TERRAIN INTELLIGENCE AND CURRENT MILITARY CONCEPTS*

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ABSTRACT. The development of nuclear weapons for tactical use has been followed by a concept of warfare based on small, mobile combat units equipped with helicopters, aircraft which can land and take off on short, sketchily prepared runways, and low ground-pressure vehicles which can move across country to supply a rapidly shifting force. This requires that terrain intelligence, dealing with the effects of the ground on military construction and maneuver, be made available to forward units that may have to act quickly on their own initiative. Help in this effort will come from new means of gathering information, such as radar, infrared photography, and television. Use of statistical methods will accelerate terrain analysis, especially at the strategic level. Analysis of landforms as they offer shelter from nuclear blast, and of soils which may emit neutron-induced gamma radiation, will assume an important place in terrain intelligence, as also will selection of safe routes for helicopters, tanks and supply vehicles; sites for rapid airfield construction and paratroop landings; and the suitability of soil for hasty excavation of shelters. The rapid pace of such warfare will require frequent preparation of situation maps showing areas where tree blow-down might slow troop movement or where nuclear contamination might be dangerous.

INTRODUCTION

Terrain intelligence, or terrain analysis, is "The process of interpreting a geographical area to determine the effect of the natural and man-made features on military operations. This includes the influence of weather and climate on those features." (Dictionary of U. S. Army Terms, 1953). This paper deals only with the analysis of natural features. Such analysis has, at least since the beginning of World War II, been widely referred to in the United States as military geology. Similarly in Germany, from World War I on, it was categorized as Wehrgeologie. In fact, however, as can be seen even in the above brief definition, the analysis of natural terrain for military purposes transcends even a liberal definition of geology. It includes meteorology, climatology, hydrology, soil science, botany, and forestry; and with modern developments in warfare geochemistry, geophysics and statistics have assumed great importance in this field. The knowledge of terrain derived from analysis by specialists of many sorts is combined in the intelligence report, a document, usually with a number of specially designed maps, which predicts terrain conditions of an area of military interest. The area of study is usually inaccessible, although terrain studies may also be made of maneuver areas or test sites for training or experimental purposes. Because terrain intelligence reports are designed for military users, those who write them can at present assume no technical knowledge on the part of the reader beyond that normally gained in military training (Whitmore, 1959). Furthermore, the user of such reports is usually pressed for time; therefore texts must be kept brief, and as much information as possible must be put on maps or in tabular texts which serve as expanded map explanations and enable the reader to look up terrain conditions at a given point of interest without reading through a running text.

The subjects included in terrain intelligence have increased in number as warfare has grown more complex, and this trend is, of course, continuing. Physiography was the first branch of earth science to be applied to military intelli-

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gence; this application was pioneered by the French military geographers (Marga. 1884-85, cited in Bryan. 1920). This example was followed by geologists assigned to the American Expeditionary Force in World War I (Bryan, 1920), who prepared terrain appreciation maps of parts of France for use at Corps level. The war of position, with its emphasis upon extensive networks of trenches with ancillary bunkers and tunnels, and the related problems of drainage and of water supply for large numbers of more or less stationary troops, led for the first time to a need for information on subsurface conditions (Brooks, 1920).

Between World Wars I and II, the Germans continued an interest in military geology and related applications of the natural sciences to terrain intelligence (Sonne, 1936; Wasmund, 1937; von Bülow. Kranz. and Sonne, 1938: Kranz, 1940). The results of their extensive studies in the field were summarized and applied to the warfare of the time in a series of 38 papers prepared for a course in military geology held by the German army military geology organization at Heidelberg in 1940 (Kraus, et al., 1941).

