these words he died.[16(p10)]

Like Alexander's men, the 5th-century party also experienced snow blindness, and they noted another unusual mountaineering peril, as well:

> The snow reflects a white light so strong that the traveller has to shut his eyes and cannot see anything. Only after he has made sacrifices to the King of the Dragons will his eyesight be restored.[16(p10)]

South America

Soon other travelers noted problems due to altitude. In 1590, Father Jose de Acosta astutely blamed "thinne aire" for the acute sickness he experienced while crossing the high Pariacaca Pass in the Andes Mountains.[17(p10)] His contemporary, Father Alonzo de Ovalle, agreed:

> When we come to ascend the highest point of the mountain, we feel an aire so piercing and subtile that it is with much difficulty we can breathe, which obliges us to fetch our breath quick and strong and to open our mouths wider than ordinary, applying to them likewise our handkerchiefs to protect our mouth and break the extreme coldness of the air and to make it more proportionable to the temperature which the heart requires, not to be suffocated; this I have experienced every time I have passed this mighty mountain. [18(pp46–47)]

A century later, Gruber repeated Acosta's "subtile aire" theory, but added:

> In summer certain poisonous weeds grow there which exude such a bad smell and dangerous odor that one cannot stay up there without losing one's life.[19]

Not until the end of the 19th century would the true cause of altitude illnesses be proven to be due to decreased barometric pressure and the resulting lack of oxygen. The various forms of mountain sickness would be experienced by armies that campaigned above 2,500 m (8,000 ft).

MILITARY CAMPAIGNS

Asia: The Mongols

From 1200 to 1400 AD the tribal peoples from a remote corner of central Asia—the Mongols—dominated the political and military life of the known world except for western Europe.[20] Genghis Khan (also known as Temujin), perhaps the greatest military genius of all time, initiated these conquests; his forces and those of his successors were known as the Golden Hordes. For 200 years the Hordes roamed and conquered much of China, all of central Asia, and Europe to the Adriatic and the Black seas, in bitter winter cold and debilitating desert heat. Although little information describing their health has survived, their standard diet of grains and curd gave them adequate nutrition, and their woolen dress minimized cold injuries.

Their military success as well as their resistance to hostile environments was because of their mobility. Genghis Khan learned very early in his career that speed meant victory. His only fighters were mounted cavalry, each man with a string of relief horses. Men and horses alike were incredibly tough and fast. Living on the grasslands of the Asian steppes, advancing on a very broad front but able to concentrate forces rapidly when faced with battle, the Hordes were brilliantly trained, disciplined, and led. After some years they spread out to form other Hordes, whose cavalry also terrified their opponents by ruthless slaughter and plunder, massacring all the people in the cities they conquered and then razing them to the ground.[21] It was a scorched earth policy in the extreme, like Alexander's.

One Mongol chieftain, Mirza Muhammad Haider, filled a book with detailed descriptions of the campaigns in which he participated. This account, written in 1544 near the end of his long life, is a record of incessant fighting between infidels and Moslems, between members of a family, and between rival clans.[22] Much of the action took place around Samarkand, Tashkent, Yarkand, Khotan, and Kashgar, now largely arid desert. Considerably

more rain fell during those years, so that parts of the now-almost-barren high desert were fertile enough to provide fodder for the horses and grain for the people, ensuring the Hordes' mobility. Nevertheless, campaigning was incredibly difficult for these armies (large and small), and their total dependence on horses adds special relevance to the following selection from Haider:

> It is clear that Tibet is a very high-lying country, since its rivers run in all directions. Anyone wishing to enter Tibet must first ascend lofty passes, which do not slope downward on the other side for on the top the land is flat. ... On account of the height, Tibet is excessively cold. … Having reached this point in my narrative it is necessary for me to give some account of the land of Tibet, for this country is so situated that very few travellers have been able to visit it. On account of the difficulties of the route, which from every point of view is most dangerous whether by reason of its hills and passes, or the coldness of the air or the scarcity of water and fuel, or the shameless and lawless highwaymen, who know every inch of the way and allow no travellers to pass—no one has ever brought back any information concerning this country.
>
> Another peculiarity of Tibet is the *damgiri* [literally, breathtaking], which the Moghuls call Yas and which is common to the whole country, though less prevalent in the region of forts and villages. The symptoms are a feeling of severe sickness (*nakhushi*). And in every case one's breath so seizes him that he becomes exhausted, just as if he had run up a steep hill with a heavy burden on his back. On account of the oppression it causes it is difficult to sleep. Should, however, sleep overtake one, the eyes are hardly closed before one is awake with a start caused by the oppression of the lungs and chest.
>
> . . . .
>
> When overcome by this malady the patient becomes senseless, begins to talk nonsense, and sometimes the power of speech is lost, while the palms of the hands and the soles of the feet become swollen. Often, when this last symptom occurs, the patient dies between dawn and breakfast time; at other times he lingers on for several days.
>
> . . . .
>
> This malady only attacks strangers; the people of Tibet know nothing of it, nor do their doctors know why it attacks strangers. Nobody has ever been able to cure it. The colder the air, the more severe is the form of the malady.
>
> . . . .
>
> It is not peculiar to men but attacks every animal that breathes, such as the horse, as will be presently instanced. One day, owing to the necessity of a foray, we had ridden faster than usual. On waking next morning I saw that there were very few horses in our camp and on inquiring, ascertained that more than 2,000 had died during the night. Of my own stable there were twenty-four special riding horses, all of which were missing. Twenty-one of them had died during the night. Horses are very subject to *damgiri*. I have never heard of this disease outside of Tibet. No remedy is known for it.[22(pp412–413)]

This account is important because it is an early and very detailed description of the problem of altitude sickness, and of acclimatization, which affected a powerful and resourceful leader campaigning in a high and hostile environment.

