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SWORDS INTO PLOWSHARES: MILITARY GEOLOGY AND NATIONAL SECURITY PROJECTS

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ABSTRACT

Military geology and national security projects are often comparable, achieving their *raison d'etre* in support of national goals, military operations, and/or systems–all for vital national interests. The application of Geoscience to these ends, especially engineering geology, has occurred from pole to pole and included every conceivable environment and natural condition. In the conduct of such projects, the Geosciences have advanced, and vice versa.

Desert trafficability, most notably regarding playa surfaces, is both temporary and variable and not a persistent condition as some early authors believed. Playas in Australia, Iran, and the U. S. show that saline efflorescence is removed following surface water dissolution and subsequent deflation, resulting in very hard crusts. Magadiite, a hydrous sodium silicate and possible precursor of bedded chert, was first discovered in North America at Alkali Lake, OR, during a military project. Pleistocene Lake Trinity, a small and mostly buried evaporite basin in the northern Jornada del Muerto, NM, was discovered during exploratory drilling in support of a military test program.

The Strategic Petroleum Reserve (SPR), operated by the U. S. Department of Energy, has underground cavern storage of ~600 MMB of crude oil in five Gulf Coast salt domes. The geologic characterization of sites for the SPR program is a major component of these comprehensive engineered works unparalleled in modern times, on scale with the

Panama Canal. Numerous studies of salt-stock heterogeneity, salt-karst features, and structural and physical attributes of salt deposits are broadening our database for use in the commercial storage sector.

Geological practitioners serving in military and national security endeavors are fully functioning members of the project technical teams, and have made significant advances to the discipline.

INTRODUCTION

.....they shall beat their swords into plowshares, and their spears into pruning hooks; nation shall not lift up sword against nation, neither shall they learn war anymore.... Isaiah II, 4.

The biblical vision to convert instruments of war into tools for peace may or may not be materializing as we approach the year 2000, but hope has not faded. In fact, that aspiration is even more urgent, because of the advent of ever more deadly weapons and associated delivery systems.

The U. S. Plowshare Program of the 1950s and 1960s examined the use of nuclear explosives for peaceful applications, such as rapid excavation and tunneling. Although never applied commercially in peacetime, that technology is available for future generations (Hamburger, 1973). The Plowshare Program exemplifies the metaphor discussed in this paper–the beating of swords into plowshares, or literally, the application of information and technology obtained for military purposes to peaceful endeavors.

The application of the Geosciences to military strategy and tactics has been taught in the military academies of most countries in one form or other for many years and is hardly novel; it is practiced in combat theatres often. Examples of the use of engineering geology in wartime were described by Kiersch (1991), and in this symposium. Peacetime benefits from military technology are perhaps best known in regard to reconnaissance systems, especially remote sensing. In 1995 the widespread availability of satellite imagery in its many manifestations for use in modern Geoscience is a wonder to behold, when we consider its rudimentary beginnings in the 1960s (Williams, 1976). Likewise, the use of the Global Positioning System in geological mapping, geodesy, and surveying in 1995 is awe inspiring. Hand-held receivers capable of providing virtually immediate ~50-75 meter horizontal accuracy are virtually as affordable today as the time-honored Brunton® compass. And, even more sophisticated receivers and methods achieving centimeter-range accuracy are employed regularly today in studies of regional and global tectonics.

Discoveries made during the course of U. S. Military Geology and National Security projects over the past half-century are legion, and some of them are discussed in this Symposium. This author has been personally associated with several: playa trafficability, the mineral magadiite, Pleistocene Lake Trinity, and salt-karst dissolution, as discussed in the following sections.

PLAYA-SURFACE TRAFFICABILITY

Playas attract attention because they are the flattest of all landforms, and because they provide unimpeded mobility for heavy vehicles and aircraft when in their most trafficable condition. They have been used routinely for aircraft operations at Edwards Air Force Base and nearby Fort Irwin military reservations, CA, for more than 50 years with relatively little maintenance **(Figure 1)**. Each flooding by infrequent desert rains reconditions the upper few centimeters of the clayey soil, forming a hard surface crust upon drying.