In the United States, military geology was revived early in 1942 with the organization of the Military Geology Unit of the United States Geological Survey under the leadership of W. H. Bradley. Although Bradley’s writing on the subject consists only of one abstract (Bradley, 1945), his influence upon the development of methods and formats for the preparation and presentation of terrain intelligence, and upon the use of the resulting reports by the U. S. Army, has been one of the major factors in the evolution of modern terrain intelligence. The Military Geology Unit, which by the end of the war had grown to a staff of about 180 scientists and supporting workers, prepared studies for many different military echelons dealing with cover, concealment, fields of fire, hasty fortifications, location of natural construction materials, foundation conditions, water supply, trafficability (suitability of the ground for cross-country movement by vehicles), airfield site selection, road construction and maintenance, and the effect of ground upon mine detectors. An account of the organization and methods of the Military Geology Unit, with examples of its work, has been prepared by Hunt (1950); additional information concerning the history of military geology is given by Whitmore (1954).

As modern terrain intelligence has evolved, all armies which use it have developed, more or less independently, the “combination method,” a term coined by the Germans for the team approach, in which a number of specialists in different disciplines collaborate in the preparation of a report. Furthermore, three levels of intelligence have been generally accepted both by the users and the producers as a means of defining the use to which a study will be put, and thus its content, format, and degree of detail. The most generalized of these is strategic intelligence, prepared for the use of headquarters staffs down to field army level, and required for long-range planning. Strategic intelligence reports generally require map scales of 1:1,000,000 or smaller and deal with areas of sub-continental size. Next is operational intelligence, with map scales larger than 1:1,000,000 (usually 1:250,000 or larger), which are used in preparing plans for a specific military operation and for bringing intelligence information up to date as the operation progresses. Such intelligence reports are usually used
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at field army headquarters or below (corps, division, battle group, regiment, or battalion). The third, and most detailed, category of terrain intelligence is field intelligence, a phrase coined here to include battlefield reconnaissance and surveillance, and also field consulting. Examples are field observation of the suitability of ground for cross-country movement, and of the detailed engineering geology characteristics of an area. Field consulting is a familiar function to the geologist, and has proved useful in the armies of the United States, Great Britain, Germany, and Russia. It involves such activities as location of water supplies, selection of quarry sites, search for sources of gravel, on-the-spot advice to engineer construction units as to road construction and maintenance, drainage, subgrade, base course and soil stabilization, and examination on the ground of sites that have been selected by operational intelligence as suitable for airfields or for underground installations.

All the major aspects of terrain intelligence as described above—team approach, concise format, specially designed maps, subject coverage, and levels of intelligence—will undoubtedly continue to characterize this activity in the future. But it is already apparent that modern concepts of warfare will alter each of these aspects in greater or less detail. New subjects of importance to military operations have appeared because of the advent of new weapons and vehicles. New means of gathering information force us to reopen the question of what information is useful to the military planner and how it should be presented; this is particularly important in view of the high level of technical training now required of officers in certain parts of the armed services. The resolution of these and many other problems will determine where and how the natural scientist can be of greatest use in terrain intelligence.

CURRENT MILITARY CONCEPTS

Factors influencing development of concepts.—The means of waging war determine how war is waged; and the three major “means” are weapons, transport, and communications. It is true now, as it has always been, that development of the various tools of war has not taken place at the same rate. Modern military thinking is, of course, more influenced by the availability of nuclear weapons than by any other consideration. In the past, innovations in weapons development have favored either the offense or the defense, thus focusing military thought on the development of ways of neutralizing the newly-gained advantage of the enemy. In the case of nuclear weapons the reaction of military thinkers has had to be more complex: not only is the obvious matter of defense and survival against enemy bombardment to be considered; there is the equally knotty problem of the use of the weapon to the tactical advantage of the user. The mission of land warfare is to neutralize the enemy’s forces and to secure and hold his territory. In pursuing this objective by the use of nuclear weapons, the offensive commander must be aware of the troop safety factor, i.e., that there is a considerable possibility of damaging his own troops with his own weapons. The three effects of nuclear bombardment are blast, heat, and radiation (both immediate and delayed). Blast and heat effects can injure friendly troops if they are not warned of an imminent bombardment, or if there is an error in bomb delivery. This situation is, in a greatly magnified way, like the problems
of large-scale conventional artillery bombardments in World War II, when errors of placement sometimes put friendly troops under fire.