The Mongol Hordes were among the most efficient, ruthless, and powerful fighting machines the world has ever experienced. They were an early model for modern mobile forces, living on the land, traveling light and fast, with minimal supplies but able to fuel their transport (horses) as they went. By contrast, tank offensives in World War II were often halted because fuel could not be obtained. The Mongols crossed high mountain passes, fought through severe sand and snow storms, in drought and famine-stricken areas, always moving. During the first decades the strong and brilliant leadership of Genghis Khan brought seemingly impossible successes. Later, as the original Horde split into several smaller ones, most of the leaders were still able and strong. But unbelievable success and booty led to corruption and internal quarrels between leaders. After 2 centuries, all of the territories they had conquered were lost.

Asia: The Great Game

For thousands of years military campaigns have been fought in Asia among the harshest mountains on Earth between bitter enemies. Since the 18th century, these have attracted attention to what Rudyard Kipling called "the Great Game." Sometimes only a few men were involved, but small armies were engaged at others.[23]

Several great and discrete mountain ranges run for 2,000 miles from northwest to southeast across Asia, forming a nearly impassable barrier between the Russian confederation, Mongolia, and China to the north and Iran, Afghanistan, Pakistan, and In-

dia to the south. For most of their length the summits are from 6,000 to 8,000 m (20,000–26,000 ft) high. This formidable barrier is breached in many places, but few of the passes are lower than 5,000 m (16,400 ft) and all are covered by perpetual snow and ice. Yet for many centuries, invaders have crossed these passes from the inhospitable north to the warmer, richer, and softer south.[23,24]

Ever since the British Empire gained control of India 300 years ago, the English have been major players in the Great Game against the Russians. Both played for high stakes: the British to retain the riches of India, and the Russians to claim them. Both sought passes by which an army from the north might invade India, and where such an invasion could be halted, even though few places on Earth are less suited to war because of the terrain, extreme cold, great altitude, and lack of food and often of water. The area was unexplored and almost unknown until both sides sent intrepid soldiers, usually disguised as Muslim traders or priests, to penetrate this wild country, map the great rivers, and locate villages and oases. The Oxus and Indus rivers were thought to offer possible routes for an army, ones where bitter cold and altitude would not be problems, but even to reach the rivers involved crossing high mountains.

Not only were these early travelers seeking routes for armies and for traders, they were also trying to win the support of the rulers of the many petty, often warring states. Many of the covert agents took 6 months even to reach their destinations—often being executed if one ruler or another was offended or suspicious. They crossed high mountain passes and endured severe privation on snow and in barren deserts. Their instructions were dictated from India or Britain, took many months to arrive, and were often unclear or contradictory. It is not surprising that, given greatly delayed and wavering leadership from London or Delhi, the hardships they experienced are not as frequently mentioned in their reports as are the political and personal confrontations and frustrations. Although these intrepid agents were few in number, the maps and information they brought from central Asia should have improved strategy and tactics for generations—but unfortunately did not—both because of the long delays in communication and because of vacillating policies and incompetent generals.

In Afghanistan, a climax came in 1843 when Shah Shuja, the Afghan premier, was forced by a revolutionary group to expel the British mission that had installed him as Prime Minister and was negotiating a peace between the two parties.[25] Although promised safe conduct during their retreat from Kabul, the British were treacherously attacked by Shah Shuja's Afghan soldiers and suffered horrible losses. British troops returned a year later and took savage revenge. The Great Game played on for another hundred years, but prior to 1970, the incessant intrigues and struggles for power did not attract much international attention.

Then in 1978, for complicated reasons still being debated, Russia, by then loosely consolidated as the dominant member of the USSR, decided to intervene in the chronic political struggles between Afghan rebels and their government. Without warning, Russian troops invaded Afghanistan through a tunnel that Russia had built beneath Pamirs (the high-altitude region of central Asia, which contains numerous mountain peaks higher than 6,100 m [20,000 ft]) to encourage, as they claimed, free trade.[26] This invasion was what the British had feared and had tried to prevent for a century, but when it happened they were able to do little about it. Using the tunnel enabled Russian troops to avoid many of the problems due to cold and altitude encountered on the peaks and passes that hampered the Afghans, even inured as they were to these hazards. The Russians also used air support, but this was effective only at first.

In Afghanistan the land is high, wild, and barren—frozen or scorched—and dry, with scattered oases along rivers that flow from high and impregnable, snow-clad mountains to disappear in sandy wastes. Ragged, tortured, rocky ridges provided sanctuary for ground forces and gave some shelter from air attack. Russian ground transport was hampered by heat or cold, endless rocky spurs and outcrops, and sand or snow. Supplies had to come by air. The Russians were trying to restore a disheveled government, torn by deceit and murder, as well as many independent guerilla factions, often operating independently and at odds with one another. Despite superior equipment and unopposed air assaults, the Russian armies did not tolerate the mountain hardships, and finally the Afghan rebels, poorly disciplined and led though they were, used the mountainous wasteland better than the Russian troops, and forbade them ground control. After 10 years the Russians could not prevail and, after an ignominious stalemate, withdrew.