At other playas such as Harper Lake, CA (between Edwards AFB and Ft. Irwin), evaporite efflorescence creates a friable surface with greatly reduced trafficability. These surfaces have been described as "puffy" or "self-rising" ground (Motts, 1972). Previous authors have implied that these conditions were persistent, and attempted to classify playas on the basis of these surface characteristics. However, extended observations by Neal (1972), Krinsley (1976) and others have showed that playa surfaces change over time, responding to both short- and long-term influences in *both* surface and groundwater hydrology **(Figure 2)**. For example, jagged salt pan accumulations of thick evaporites are made smooth naturally by regular washing from surface waters. Automobile racing and speed trials at the Bonneville Salt Flats, UT, would be impossible otherwise.

Playas are very sensitive indicators of changing environment and show a wide range of climatic, hydrologic, and geomorphic responses (Neal and Motts, 1967; Neal et al., 1968, Neal, 1972, Krinsley et al., 1968). Large fissures in playas reveal long-term geohydrologic response and are one indicator of man's activities, or of climatic change. Some giant fissures are of tectonic origin **(Figure 3)**, although most result from deep-seated desiccation. The knowledge discussed above was obtained during the course of several military projects, primarily addressing aircraft trafficability.

Other peaceful applications of playa investigations include the widespread artificial recharge of ground water in arid and semi-arid regions around the globe, installations of solar and radiotelescope arrays which require very large and flat areas, and for auto racing and other recreation.

MAGADIITE AT ALKALI LAKE

The mineral magadiite ($NaSi_7O_{13}(OH)_3$ $3H_2O$)was named for the locale of its discovery and identification at Lake Magadi, Kenya (Eugster, 1967). Eugster believed that magadiite could be a precipitate that might be subsequently converted to bedded chert. Such a mechanism could explain the previously enigmatic depositional environment for bedded chert. During the study of the playa at Alkali Lake, OR, several years prior to Eugster's 1967 paper, the mineral was observed but not recognized for what Eugster later described it to be **(Figure 4)**. Subsequently, we noted the similiarity and announced its first identification in North America (Rooney, et al., 1969).

PLEISTOCENE LAKE TRINITY, NEW MEXICO

During the search for a test site that would represent a scaled geology similar to a potential military objective, a buried 200-km^2 Pleistocene evaporite basin was identified, and verified by several coreholes. The basin was shown to be similar to Pleistocene Lake Otero in the adjacent Tularosa Basin of south-central New Mexico, and yet had distinctive sulphate hydrochemistry unlike any other lake in the western United States (Neal, et al., 1983) **(Figures 5, 6)**. The discovery of this basin has enhanced the overall understanding of Pleistocene and Recent pluvial climates, providing further evidence of widespread, perennially lacustrine conditions throughout the Great Basin of California, Nevada, Oregon and Utah, and extending into enclosed basins of Arizona, New Mexico, western Texas and southern Colorado.

U. S. STRATEGIC PETROLEUM RESERVE

Following the oil embargoes during the winter of 1973-74, the U. S. Congress created the Strategic Petroleum Reserve (SPR) in 1975 to provide a buffer against further interruption in foreign oil imports. Six salt dome sites were identified for petroleum storage and about 600 million barrels of crude are now stored in five remaining sites–one site-Sulphur Mines, LA, was decommissioned in 1992 to gain system efficiency. During the Persian Gulf War the SPR was partially drawn down, largely to encourage market stability by showing the Reserve's immediate availability. The site at Weeks Island, LA, the only site created by room-and-pillar mining, was being decommissioned starting in November 1995 because a sinkhole had created a flowpath between groundwater and the oil storage chamber. The diagnostics and groundwater control and mitigation established at this site are directly relevant to conventional salt mining (Neal et al., 1996).

Brine has been extracted from caverns in salt during most of the 20th Century, but the underground storage of liquefied petroleum gas (LPG) therein did not become a widely used technology until after 1950. Geologic site characterization has been an essential element of studies required to support the SPR, and this methodology is directly applicable to cavern storage for other purposes (Neal and Magorian, 1996). The understanding of salt-dome geology has increased markedly during the past 20 years, partly because of SPR studies. During the past 50 years, more than 1000 caverns have been constructed in domal salt and contain a variety of liquid and gaseous hydrocarbons. Salt-creep phenomena, which leads to cavern closure and surface subsidence, has been modeled with remarkable accuracy (Hoffman, 1992; Ehgartner, 1992), and requires attention in all cavern applications. The recognition of inhomogeneities in domal salt in particular has led to the conceptualization and understanding of anomalous zones (Kupfer, 1990; Talbot and Jackson, 1987; Neal et al., 1993). Anomalous zones are believed to separate individual spines or lobes of differential movement in salt diapirism.