But, in terms of troop safety, it is the radiation effects which pose a new and difficult problem for the offensive commander. He can interdict an area from the enemy by the use of atomic weapons, but how can he occupy or cross it? Efforts to answer this question must have great influence on the development of future tactical doctrine and hence on the development of terrain intelligence.

Turning from the offensive to the defensive viewpoint, the fundamental premise in planning for nuclear warfare must be that the smallest possible target will be presented to the enemy. This can be achieved in one of two ways: either by going underground or by achievement of far greater mobility than troops have had before. The consideration of underground installations for defense is different in degree rather than in kind from similar defense against conventional weapons. The matter of mobility, on the other hand, forces radical changes in our concepts of tactics, and both military theory and specific vehicular development have been in recent years greatly influenced by this factor.

It is generally agreed (Parham, 1957) that in two-sided atomic war, it will be necessary to separate groups of soldiers so that only a small number will be vulnerable to atomic bombing except possibly during a short massing period before an attack. This means that there will be gaps between fighting groups and thus an end to the classical concept of the continuous line facing the enemy. The existence of separate units of this sort means a great increase in the periphery to be guarded, in addition to which the gaps between fighting units must be kept under surveillance. This in turn means that each unit, after being well briefed in advance on its mission and objective, must be semi-autonomous within the limits of its mission. A great deal of intelligence information must be given it before action starts, but it must also be capable of collecting detailed information about the battlefield as it goes along. The unit must be able to move rapidly from place to place, and it must be supplied from depots in the rear. These requirements have led to the development of new vehicles, both ground and air. Troop-carrying helicopters have been designed, as well as an experimental series of turbo-rotor or "zero ground pressure" vehicles such as the individual flying platform and the "aerial jeep." For cross-country movement, especially of supplies, attention is being given to a class of vehicles known as Goers, with large wheels and low-pressure pneumatic tires similar to the large earth-moving equipment now in wide use (McKee and Rigg, 1958). Air supply and movement of troops from place to place on the battlefield may also be achieved by the use of aircraft capable of vertical take-off and landing, and also of aircraft which can land and take off on short runways which have been prepared only to the extent of removing major obstacles and grading and filling the extremely rough spots.

Planning a military force which will make optimum use of these new developments both in weapons and mobility is further complicated if the planning is aimed at developing a force that has dual capability, i.e., that can fight either a nuclear or a non-nuclear war (Lemnitzer, 1959). Whether this is possible or advisable is a matter of disagreement among military authorities.
Army organization.—Since terrain intelligence is primarily concerned with land warfare, the organization and intelligence requirements of the U. S. Army, as influenced by the new developments discussed above, will be considered here, together with certain Air Force developments that relate to land warfare. By extension these considerations will also apply to amphibious operations of the Marine Corps and Navy and, on a broader scale, to strategic operations of the Air Force.

To meet the requirements of nuclear warfare, with the attendant necessity for quickly placing a striking force anywhere in the world, the U. S. Army has established a new type of unit, the Strategic Army Corps (Clarke, 1958. Westmoreland, 1958). This consists of two airborne and two infantry divisions with combat and service support elements such as an armored cavalry regiment, corps artillery, engineers, transportation, and quartermaster troops. The major elements of the Corps are ready for deployment overseas by air on a few hours' notice; the remainder could be deployed by air and surface lift shortly thereafter.