The struggles in Afghanistan demonstrate the obstacles that make mountain warfare so difficult and costly. Most of the land is parched and water is available only from the few large rivers, making agriculture possible only in irrigated areas; food is always scarce. The mountains are from 2,500 to 6,000 m (8,200–19,700 ft) high and are always covered with ice and snow. The temperature varies

from above 40°C to –30°C (> 104°F to –22°F). Sandstorms, rockfalls, and avalanches are frequent. Cold injury and altitude sickness are major hazards in the high mountains. Belatedly, the Russians recognized that their troops had not been adequately prepared for the terrain and the extreme climate encountered in Afghanistan, and they established a mountain warfare training center in Russia.

Tibet: Geopolitical Machinations

The Great Game was played in another region at the start of the 20th century as Russia increased its efforts to acquire Tibet, at that time still an aloof and little-known country. The British, determined that no other power should control this high, wild land, matched Russia's diplomatic overtures until, in 1904, the delicate negotiations collapsed, and the British monarch sent a small army to escort a diplomatic mission to Lhasa, the principal city in Tibet.[27,28]

Colonel Francis Younghusband was chief of mission, with General Macdonald and 2,000 troops in support. Their orders were ambiguous and fluctuating in an effort to persuade rather than to force the lamaistic theocracy to accept relations with Britain and to lock the door against Russia. When the last polite exchanges failed, Younghusband's party marched from the lowlands of India up into the Himalayas in February 1904 in battle array, dragging artillery along rough and stony tracks and over passes higher than, and almost as difficult as, those that Hannibal's elephants had crossed. After a few minor skirmishes, they faced a Tibetan force of several hundred men armed with ancient firearms and large knives, sheltering behind a formidable stone wall at an altitude of 5,500 m (18,000 ft). One of the party described the difficulties:

> Climbing over boulder strewn surfaces would be bad at sea level; here where the air is so thin it soon becomes a burden. … The lungs seem foolishly inadequate to the task imposed on them … the heart goes on beating with increasing strokes until it shakes the walls of the body … speech comes with difficulty. … The brain seems cleft in two and a wedge, all blunt and splintery, is hammered into it by mallet strokes with every pulsation of the heart. … Here too the wind exacts its toll and drives a cold aching shaft into your liver.[27(pp52–53)]

The first battle was joined at the strongly defended wall, which ran across a barren plain between hills that were prelude to immense snow peaks. A strong force of Tibetans was routed and several hundred were killed. Six weeks later, in a narrower valley at 5,600 m (18,500 ft), the Tibetan forces were larger, and after the battle, the Tibetan dead were estimated at 2,000. The terrain was extremely difficult. A dozen men under a native officer were sent up the almost-vertical face of the 460-m (1,500-ft) southern scarp to outflank the enemy at 18,500 ft—incredibly difficult work even for experienced mountaineers.

Apparently, altitude hypoxia—so vividly described by Landon,[27] who was there—did not halt or greatly impede the comparatively unacclimatized British forces. The Tibetans had lived at altitude all their lives and were fully adapted, an important factor favoring indigenous people meeting freshly arrived invaders anywhere in the mountains. The benefits of acclimatization were very clear when the Chinese invaded Tibet 50 years later, and were even more dramatically illustrated when they were ignored by the Indian armies when they faced the Chinese in 1962.

Younghusband's British party eventually forced its way through to Lhasa at 4,000 m (13,000 ft) and concluded a treaty with the Tibetans. The British force, although smaller than the Tibetan, was better trained, disciplined, and led; they had superior equipment that enabled them to prevail despite the great difficulties of altitude, cold, terrain, supply, and transport. Their advance was slow enough to enable the troops to acclimatize partially to the high altitude. This small military campaign should serve as a model for other larger operations in the mountain environment.[27]

China: The Long March

Perhaps the longest and most grueling campaign fought partly in the mountains was the Long March of the Chinese Communist party. In 1934, about 100,000 Chinese Communist troops and camp followers (85,000 soldiers, 15,000 administrators, and 15 women) were greatly outnumbered and encircled by the Chinese Nationalist armies. The Communists managed to break through the besieging armies and began their journey in October 1934. For the next 18 months the ragged, underfed, underequipped soldiers fought their way across western and northern China over rugged, almost-unknown country.[29,30]

Soldiers and civilians alike suffered their greatest hardships from cold and altitude while crossing the Snowy Mountains, possibly the same range on which Fa Hsien[16] had first recorded a case of high-altitude pulmonary edema many centuries before. Because the Chinese Communists were constantly harassed from the air, they often traveled at night despite the intense cold. Their clothing was inadequate for the glaciers and snow they had to cross. They had little

food. Despite acclimatization, their malnourished and weakened conditions increased the adverse effects of altitude, which, together with the cold, killed many thousands. After this high-mountain travel they had to cross a few hundred miles of swampland at 2,000 m (6,500 ft) elevation. They had few medical supplies, and disease and trauma took a heavy toll. They crossed 18 mountain ranges and 24 rivers in 1934 and 1935. Of the 100,000 who had begun the Long March, only 8,000 survived.[30]

Korea: The Retreat From the Chosin Reservoir

Another brutal campaign was fought in Korea in very harsh mountain terrain, although altitude was not a factor. During an intense period beginning 1 November 1950, US Army and Marine troops, recovering lost ground, were attacked by Chinese forces north of the Yalu River near the Chinese border. For 3 weeks the Americans retreated from the Chosin Reservoir along mountain roads, through narrow passes, in heavy snow and blizzard conditions. Although the campaign was described as a "strategic retreat," morale and military discipline deteriorated and there were heavy casualties. The terrain forced the battered troops into narrow defiles, where they were attacked on both sides from steep mountain ridges, reminiscent of the attacks suffered by Hannibal in similar terrain.