Although the SPR was established for National Security purposes, the same geotechnical data have been applied to industrial use, such as storing LPG. Natural gas is now stored, especially for seasonal peak demands, in some fifty caverns in both domal and bedded salt. New applications are continually being considered; for example, compressed air energy storage (CAES) has been tested, but is not yet economically practical. The storage of other products including grain and hazardous waste has been proposed also (Bishop, 1993).

Salt karst is relatively lesser known in the geologic literature in comparison with limestone karst. During the last 35 years much of the technical literature about salt karst has been produced under the sponsorship of national security projects, e. g., Projects Gnome and Salmon, Office of Nuclear Waste Isolation, Waste Isolation Pilot Plant, and The Stategic Petroleum Reserve--all managed by the U. S. Department of Energy and its predecessor agencies, (Neal, 1994). The literature is replete with discussions relating rates of dissolution and potential risks to underground facilities, or hydrologic flow rates involving hazardous materials. It seems likely that without the intense effort by these projects, today's understanding of salt karst would be much less mature **(Figure 7)**.

CONCLUSIONS

The studies described here are a direct outgrowth of military and national security projects and are relevant to peacetime use of the Geosciences. Some of the results described here were not specifically sought, and their application to peacetime purposes needed to be recognized. Many other projects have also shown similar use. The Geosciences can benefit in many ways from military and national security projects; however, practitioners must become aware of opportunities for the use of such knowledge, *and must be willing to disseminate it.*

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FIGURES

Figure 1 The extensive, hard playa crust on Rogers Dry Lake at Edwards AFB, CA, has been used routinely for the landing of air and spacecraft for some 50 years. The Space Shuttle of the 1990s is now able to make precision landings on concrete runways, but numerous emergency playas similar to that shown here exist all over the world.

Figure 2 Automobile tracks show transition from an extremely hard playa surface to a soft, friable condition. Such changes are sometimes caused by slight topographic variations that influence surface-water movement, producing a flushing action and the removal of evaporite minerals by dissolution and deflation–which otherwise manifest as soft surfaces resembling plowed fields. Amargosa Playa, NV, 1963.