Each of the airborne divisions of the Corps consists of five battle groups, and each of these consists of five rifle companies, a headquarters company, and a heavy-mortar battery (Gray, 1958). The battle group, consisting of 1,584 officers and men, is the fundamental unit of mobile warfare; and the five-fold structure of division and battle group is the Pentomic concept which now governs the battle organization of the U. S. Army. A test of the Strategic Army Corps organization was made in May 1958 (Westmoreland, 1958). The 101st Airborne Division, a unit of the Strategic Army Corps stationed at Fort Campbell, Kentucky, received an alert at 2:00 P.M. on May 13. By daybreak on May 14 a task force, consisting of 560 men, 59 vehicles, one helicopter, and ammunition and rations for four days, was in the field in Puerto Rico, 1,600 miles from its base. For operations of this sort, initiated on a few hours' notice but likely to develop into campaigns of length similar to those of World War II, it is necessary to prepare terrain intelligence studies well in advance, in such a form that they can be easily carried and quickly used; and the initial studies must be supplemented by terrain estimates made by specialists who move to the operational area with the combat troops.

NEW DEVELOPMENTS IN THE APPLICATION OF THE NATURAL SCIENCES TO TERRAIN INTELLIGENCE

New means of gathering information.—A number of sensing devices, such as radar, infra-red photography, and television, have been developed to the point where they can be used in gathering terrain information. They can be used by troops in forward positions on the ground or by manned or drone aircraft flying over enemy-occupied territory, which can then transmit impulses (or, in the case of television, pictures) either to advanced command posts or to intelligence centers in the rear. In the case of radar, for instance, Feder (1959) emphasizes its ability to record terrain characteristics in all weather and to penetrate vegetation. He points out that "some X-through K_b-band reradiation data show radar's ability to interpret surface textures, moisture content, and snow
cover for trafficability purposes and texture and composition for civil engineering and geologic purposes.” Terrain images received over radar are not clear enough to serve as the sole source of information on an area, but they can be a valuable adjunct to previously prepared terrain intelligence reports based on compilation from geologic, soil, and vegetation literature and from aerial photographs.

Another device for gathering supplementary terrain data is the portable reflectance spectrophotometer developed by the U. S. Army Engineer Research and Development Laboratories (Dwornik, et al., 1959). Spectral-reflectance data, which can be used in conjunction with photointerpretation, appear to be particularly useful in detecting areas where the soil has been disturbed.

Besides the new sensing devices, terrain intelligence will benefit from improved quality of aerial photographs and from increased speed of film processing and delivery.

Despite the many ways of gathering information at a distance, on-the-ground reconnaissance will still be necessary to determine the details of terrain configuration. Several instruments have been developed to measure soil bearing strength in the field to determine suitability for cross-country movement. Probably the most widely used of these is the cone penetrometer, described by Knight (1956). This is a rod tipped by a cone the area of whose base is one square inch, and, at the upper end, a flexible ring with a dial which records the pressure necessary to push the cone into the ground. The penetrometer measures the strength of the ground against vertical loads. It can be supplemented by a shear-meter, a ring-shaped load plate fitted with cleats. “This plate is applied to the ground with a constant vertical loading and provides a measure of the strength of the ground against horizontal thrusts by producing a record of torque vs. angle as the plate is rotated.” (Sattinger, 1959). Such devices, while they probably could not be widely used under combat conditions, would be valuable in spot-checking existing intelligence, especially in areas of medium-grained soils whose reaction to precipitation might be difficult to predict with sufficient accuracy.

Quantitative terrain studies.—Terrain analyses have, since their inception, been for the most part qualitatively descriptive. Slopes are described as steep or gentle, ground as suitable or unsuitable for movement by tanks or as poorly drained or well-drained. Most often this description is presented in tabular form; examples are given by Hunt (1950). The exceptions to this rule have generally been in the form of stating limiting values: as, for instance, delineating areas with slopes too steep to be negotiated by a tank, or mapping areas of vegetation on the basis of whether or not the trees are far enough apart for a tank to pass between them.