The roads were in such bad condition that wheeled transport was almost impossible, and even tracked vehicles had great difficulties. The resulting traffic jams compounded the problem. The wintry cold was extreme and clothing and footwear were inadequate, causing hundreds of cases of hypothermia, frostbite, and ensuing amputations. The greatly hampered transport made food and water scarce, so the troops became weak from hunger and dehydration in the dry cold air, perhaps suffering what Xenophon had called "bulimia." Throngs of civilian refugees clogged the roads and hindered retreat and rearguard action. In this campaign it was the *mountain environment*, although not including altitude, that caused the many casualties.[31] (For more about the Chosin Reservoir retreat, interested readers should also see Chapter 10, Cold, Casualties, and Conquests: The Effects of Cold on Warfare; and Chapter 14, Clinical Aspects of Freezing Cold Injuries, particularly Exhibits 14-7 and 14-8; in Section IV, Cold Environments, in *Medical Aspects of Harsh Environments, Volume 1*.[32])

This tragic operation is almost a replica of the British Army's retreat from Kabul a hundred years before. Then, in January 1842, British forces, expelled from Kabul with a safe conduct, were betrayed by Shah Shuja and attacked from all sides by Afghans. The British fought their way through 50 miles of the narrow Kabul River gorge in bitter cold and heavy snow. Most of the horses were killed, making wheeled transport impossible. Clothing was completely inadequate for the weather, although it had been suitable for garrison duty in Kabul. The 4,500 British soldiers were handicapped by the presence of some 15,000 wives, children, servants, and camp followers. Little or no medical care was possible. The horse-drawn artillery was abandoned when the Afghans shot the horses and blocked the road through the Khyber Pass. One man survived to gallop, badly wounded, into the fort at Jallalabad bringing word of the disaster to the horrified and beleaguered British garrison. Some weeks later, 65 more officers and men, most of whom had been held hostage in Kabul at the start of the journey, found their way around the Afghans to Jallalabad. Only that handful survived the cold and the fighting.[15] The Americans retreating from the Chosin Reservoir a century later, although badly hurt, fared much better.

These two 19th- and 20th-century "campaigns" were disasters in which the forces suffered all the handicaps imposed on military operations in the mountains except for altitude: bitter cold; heavy snow; long winter darkness; and limited food, water, and other supplies. Difficult and constricted terrain for maneuver, vulnerability to ambush and attack from high ground, fearful roads for vehicles, and the heavy handicaps of accompanying refugees or noncombatants made the retreat from the Chosin Reservoir a terrible ordeal for US troops. One of the worst medical problems for the US troops was injury from cold. Most of the survivors had frostbite injuries often requiring amputation. These could have been avoided if the suitable footwear, already field-tested in the Italian campaign 5 years before, had been provided in time. Inappropriate leadership before the Chinese attack laid the base for the Allied retreat, but leadership during the retreat was brilliant and undoubtedly prevented more casualties from enemy action.

South America: Liberation and Continuing Conflict

The valleys and high plateau (altiplano) of the Andes mountains that rim the Pacific coast of South America are relatively hospitable to human habitation. The Amerindian cultures who settled these mountains developed an effective agriculture and high-nutrition crops (eg, high-protein grains, potatoes, fruits) that allowed the altiplano to support

very large populations before Europeans arrived in the 16th century. The mineral wealth of the Andes attracted the conquistadors, and Spain colonized the area and subjugated the indigenous populations. Throughout history, the presence of large numbers of people with often-conflicting economic and political interests has provided tinder for armed conflict, and intermittent warfare has occurred in the Andes Mountains from the beginning of human settlement there and continues to this day.

The history of Amerindian societies in the Andes was one of frequent warfare between various tribes until the Quechua-speaking Incas conquered most other tribes and consolidated a sophisticated, mountainous empire during the last half of the 13th century; it stretched from northern Ecuador to the middle of Chile. Owing to the lack of a written language, historical account of the battles was by spoken word; much of that history was lost when the Spanish conquest destroyed the Inca culture. The high altitude of the Andean region probably had little effect on Amerindian warfare because the combatants, who resided there permanently, were acclimatized to the altitude. The rugged topography probably did *shape* the warfare, however. Because there were no ballistic weapons, combat was mostly hand to hand and had to take place in the relatively flat areas where combatants could face each other. Further, the battles were somewhat formalized, with the location and timing chosen to avoid the geographical and climatic impediments of hand-to-hand combat. Some of the battles were immense, with thousands of combatants. The Spaniards were able to conquer and subjugate the Inca in 2 years (1531–1533) with a very small number of soldiers, owing to the following factors[33]:

- the devastating effects of European diseases, which rapidly decimated the Amerindian populations in both North and South America,
- their use of guns and horses, which were advanced technology at that time and intimidated the Inca, and
- the effective exploitation of political unrest in the Inca empire and use of blatant treachery by Spanish conquistador Francísco Pizzaro.

Spanish rule of South America ended with the Wars of Liberation, a series of revolutionary movements and military campaigns that began in 1808 and continued until 1824. Two men are credited with liberating the continent: José de San Martín and Simón Bolívar. To achieve the element of surprise in their campaigns, they used mountain crossings by their armies (similar to Hannibal and Alexander before them), but they also fought many battles in the mountains.