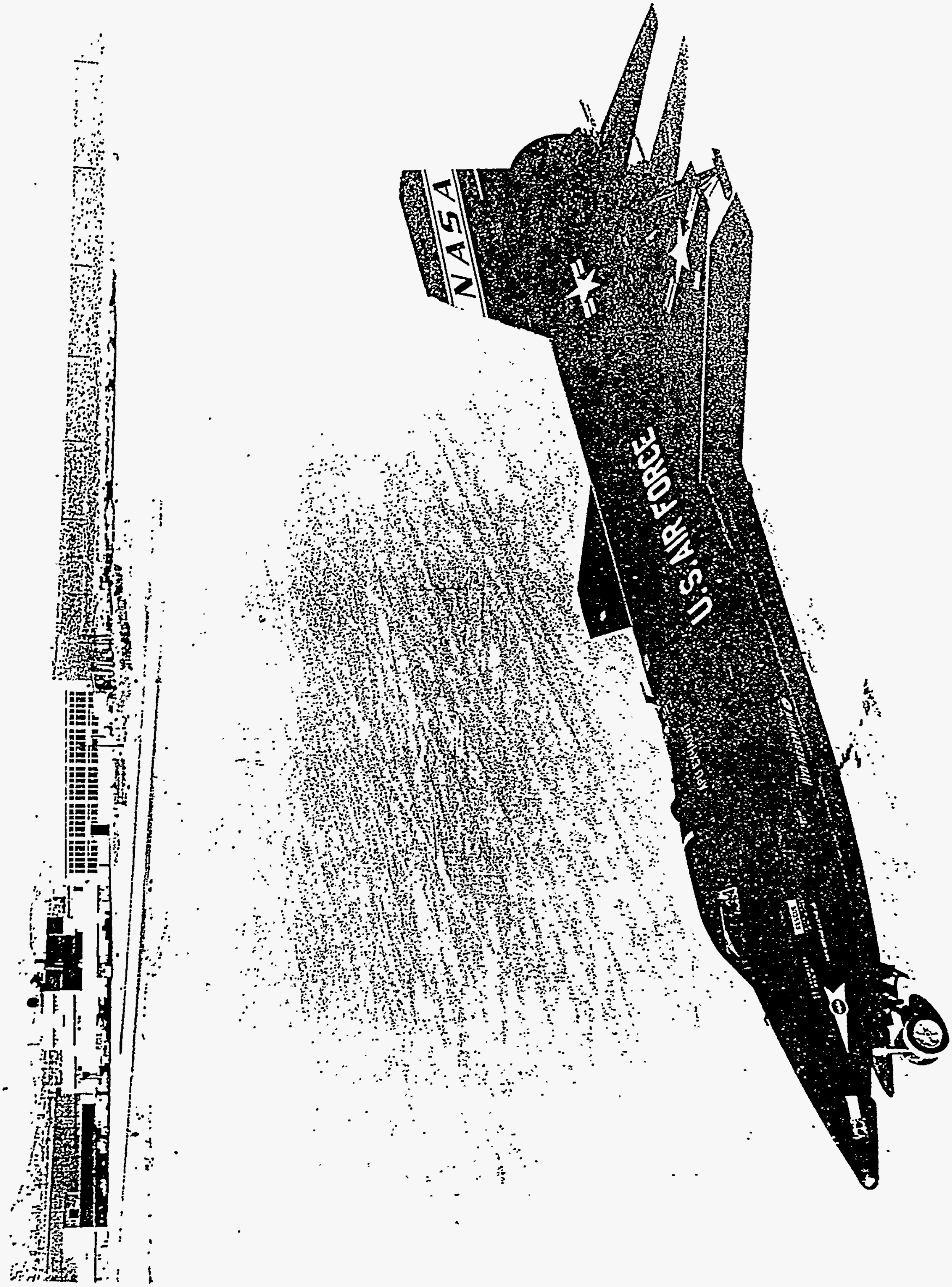
Figure 3 Fissures of tectonic origin transect numerous playas, such as at Yucca Lake, NV. This occurrence in 1963 drained the playa of more than 10^6 m^3 of water overnight. The fissure was initially more than 30 m deep and 1 km long but was quickly infilled with clayey sediment, as eroded gullies formed adjacent to it. Similar fissures elsewhere which form giant polygons 50 m across are attributed to long-term desiccation.

Figure 4 Magadiite, a hydrous sodium silicate first discovered in Kenya, occurs in veins and forms rectilinear patterns at Alkali Lake, OR, a hyperalkaline playa.

Figure 5 LANDSAT view of Pleistocene Lake Trinity basin, NM, and adjacent features: (1) Elephant Butte Reservoir; (2) Rio Grande; (3) San Marcial lava flow; (4)L. Trinity shoreline; (5) location of Fig. 6; (6) lava of Tularosa Basin (7) White Sands (gypsum dunes); (8) basin of Pleistocene Lake Otero (Scale 1:1,500,000).

Figure 6 Expanded airphoto view of location "5" on Figure 5, showing four distinct facies from center to edge of Pleistocene Lake Trinity basin, verified in boreholes A, B, C, D: (A) windblown sand (Holocene); (B) sulfate; (C) shoreline; (D) alluvial fan underlain by (B) at depth.

Figure 7 Salt-karst features over Permian evaporites in Holbrook Basin, Arizona. Jointing in surface Coconino sandstone controls development of sinkholes, infiltration and the subsurface dissolution front coincident with the Holbrook Anticline. Largest sinkholes are 200 m across and 50 m deep.