As in most other branches of geology, there has been in military geology and its related sciences an increased effort at quantification in the last few years. The cone penetrometer is an example of this: it is used in an attempt to express the bearing strength of soil on a numerical basis. Besides trying to devise instruments specifically for military use, geologists and soil scientists have adapted the tests and measurements of civil engineering to reports for military engineers involved in the siting and construction of military bases, including
buildings, airfields, artillery and missile emplacements, roads, and underground installations. Nicol, Flint and Saplis (1957), in one of a series of military geology reports on islands of the western Pacific area that have been prepared by the United States Geological Survey, have presented the following numerical test results, in tabular form, for each of the units presented on their engineering geology map: mechanical analyses; physical test constants of fraction passing No. 40; specific gravity; moisture-density relation (undisturbed: field moisture: disturbed: optimum moisture; undisturbed: field density, lb./cu. ft.; and disturbed: optimum density, lb./cu. ft.); consolidation test with 0.341 tons/sq. ft. (initial void ratio and void ratio after 24 hours); California Bearing Ratio on water-soaked samples (% C. B. R. with 10 lb. surcharge and % swell during soaking); and direct shear test with 3,000 lb./sq. ft. vertical load. The figures given result from standard engineering tests of samples collected in the course of mapping the island. These samples were, in the judgment of the field geologist or soil scientist, typical of the map unit within which they occurred. The figures given are chiefly valuable in indicating order of magnitude of expectable conditions, and, especially, in comparing the worth of one site with that of another. It is understood that, before actual construction is begun, a detailed on-site survey must be made. This type of report has proved very useful to military planners.

Statistics as applied to landforms is a promising method that may be useful in future terrain analysis. The work of Strahler (1954, 1956; Strahler and Koons, 1959) and others in the field of quantitative geomorphology has been devoted to quantifying various landform characteristics in such a way that numerical values can be used to make comparisons between regions or to relate two or more categories of values to each other—as, for instance, slope related to the lithology of outcropping rocks. The application of statistical techniques to terrain analysis is difficult because of the number of factors involved. The preparation of a cross-country movement map for tanks is an example. The ability of a tank to move across country is governed by the following characteristics of the terrain: (a) slope; (b) soil: well or poorly drained, slippery or not; (c) state of the ground: frozen (to what depth?), snowcovered, flooded, saturated, or dry; (d) vegetation: presence and type of underbrush, size and spacing of trees, and amount and density of blow-down; (e) roughness (micro-relief); (f) distribution, size, and depth of water bodies. A particularly difficult aspect of this problem is that the resulting intelligence map is a simple one, classifying the ground in terms of a tank's ability to move (a) at any time, (b) at no time, or (c) seasonally (Whitmore, 1950, p. 644). This means that quantitative expression of landform characteristics will be a tool used in preparation of the intelligence report but will not appear in the report itself. This is in contrast to the presentation of the physical properties of soil and rock for construction purposes. The reason for the difference is that the construction engineer is accustomed to using numerically expressed properties in planning his operations, whereas the tactician, both in developing and executing his battle plan, must have his data reduced so they can be quickly absorbed and combined with the many other factors that require consideration in planning. A special-purpose
map, accompanied by a table or brief text, is the best way of doing this. It appears now that the major contribution of quantitative terrain studies to terrain intelligence lies in the possibility of quicker and more accurate delineation on maps of such important factors as slope classes.

Interpretation of an inaccessible area for military purposes requires intensive study of topographic, geologic, soil, and vegetation maps as well as of air photographs. The finished intelligence map results from a two-step process. First, the basic data are compiled. An example of this is the slope map. Then the various types of data are combined to form the interpretive map—one, for instance, dealing with cross-country movement. One of the most important aspects of both the basic-data map and of the interpretive map is the drawing of boundaries significant to military operations: an example is the line on the map representing the break between areas which a tank can negotiate and those which it cannot. Such a line on the interpretive map is usually derived from a consideration of the interaction of two or more factors. For instance, the maximum slope that a tank can negotiate is one of the characteristics of the vehicle that is included in its design. This slope as presented in the official performance characteristics refers to the pitch of a straight, smooth ramp that the tank can climb. In the field, however, the maximum negotiable slope for the same tank will practically always be less than the maximum established by the manufacturers' test because of roughness of ground, slipperiness, and the presence of vegetation. A tank operating on a slope which approaches its maximum will be stopped by a tree or a fallen log which would present no obstacle on level ground.