Wars of Liberation

José de San Martín, called the Liberator of the South, was born in Argentina but grew up in Spain, where he trained as a military officer; he fought in North Africa and on the Spanish peninsula before the Napoleonic Wars. When the independence movements began in South America, he returned to Argentina and fought for its independence. He became convinced that the stability of the liberation from Spain depended on removing the Spaniards from their main stronghold in South America, which was centered in Lima, Peru. To invade Peru from Argentina, an army would have to cross part of the Amazon basin and then a wide stretch of the Andes Mountains. To circumvent those formidable geographical barriers, San Martín conceived a different plan: to cross the Andes from Argentina into Chile, liberate that region, and then move up the Pacific coast to Peru. To accomplish his plan, he moved to the Cuyo province of Argentina on the east side of the Andes, where he raised and trained an army near Mendoza; from there, San Martín and his Army of the Andes set out to cross the mountains into Chile in 1817. He provisioned his troops with large amounts of garlic and onions to combat mountain sickness and dismantled his artillery pieces to be packed by mules over the rough mountain passages.

To confuse the Spanish and colonial Royalist forces in Chile, San Martín divided his army into three columns, each of which crossed the Andes Mountains by a different route. He led the largest force over the 4,575-m (15,000-ft) Uspellata Pass near Cerro Acongagua (6,960 m; 22,836 ft), the highest mountain in South America. The crossing took 3 weeks and, as had happened with previous armies crossing mountain ranges, the mountain environment and terrain extracted a heavy toll of men and equipment. San Martín lost about one third of his troops to cold, altitude illness, and injury; more than half of his horses and mules; and most of his artillery and ammunition. Despite his losses, however, the element of surprise worked in his favor: the Spanish and Royalist army was divided because its leaders were unsure where San Martín planned to cross. He defeated the Spanish and Royalist forces at Chacabuco, a battle in which San Martín's use of features of the terrain (he had surveyed potential battle sites in Chile before crossing the Andes with his army) and the inspired leadership of his Chil-

ean subordinate, commander Bernardo O'Higgins, carried the day.

San Martín and O'Higgins later defeated the remaining Royalists in the Maipú Valley near Santiago, Chile. San Martín then raised another army, which, with the help of British Admiral Lord Cochrane, he transported by sea to Peru in 1820. There he blockaded Lima, forcing the Spanish military to retreat into the Andes east of Lima. San Martín then attempted to set up a stable independent government and did not immediately pursue the Spanish and Royalist troops, which were between his own force and those of Simón Bolívar fighting in Colombia and Ecuador to the north. San Martín and Bolívar met privately in Ecuador in 1821 to discuss the final campaign to eliminate Spanish rule. What was said during the meeting is unknown, but afterwards San Martín resigned as head of the Peruvian government and returned to Argentina, leaving Bolívar to drive the last of the Spaniards from the Peruvian highlands and, thus, from South America.[34,35]

Simón Bolívar, known as the Liberator of the North, also used mountain warfare to his advantage during his campaigns to free northern South America from the Spaniards. In his early struggles to free Venezuela, he fought in the lowlands but had only intermittent and transient success. Several times his armies were defeated, forcing him to flee to Caribbean islands to find funds for munitions and supplies and to recruit new soldiers. In 1819, after forcing the Spanish and Royalist sympathizers out of many areas in Venezuela, he was joined by a large group of soldiers from Europe who were looking for employment after the Napoleonic wars had ended. These expatriate soldiers constituted about a third of Bolívar's troops and stayed with him throughout the remaining wars, although their numbers were considerably reduced by combat casualties. With his reinforced army, Bolívar set out from Angostura, Venezuela, on the Orinoco River in the interior of the country to help liberate Colombia. He marched his troops through the lowland jungles and pampas of Colombia to the base of the Andes Mountains and then across a 4,880-m (16,000-ft) pass to surprise and defeat the Spanish and Royalist forces at the Battle of Boyacá. The army crossed the Andes as a single unit over a pass that was 1,000 feet higher than the passes that had been used 1 year earlier by San Martín's army in Chile. As with San Martín's crossing, Bolívar's army suffered tremendous losses of men and equipment to the high-mountain environment, especially to the cold, for which his soldiers were poorly provisioned. Bolívar marched at the head of his troops during this crossing; his strong leadership held the army together and inspired it during a series of battles over the subsequent weeks, culminating in the Battle of Boyacá, which allowed him to claim the city of Bogatá.[36]

Following Boyacá, Bolívar's subordinate general, Antonio José de Sucre, fought a series of battles in the mountains of Colombia and Ecuador that resulted in the final liberation of that region. The last battle there was fought on the slopes of the Pichincha Volcano, near Quito, Ecuador, in 1822. The battlefield was so steep that neither side could deploy its cavalry, and the battle was fought entirely by infantrymen, who struggled up and down the difficult terrain.

That same year, Bolívar turned his attention south to Peru, where the last Spanish and Royalist troops in South America were caught in the mountains between Bolívar's army to the north and San Martín's army in Lima on the Pacific coast. When San Martín left Peru after their meeting in Equador, Bolívar moved his own army nearly 1,000 miles through the Andes Mountains into the Peruvian altiplano. Like his previous crossing of the Andes into Colombia, the long march through the mountains was difficult, and hundreds of troops were injured, died, or deserted the army. The first battle took place in 1823 on the high (4,270 m; 14,000 ft) altiplano in the Junín region of Peru (near the present-day city of Huancayo). There, units of Bolívar's army, led by General Sucre, routed the Spaniards in a short, intense cavalry battle fought entirely with lances and sabers. The Spanish forces fled southward into the mountains, pursued by Bolívar's forces commanded by General Sucre.