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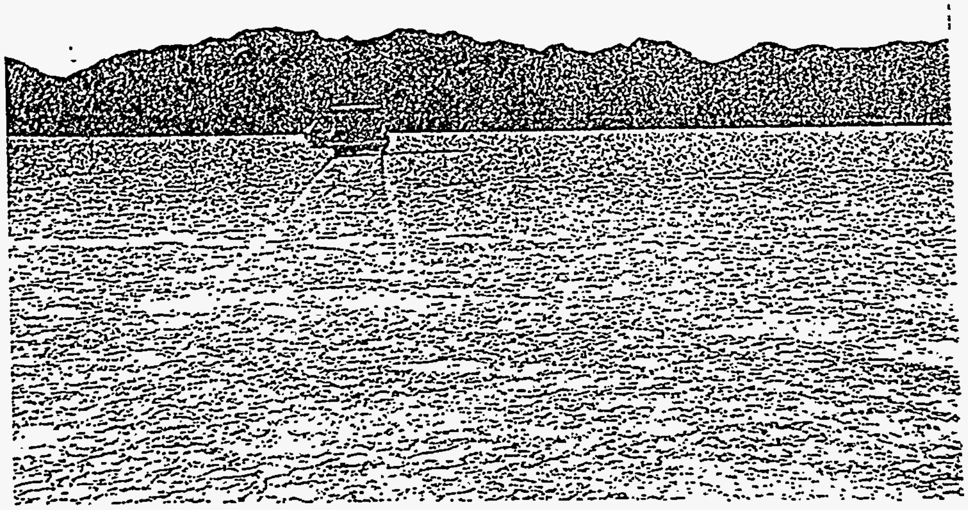