Statistical methods can be applied to the preparation of basic data maps, each of which is based on only one, or at most a few, types of measurement. Even when one is making measurements on maps rather than in the field, time is a limiting factor; and the use of statistical sampling methods, analytical treatments such as frequency-distribution analysis, and curve-fitting and testing techniques (Strahler, 1954) may serve to accelerate the work of data compilation for intelligence purposes, particularly since machine methods may be used to handle statistical data. Allowance must, of course, be made for the plotting error of the base map; aerial photographs will be useful in determining this.

At present it appears that statistical analysis may be especially useful in strategic intelligence, where the area of a study is measured in thousands of square miles and the map scale is smaller than 1:1,000,000. Terrain analysis at such scales is made for the purpose of showing the distribution of mountains, foothills, plains, valley systems, and extensive poorly drained areas, and of pointing out their significance as barriers or corridors, or as suitable or unsuitable areas for military construction. A terrain unit on such a map may be several hundred miles long; and although it is predominantly of one landform type—foothills with maximum relief of 500 feet, for instance—it will naturally include within its extent other landform types which are too small to show at the required map scale. Statistical treatment may provide a rapid means of determining the dominant terrain type in such an area, together with a definition of its borders which is concomitant in accuracy with the map scale, and also may
furnish a good estimate of the nature and extent of subsidiary terrain types contained within the map unit.

In contrast to the strategic map, the large-scale tactical map, made to be used by troop commanders in the field, is probably not susceptible of statistical treatment. It attempts to show the exact conditions at a given spot rather than, as in the strategic map, the probability that a given condition exists there. Therefore direct compilation by skilled earth scientists, time-consuming as it may be, appears necessary in this case.

TERRAIN INTELLIGENCE SUBJECTS AFFECTED BY NEW CONCEPTS AND METHODS OF WARFARE

Terrain appreciation.—This term is used here for the analysis of the land surface as it affects maneuver. This includes cover; concealment; location of defiles, corridors, and barriers; suitability for hasty excavation (slit trenches, bunkers); and ease of observation. Cross-country movement for vehicles, because of the numerous special problems that it entails, is considered separately.

In nuclear warfare the troop safety factor will necessitate great accuracy in terrain intelligence concerning the area to be occupied by our troops. Troops can be protected from nuclear effects by being in the lee of a topographic barrier and by being in shelters, even hasty ones like slit trenches. Prominent terrain features will protect troops from thermal radiation, but the matter of protection from air blast effects is not as simple as it may appear. Studies at Hiroshima showed that some structures escaped destruction because there was a hill between them and the point of detonation of the bomb, but detailed analysis has demonstrated that blast waves can easily diffract around apparent obstacles (Glasstone, 1957, p. 86). These phenomena have two results as far as intelligence is concerned: first, a commander must, before making the decision to use a nuclear weapon, know the disposition of his own troops with respect to sheltering terrain; and second, the commanders of combat units must, before entering an area, have maps showing where they can dispose their troops for greatest safety, where the soil is suitable for digging shelters, and the location of existing underground shelter such as caves and mines. If we recall the mobility concept stated above, it becomes plain that battle groups and lower organizations will need to carry with them more detailed intelligence information than has been required in the past.

In addition to danger from blast and heat, troops in nuclear war will be endangered by fall-out and residual radiation. Fall-out patterns depend on winds and upon the shielding effects and eddies caused by landforms. The major protection against fallout from enemy bombardment will be the placing of troops in hastily dug covered shelters (again this emphasizes the fact that troops, no matter how often they move, will dig in at every opportunity). In planning for the safety of his own troops, the commander who contemplates using a nuclear weapon must be well briefed by his meteorologist.