The last battle of the Wars of Liberation was fought between these forces in 1824 in the mountains near the present-day city of Ayacucho, Peru. The rugged mountain topography hindered effective lines of artillery and rifle fire, and much of that battle was fought with bayonet and saber. Sucre's use of the rugged topography and the inspired fighting by legendary units of Bolívar's army carried the day and ended Spanish dominion in South America.[36,37]

Continuing Conflict

Following the Wars of Liberation, South America has been (and is still) the site of frequent revolts, violent changes of government, and border conflicts within and between the newly independent countries. Of particular significance in terms of mountain warfare were the Wars of the Pacific (1879–1883)

fought between Bolivia and Peru on one side and Chile on the other. The conflict started in a dispute between Bolivia and Chile over nitrate-rich guano deposits in the Atacama Desert on the Pacific coast. Peru was drawn into the conflict through an alliance with Bolivia. Early on, however, Bolivia withdrew from the conflict and subsequently lost its only access to the ocean. Peru and Chile continued to fight. After the Peruvians lost fierce battles on their southern border, the Chileans invaded Peru from the sea, and in more fierce fighting, defeated Peruvian defenses and occupied the Peruvian capital, Lima. Like the Spanish forces before them, the surviving Peruvian forces retreated into the mountains and high altiplano in the interior of the country to regain strength and carry on the resistance. There, under the leadership of Colonel Andrés Cáceres, the Peruvian forces fought a series of engagements known as the Breña Campaign (1881–1882) against the Chilean forces that had been sent to destroy them.

The fighting was part guerrilla and part conventional warfare, and the mountain environment adversely affected both sides at different times. For example, after a victory at Pucara, Peru, Colonel Cáceres marched his forces toward Ayacucho, intending to finally drive the Chilean forces out of the Peruvian mountains. However, he and his troops were caught by a storm in a high Andean pass between Acobamba and Julcamarca, where he lost approximately half his men and all his horses and mules and was unable continue to Ayacucho to capitalize on the momentum from his previous victory. Despite many small victories, the Peruvians were never strong enough to make a serious attempt to take back their capital, Lima.[38]

The war was eventually settled through diplomatic negotiations led by outside countries, but the determined resistance of Colonel Cáceres was a notable demonstration of the concept of the use of mountains for refuge by forces who know how to survive and fight there. This principle was again demonstrated in the same region during the last half of the 20th century, when the Sendaro Luminoso guerillas fought the Peruvian government there for more than 2 decades.

Modern Border Wars

China and Tibet

Since long before the Great Game began, China has claimed sovereignty over Tibet, and exact borders have long been disputed. In 1950, Chinese armies invaded Tibet and soon controlled the entire country. Although much of the action occurred on the high, inhospitable plateau, the Tibetans' acclimatization advantaged them only for the first few months: soon the lowland Chinese adjusted to the altitude and acclimatized fully during the following years.

However, among the occupying Chinese a previously unreported medical syndrome called subacute mountain sickness, appeared in Han (Chinese) infants who were either born at altitude or taken there when very young. This cardiac problem is a form of right ventricular enlargement and failure due to the pulmonary hypertension caused by hypoxia.[39] This is truly an environmental illness and is apparently an infantile form of a syndrome later described among Indian troops fighting at even higher elevations in the Karakoram mountains. Both the adult and the infantile forms are reversed after a few months by descent to lower altitude, but they are often fatal if descent is delayed.

China and India

In 1962 Chinese armies suddenly attacked India, crossing the Himalayan mountain ranges in half a dozen places from the southeastern end (Assam) to the northwestern section (Ladakh). Much of the fighting was between small patrols and pickets, but these engagements were no less bitter because relatively few men were involved in any one place. For the Indian forces, it was not military might but environmental forces that ultimately brought stalemate.[40] Because the Chinese troops had occupied the Tibetan highlands at 4,000 m (13,000 ft) for over a decade, they were well acclimatized to altitude. By contrast, most of the Indian troops were taken up hastily from the low, hot, plains only a few hundred feet above sea level. They were not clothed for the cold mountain environment and were unaware of, and unprepared for, the hazards of altitude hypoxia.[41]

In Ladakh, at the northern end of the Himalayan ranges, many men were taken up by truck and even more were flown up, to defend difficult positions at 5,000 to 5,500 m (16,000–18,000 ft) above the low plains of India. The Indian troops promptly suffered severely from the altitude and cold, whereas the Chinese, well acclimatized and also cold adapted, were unaffected.[42,43]

In Assam at the southeastern end of the Himalayan ranges, cold was somewhat less a problem than altitude, which incapacitated men at crucial periods. Indian regiments moved into the mountains rapidly

> in summer uniforms with one blanket per man—and bivouacking that night at 4,500 meters (15,000 feet) … they moved next day to Yamato La, a 4,000 meter (13,000 foot) pass a mile west and higher. … [The commanders in Delhi] pointed out that the troops could not survive at this altitude without winter clothing. … Brigadier Kaul spent a restless night … . Like so many of his troops he was suffering from a pulmonary disorder consequent on his exertions at altitudes to which he was not accustomed. … [H]e had to be carried over the pass. A helicopter was waiting … to lift him to Delhi.[42(p20)]

This conflict, extending the length of the Sino–Indian frontier, was the first large-scale confrontation between armies at altitudes that can be—and in this case often were—fatal. Among the Indian troops, morbidity from mountain sickness ranged from 4% to 20% in different companies; a third of the casualties are said to have died. From experience in this theater, many studies of acute mountain sickness and of high-altitude pulmonary and cerebral edema have been published. There is no doubt that the Indian troops suffered far more casualties from altitude and cold than from enemy action, although the numbers still remain classified.[43] The conflict continues today, occasionally flaring up and endangering the stability of the subcontinent.