Figure 2

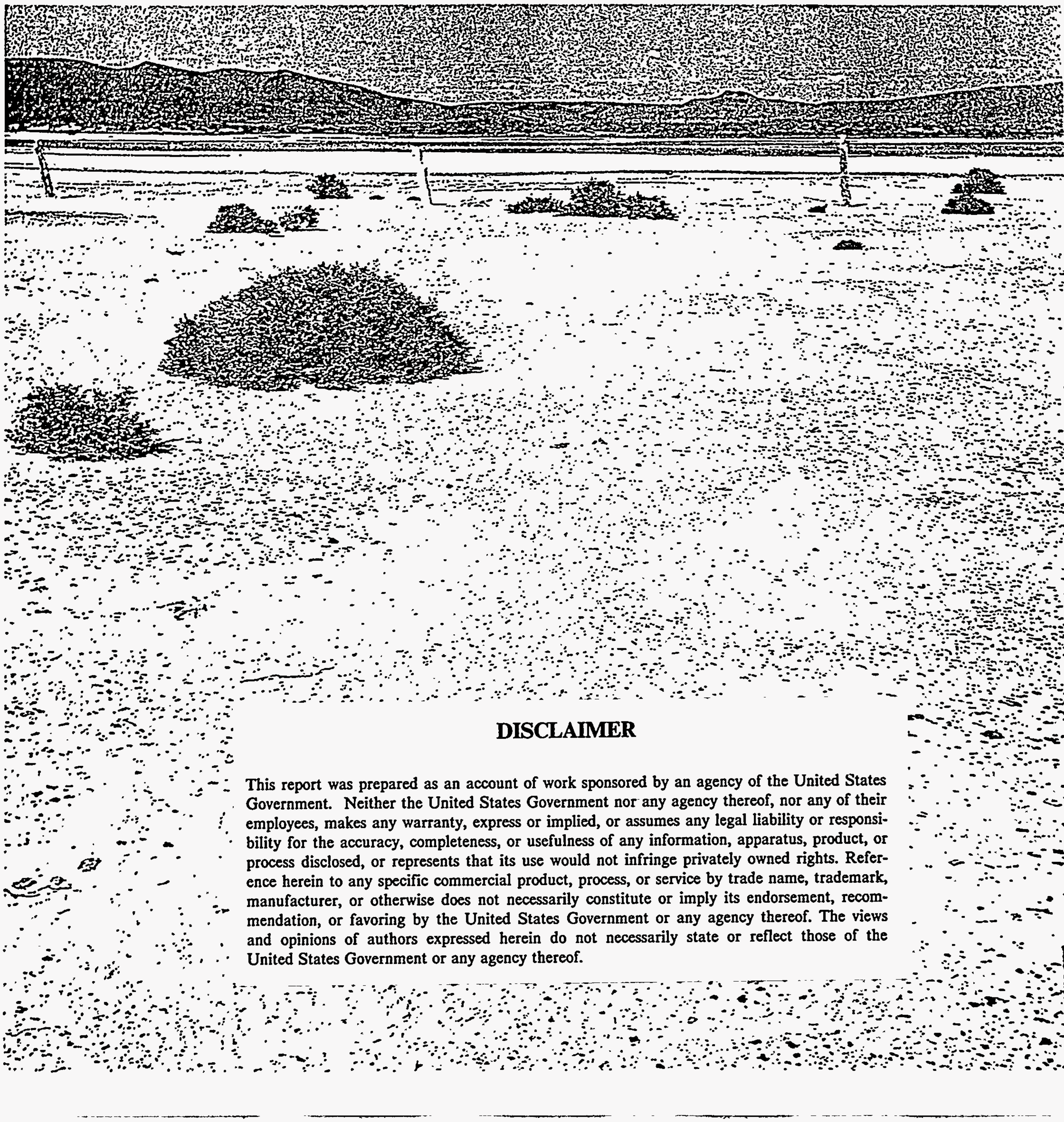

Figure 4

Figure 3 (can be reduced substantially)

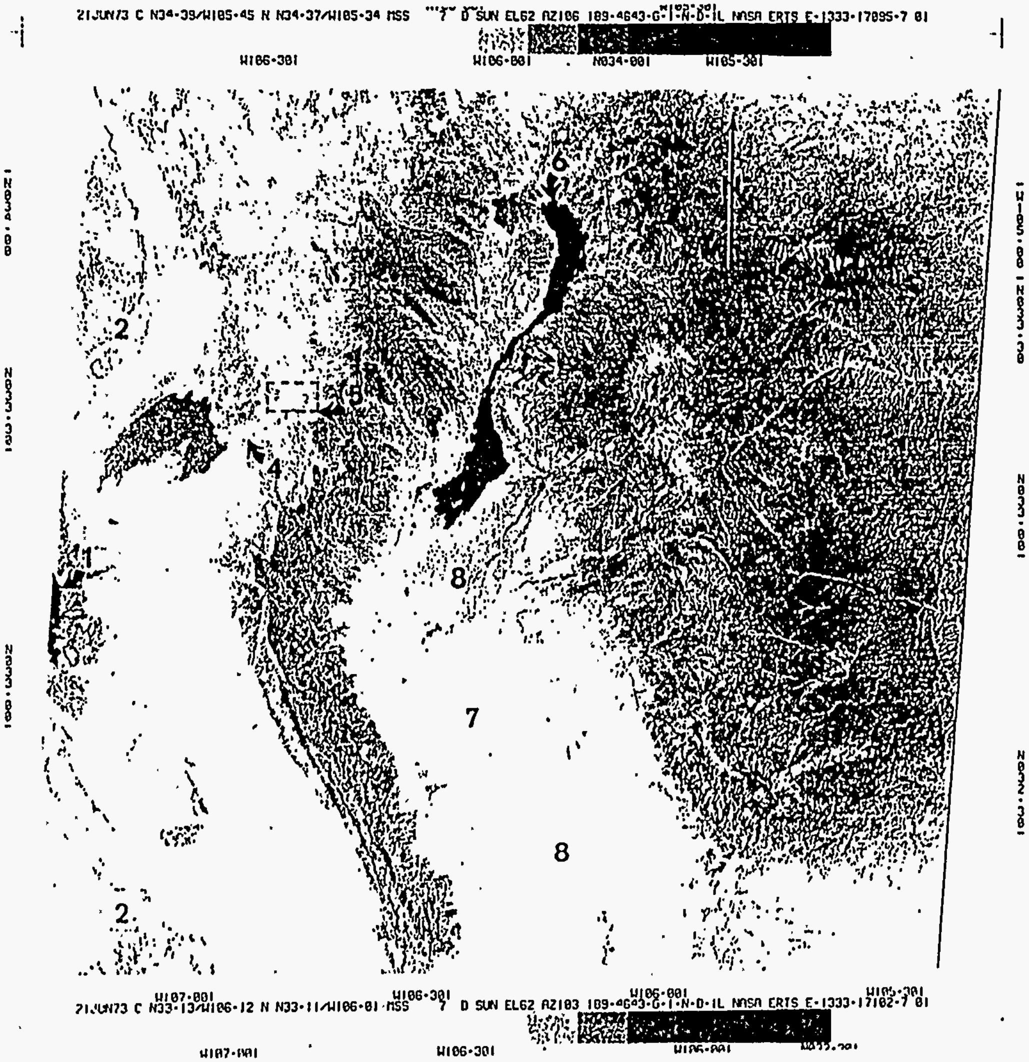
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Figure 5