One of the most dangerous types of residual radiation for troops in the field is neutron-induced gamma radiation, which results from the capture by certain elements in the soil of neutrons liberated in the fission process. Among
these are sodium and manganese, which can constitute a serious hazard during the first few hours after a nuclear explosion (Glasstone, 1957, p. 398-399). In order to be prepared for this danger, troops should have information as to the distribution of soils containing critical concentrations of dangerous elements.

In addition to intelligence studies prepared before the beginning of an operation, this type of warfare will require that terrain intelligence staffs prepare a sort of situation map at intervals during the fighting. This tactical intelligence, which should be distributed to front-line troops in each sector, would report on such recent developments as tree blow-down and newly contaminated areas, the location of which would affect the movement of troops from one place to another.

If the time should arrive when helicopters and vertical takeoff and short aircraft are used in forward areas for rapid deployment of troops, another map will have to be added to the already considerable number which comprise terrain intelligence. This would be an air movement map, pointing out low-level flight routes protected by valleys, ridges and forests. This same sort of intelligence would be useful for turbo-rotor vehicles and individual rotor platforms.

Recent developments in line-of-sight communications, such as television and surveillance equipment, make it necessary to determine for the battlefield area where the obstacles lie and where clear transmission or viewing is possible. Something on the order of Barrellian profiles would be useful in this determination. Snell (1959) has devised a mathematical model of terrain "from which it is possible to predict the number of valleys which cannot be seen (protected valleys) at specified distances from the highest elevation within an area."

Cross-country movement.—In World War II, except for the North African campaign, tanks generally moved on the roads most of the time, leaving them only when maneuvering room was needed in meeting the enemy, or when the road was threatened by aircraft or artillery. In a more mobile war off-road movement would become more important.

During World War II the United States Geological Survey designed a trafficability (now called cross-country movement) map, scale 1:100,000, for the medium tank. An example of a legend for such a map is given by Whitmore (1950). The 1:100,000 map has since been improved and simplified by Frederick Betz, Jr., A. C. Orvedal, M. M. Elias and their associates, and appears to be appropriate for the mobile warfare that has been described above. Although further study of recent concepts as they develop might lead some to conclude that, because of the size of areas covered in an operation, the 1:250,000 scale would be preferable.

In mobile war waged by small units, logistics will be very difficult. Ammunition and rations for a battle group cannot be moved by air, and it seems unlikely that they can always, or even usually, be moved by road. McKee and Rigg (1958) state:

We have made tremendous strides in increasing firepower. We cannot increase logistical power the same way. Until this has been accomplished, the sparsely populated battle zone will remain a myth. . . . Road-bound vehicles can neither disperse nor concentrate with the speed and flexibility required in modern war, and dispersion is vital.
The Army is attempting to solve this problem with the “Goer” vehicle, mentioned above, having large cargo capacity, large wheels, and low pressure tires. The ground pressure exerted by these vehicles is near enough to that of the medium tank so that, with slight modifications in legend, the cross-country movement map designed for the medium tank could be used for the Goer as well.

The basic principle of dispersion in the battlefield would probably mean more hasty river crossings, as opportunity presented itself, and perhaps the virtual end of large-scale crossings at a single spot following the establishment of bridgeheads. Intelligence for this type of operation would necessitate location of all possible crossing points, no matter how marginal.

*Surface- and ground-water contamination.*—The possibility of water contamination by nuclear radiation will require a greater dependence on ground water by troops in the field than has been the case in the past, when surface water was always used when available.

*Airfield construction.*—Two contrasting trends are present in the siting, design, and construction of airfields. One is the result of the building of larger and heavier bombers and transport aircraft; the other, which has been discussed, is the advent of so-called “short takeoff and landing” aircraft.