After 18 months of indecisive action, the Chinese unexpectedly withdrew, although minor skirmishes persist today as they have for many decades. Hundreds of casualties and deaths among the Indian troops on the northwestern front, but only a few on the southeastern, were due to altitude illnesses.

In retrospect, the lessons are clear: at the outbreak of hostilities the Indian command was forced to move troops very rapidly to a dangerous altitude, but they failed to appreciate the importance of acclimatization, which the Chinese understood. It is not likely that staging troops gradually to higher from lower elevations would have altered the outcome, but it would have prevented many casualties from cold and altitude. The most important result of the Sino–Indian conflict was not conquest but major medical contributions to understanding the pathophysiology of mountain sickness and acclimatization.[42]

India and Pakistan

Kashmir has been fought over for a thousand years, and it has been a theater for the Great Game between Britain and Russia since the 17th century; the territory has been even more bitterly disputed since the partition of the subcontinent into Pakistan and India in 1947. Although Kashmir was and still is predominantly Muslim, the Hindu government of India immediately sent troops to occupy the state despite ragged opposition along the always-militant northwest frontier. Several small, desperately brave military operations by Pakistani troops took place in the winter of 1948 at 4,500 m (15,000 ft), resulting in little gain but great suffering from frostbite and later amputation for those who survived.

As an adjunct to the Kashmir dispute, India and Pakistan have been fighting a difficult and undeclared war in the Karakoram Range of the Himalayas since 1985. The arena is the watershed of the Siachen Glacier, comprising about 1,000 square miles of the highest, least accessible mountains in the world. This small war is a case study of the problems of operations in very high mountainous terrain. The campaign is immobile and consists of holding positions on very high points, raids by both sides, and daily artillery duels. No large-scale engagements have been fought. Details are classified but apparently only a few hundred troops on each side are engaged at any time.

At the beginning of 2002, both India and Pakistan are in full alert across the disputed Kashmir border, both armed with nuclear weapons. This confrontation threatens to destabilize the smaller-scale fighting, which has been in progress for 10 years in the Siachen area as high as 7,000 m (23,000 ft). Personnel rotate through these positions every 6 to 8 weeks, since they are at or above the altitude where deterioration outstrips acclimatization. Replacements are taken by truck and airlifted to points from which they must climb up the remaining few thousand feet. Supplies follow the same route and are often air-dropped. Casualties are alleged to be 20% or higher owing to cold and altitude, because the troops are exposed without adequate acclimatization.

The same syndrome of right ventricular failure described in Han Chinese infants in Tibet has been reported in Indian (and presumably has also appeared in Pakistani) troops who have been stationed for long periods at great height. The syndrome is different from the well-studied chronic mountain sickness (Monge's disease) seen in long-time residents in the high Andes Mountains.[39] Cold injuries are said to be less important. The medical experience gained has been of great interest to science.

SUMMARY

Throughout history many battles have been fought in mountainous terrain because the high ground can benefit either defense or offense. Small hills offer tactical advantage with few risks or obstacles. On higher mountains, however, the rigors of cold, altitude, difficult and dangerous terrain, and wildly variable weather often exact a heavy price. Even a brief review of military history reveals that these factors are often decisive in mountain warfare. Repeatedly, although not surprisingly, leadership emerges as the most critical factor. Faced with the hazards of high mountains, the courage, genius, and panache of leaders like Xenophon, Alexander, and Hannibal have often brought victory despite great obstacles. Conversely, if the leader falters, or if leadership is divided or uncertain, defeat is more likely. Preparedness has also been a major factor. More often than not soldiers have been led to fight in an environment for which they had inadequate clothing, food, or information—as was the case for Russian troops in the Caucasus. Cold has taken a heavy toll when troops have had inadequate footwear, clothing, or shelter—as happened in the disastrous retreat from the Chosin Reservoir in Korea.

During a few campaigns in the mountains, the oxygen lack at great altitude has caused many casualties among troops required to ascend too rapidly to dangerous altitude; this was especially true among Indian troops in Ladakh. Together, cold and altitude have been devastating, as Alexander found in the Hindu Kush Mountains, and as the Chinese Communist army experienced when crossing the Snowy Mountains. The combatants in the Karakoram Range of the Himalayas today are badly handicapped by the extreme altitude. By contrast, even on high mountains, well-clothed and -acclimatized men have usually prevailed over the enemy, whether defending or attacking. Continuing supplies of food, water, weapons, and clothing are crucial but are often interrupted by terrain and weather. Lack of food, as Xenophon noted, can greatly weaken even the best soldiers. In very cold weather, ice and snow can be changed to water only when fuel for fire is available; lack of water causes weakness from dehydration.

It is ironic that despite sophisticated weapons, clothing, and food; despite airpower and advanced transport; repeated failure to learn such basic lessons from the past has continued to cause avoidable casualties and has too often led to defeat. Mountainous terrain is a special circumstance, one greatly complicating the other hazards of war.