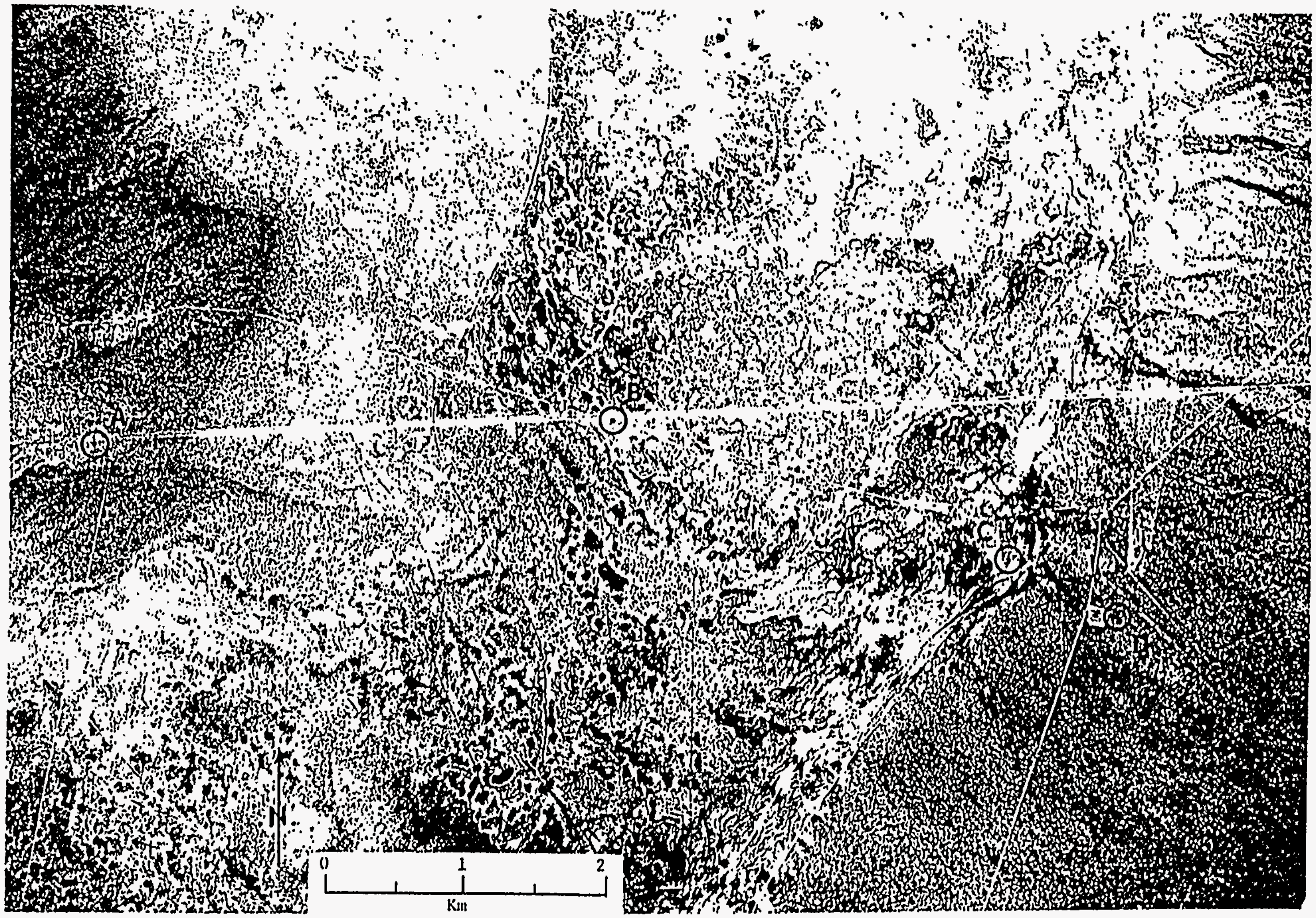

Figure 6