In the development of larger conventional airplanes, Holle (1956) reports an increase in gross weight from a maximum of 17,000 pounds for the B-17 bomber of 1942 to 500,000 pounds for the B-52 of 1956. In situations where the early B-17 required an 8-inch concrete slab, the B-52 needs 21 inches. Modern large jet aircraft also require much longer runways. This means that selection of sites for larger airfields—a task of the military geologist—will be more difficult, although the techniques used will not differ much from those of the past. It will still be necessary first to select large flat areas where the surrounding uplands offer no topographic hazards to aircraft landing or takeoff, and where the subgrade material has sufficient bearing strength.

The use of short takeoff and landing vehicles does not impose a rigorous requirement in terms of length of runway. The need for specific soils information, on the other hand, is increased because, if used in close support of combat troops, these airplanes must land on runways whose preparation has been limited to removal of obstacles such as boulders and trees, followed by rough grading. Seasonal variation in the bearing strength of natural soils must be known, and the site which has been selected should be checked on the ground with a cone penetrometer or similar device.

An example of the selection of unprepared sites for aircraft landings is Operation Groundhog, carried out in North Greenland beginning in 1957 by the Air Force Cambridge Research Center and the United States Geological Survey (Stoertz and Needleman, 1957; Davies, Needleman, and Klick, 1959). A number of landing areas were selected by photo-interpretation and subsequently studied on the ground. One of these, on the shore of Bronlunds Fjord, was selected for a landing test by a C-124 heavy cargo plane.

The landing area itself is situated on an exceedingly level, dry lake plain or old marine embayment, which is about one-half mile wide and is roughly parallel to the shore of Bronlunds Fjord for a distance of three miles ... the southeastern one-third forming a natural landing area about one mile long, composed of hard, firm clay. (Stoertz and Needleman, 1957, p. 16.)
The aircraft which made the successful test landing had a gross weight of 145,000 pounds and ground contact pressure of about 54 pounds per square inch. A ground run of only 1800 feet was required for landing, and 2000 feet for takeoff. Preparation of the strip was limited to tamping of one small soft area, clearing grass clumps, and filling several shallow gullies with tamped earth obtained nearby.

Other subjects.—Selection of sites for paratroop landings and supply drops will probably be of increasing importance, but, with the development of helicopters and versatile fixed-wing aircraft, the emphasis on glider landings has already declined. Amphibious operations will be more dispersed than in the past, so that intelligence emphasis will have to include beaches previously regarded as marginal or unusable (Michel, 1958). The siting of underground depots and other major installations will be an increasing intelligence requirement.

ORGANIZATION AND DISSEMINATION OF TERRAIN INTELLIGENCE

In the type of warfare described above, the scale and amount of strategic terrain intelligence required will be about the same as in the past, but with greater emphasis on sites for hastily constructed airfields, air drop zones, air heads, and areas where topography offers protection for troops and low-flying aircraft.

Operational or tactical (i.e., large scale) intelligence studies must be disseminated more widely among forward units than has been done heretofore. Also supplementary situation maps and reports, dealing with tree blow-down, contamination, state of the ground and similar subjects, must be prepared as often as the situation warrants. The possible rapid shift from offense to defense will place a burden on intelligence units, and will raise problems in the design of intelligence reports. For defense, areas must be selected that are suitable for strong points, barriers, alternate positions, and blocking positions (Parham, 1957). For offense, possible attack routes must be shown and information kept up-to-date as to which ones remain feasible as the battle progresses.

In order properly to use the sensing devices that have been described, trained terrain intelligence personnel should be assigned to regiment or battalion headquarters, where they could report directly to the commander. Their basic data would consist of reports prepared at higher echelons before the operation, but they would add to and modify these with their own observations plus later information received from larger intelligence centers at Division and Army level. In nuclear warfare, once action has begun, it will probably proceed at such a rapid pace that most terrain intelligence reporting will be in the form of oral briefings or, if reproduced for dissemination, will be restricted to the bare essentials. In other words, it will be necessary that detailed terrain intelligence reports be distributed in advance not only to major headquarters, but to forward units which may find it necessary to act quickly on their own initiative.

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