REFERENCES

1. Xenophon; Warner R, trans. *The Persian Expedition.* London, England: Penguin Books; 1949.
2. Arrian; Sélincourt A, trans. *The Campaigns of Alexander.* London, England: Penguin Books; 1971.
3. Dodge TA. *Great Captains: Alexander.* Boston, Mass: Houghton Mifflin; 1891. Reprinted (facsimile) Mechanicsburgh, Pa: Stackpole Books; 1994.
4. Green P. *Alexander of Macedon: 356–323* BC. Berkeley, Calif: University of California Press; 1991.
5. Quintus Curtius Rufus; Rolfe JC, trans. *History of Alexander*. London, England: Heineman; 1946.
6. De Beer G. *Alps and Elephants.* New York, NY: Dutton; 1956.
7. Lucas JS. *Alpine Elite: German Mountain Troops of World War II.* London, England: Jane's; 1980.
8. Chandler DG. *Atlas of Military Strategy*. New York, NY: Macmillan; 1980.
9. Monelli P. *Toes Up.* London, England: Duckworth; 1930.
10. Buchan JA. *History of the Great War.* Boston, Mass: Houghton Mifflin; 1922.

11. Werth A. *Russia at War 1941–1945.* New York, NY: Dutton; 1964.

12. Ellis J. *Cassino: The Hollow Victory*. New York, NY: McGraw Hill; 1984.

13. Strawson J. *The Italian Campaign.* New York, NY: Carroll and Graf; 1988.

14. Meinke AH. *Mountain Troops and Medics*. Keewaydin, Mich: Rucksack; 1993.

15. Gilbert DL. The first documented report of mountain sickness: The China or Headache story. *Respir Physiol.* 1983;52:10.

16. Fa Hsien. *The Travels of Fa-Hsien (399–414 AD), or Record of the Buddhist Kingdoms*. Westport, Conn: Greenwood Press; 1981.

17. de Acosta J. *Of Some Mervellous Effects of the Windes Which are in Some Parts of the Indies.* Quoted by: West JB, ed. *High Altitude Physiology.* Stroudsburg, Pa: Hutchinson Ross; 1981: 10.

18. de Ovalle A. Quoted by: Pinkerton J, ed. *A General Collection of the Best and Most Interesting Voyages and Travels in all Parts of the World.* London, England: Longman, Hurst, Reese, Orme, and Brown; 1813: 46–47.

19. Gruber. Cited by: Gilbert DL. *Oxygen and Living Processes.* New York, NY: Springer-Verlag; 1981.

20. Morgan D. *The Mongols.* New York, NY: Blackwell; 1986.

21. Dupuy RE, Dupuy TN. *The Encyclopedia of Military History.* New York, NY: Harper & Row; 1970: 277.

22. Mirza Muhammad Haider. *The Tarikh-i-Rashid: History of the Mongols in Central Asia.* Lahore, Pakistan: Book Traders; 1894: 412–413.

23. Hopkirk P. *The Great Game: The Struggle for Empire in Central Asia.* New York, NY: Kodansha; 1994.

24. Keay J. *The Gilgit Game.* Hamden, Conn: Archon; 1979.

25. Forbes A. *The Afghan Wars.* London, England: Seeley; 1906.

26. Urban M. *War in Afghanistan.* New York, NY: St Martin's Press; 1988.

27. Landon P. *The Opening of Tibet*. New York, NY: Doubleday Page; 1905; 52–54.

28. Mehra P. *The Younghusband Expedition.* New York, NY: Asia Publishing House; 1968.

29. Wilson D. *The Long March: The Epic of Chinese Communists' Survival.* New York, NY: Viking; 1971.

30. Salisbury HE. *The Long March: The Untold Story.* New York, NY: Harper & Row; 1985.

31. Hastings M. *The Korean War.* New York, NY: Simon & Schuster; 1987.

32. Pandolf K, Burr RE, Wenger CB, Pozos RS, eds. *Medical Aspects of Harsh Environments, Volume 1.* In: Zajtchuk R, Bellamy RF, eds. *Textbook of Military Medicine.* Washington, DC: Department of the Army, Office of The Surgeon General, and Borden Institute; 2001. Also available at www.armymedicine.army.mil/history.

33. Diamond J. Collision at Cajamarca. In: *Guns, Germs, and Steel: The Fates of Human Societies.* New York, NY: W. W. Norton & Co; 1997: 67–81.

34. Adams JR. José de San Martín. In: *Latin American Heroes*. New York, NY: Ballantine Books; 1991: 57–73.

35. Adams JR. Bernardo O'Higgins. In: *Latin American Heroes*. New York, NY: Ballantine Books; 1991: 74–91.

36. Adams JR. Simón Bolívar. In: *Latin American Heroes*. New York, NY: Ballantine Books; 1991: 28–39.

37. Adams JR. Manuela Sáenz. In: *Latin American Heroes*. New York, NY: Ballantine Books; 1991: 40–56.

38. del Campo J. The Breña Campaign, 1881–1883. Great Military Campaigns of the Peruvian Army and Navy website. Available at http://members.lycos.co.uk/Juan39/THE_BRENA_CAMPAIGN.html. Accessed 12 March 2002.

39. Anand IS. Subacute mountain sickness syndromes: Role of pulmonary hypertension. In: Sutton JR, Houston CS, Coates G, eds. *Hypoxia and Mountain Medicine.* Burlington, Vt: Queen City Press; 1992: 241–251.

40. Fisher WW, Rose LE, Huttenback RA. *Himalayan Battleground: Sino–Indian Rivalry in Ladakh.* New York, NY: Praeger; 1964.

41. Johri SR. *Chinese Invasion of Ladakh.* Lucknow, India: Himalaya Publications; 1969: 20.

42. Houston CS. *Going Higher: Oxygen, Man and Mountains*. Seattle, Wash: Mountaineers; 1998.

43. Singh I, Khanna PK, Srivastava MC, Lal M, Roy SB, Subramanyan CSV. Acute mountain sickness. *N Engl J Med.* 1969;280:175–179, 183–184.