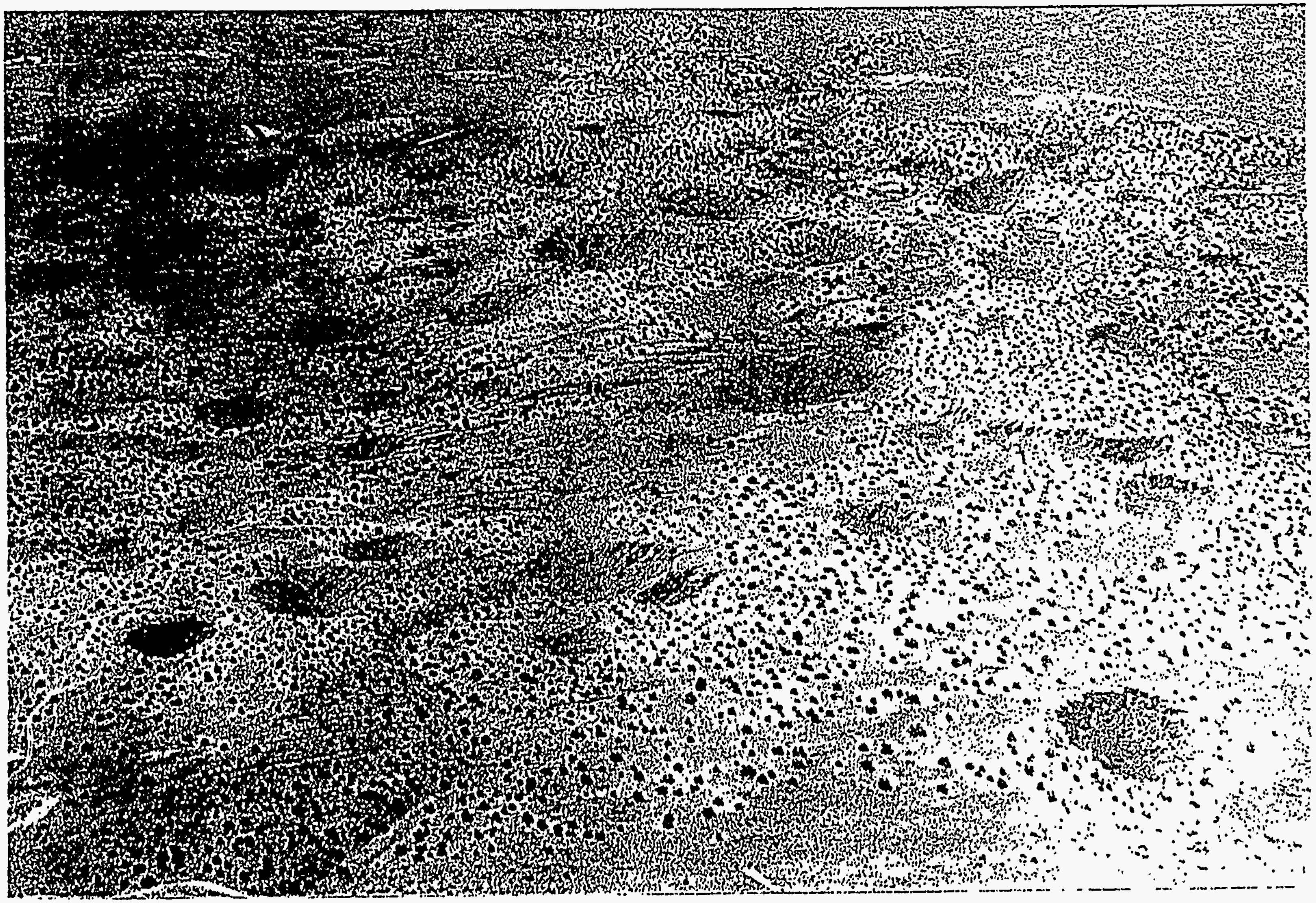

Figure 7