Reprinted from: MARINE SCIENCES INSTRUMENTATION, Vol. 4
(Plenum Press, 1968)

THE PHOTOGRAPHY FROM SPACE OF OCEANOGRAPHIC FEATURES

Robert E. Stevenson
Research Oceanographer
Bureau of Commercial Fisheries
Galveston, Texas

Richard D. Terry
Oceanographer
North American Rockwell Corp.
Long Beach, California

James S. Bailey
Research Oceanographer
Bureau of Commercial Fisheries
Galveston, Texas

Abstract

About 1500 photographs have been taken of the earth's surface by the astronauts. Of this number, about 575 are useful for interpreting oceanic features, including coastlines and the shallow submerged sea floor.

Photographs were taken using relatively simple techniques; however, the quality and usefulness of the Gemini photographs to oceanographers are surprisingly good.

With ground-truth information and improved techniques, oceanography for space could represent a major breakthrough in earth-science research.

Introduction

Spectacular photographs of the earth's surface have been taken by astronauts during the Gemini flights of the National Aeronautics and Space Administration's space program. This unique photography was obtained with hand-held Hasselblad and Maurer cameras -- definitely unsophisticated systems. The quality and usefulness of the photography are amazing. In fact, the results of all space photography have continually exceeded the expected performance, for it had been thought that atmospheric attenuation would result in meaningless blurrs of the earth's surface.

Space photography has served to stimulate the imaginations of scientists in many fields. It seems, however, that remote sensing from space can be utilized best by scientists who work with dynamic media -- the world ocean and atmosphere.

The ocean and atmosphere are dynamic. Air and water are in constant motion and interaction. Processes and movements vary in size from molecular to global. The interaction of these processes is so complex, that totally practical rationalizations will not result from classical investigations. Yet practical applications must be developed, because the ocean and atmosphere are part of man's environment. The cost for not adequately understanding the processes of these environments is enormous -- not only in money, but in the lives lost through inadequate prediction and protection.

The lack of data coverage of the world's ocean and atmosphere limits the scientists in understanding those processes that produce many observable oceanic and atmospheric phenomena. Many of the existing explanations of such phenomena are conjectural becuase of the limited number of observations.

It seems reasonable, then, that man's hope of satisfactorily understanding the air-sea processes, and of reaping the practical benefits therefrom, lies in the overall view of the oceans and the overlying atmosphere which is now possible from spacecraft.

Upwelling and Taiwan (Figure 1)

The major current system in the western Pacific Ocean flows from south to north past the island of Taiwan. Around the island, and especially in the Formosa Straits, the currents are complicated by the tides which ebb to the south along the southern shores of Taiwan.

On July 19, the day before this photograph was taken, tropical storm "Nina" was about 90 miles east of Taiwan. The storm was not well developed and winds of Beaufort Force 3 were the highest recorded. By 1200 GCT, July 20, the storm had dissipated and winds of Force 2 blew around Taiwan from an easterly direction.

In the photograph, the light blue of the sea is the result of a diffuse sun's reflection from an evenly roughened sea surface. Winds from the

Upwelling and Taiwan (Figure 1) -- National Aeronautics and Space Administration/Manned Spacecraft Center Color No. S66-45868 taken on July 20, 1966 during Gemini flight X by astronauts Cdr. John W. Young and Maj. Michael Collins with a Xenotar, 80 mm. lens.

east and northeast increased the roughness of the northerly flowing waters. The reflective, specular pattern from the sea surface thus depicts the features of water motion around the southern end of Taiwan.

The major current is parted by the island much as a ship parts the water. As the "bow" wave spreads from the island, upwelling must take place near the shore. The dark blue water is partly upwelled water.

The fishing ports along the west coast of Taiwan are concentrated north of the lagoonal complex on the southwest coast.

Bēnard Cells and Baja California (Figure 2)

The ocean waters of the coasts of California and Baja California are cool in response to the major north to south circulation in the eastern Pacific Ocean. Stratus and stratocumulus clouds form over the cool waters and are nearly constant features of the overlying marine atmosphere. The normal atmospheric circulation over this portion of the Pacific Ocean is also north to south, though variations respond to seasonal modifications in the Hawaiian High Pressure System and local conditions usual to any coast.

A typical low layer of stratocumulus clouds is seen to be moving at 6-10 knots past Guadalupe Island. The island peaks reach to 4,500 feet and thereby project through, and interfere with, the cloud layer. A "shock," or "bow" wave spreads from the north end of the island, similar to waves formed by a ship moving through water. Downstream, south of the island, von Kārmān eddies rotating to the right and to the left are formed as a turbulent "island wake." These cloud features, waves, and eddies were photographed during four Gemini missions and must, therefore, be considered climatic features of the Guadalupe marine atmosphere.

Similar waves and eddies appear in the water around islands (see Taiwan photograph). It is clearly necessary to investigate the details of these fluid motions to allow proper analyses of atmospheric and oceanic flows.

The clouds around Guadalupe Island (or toward the spacecraft) have formed into convective, polygonal Bēnard cells. Several areas of "open" cells were distributed along the edge of the more common "closed" cells of the stratocumulus layer. Most cells west of the island are regular in shape and some were typically hexagonal.

North of Guadalupe Island, the cells were deformed, showing extensions to the south. These elongated Bēnard cells indicate a gentle atmospheric shear passing mainly to the west of Guadalupe Island. The concurrence of "open" and "closed" Bēnard cells offers interesting speculation, especially considering the rather constant temperature inversion over these cool waters.

Faulting and the Red Sea (Figure 3)

This photograph indicates the value of some space photography for interpretation of regional geologic structure.

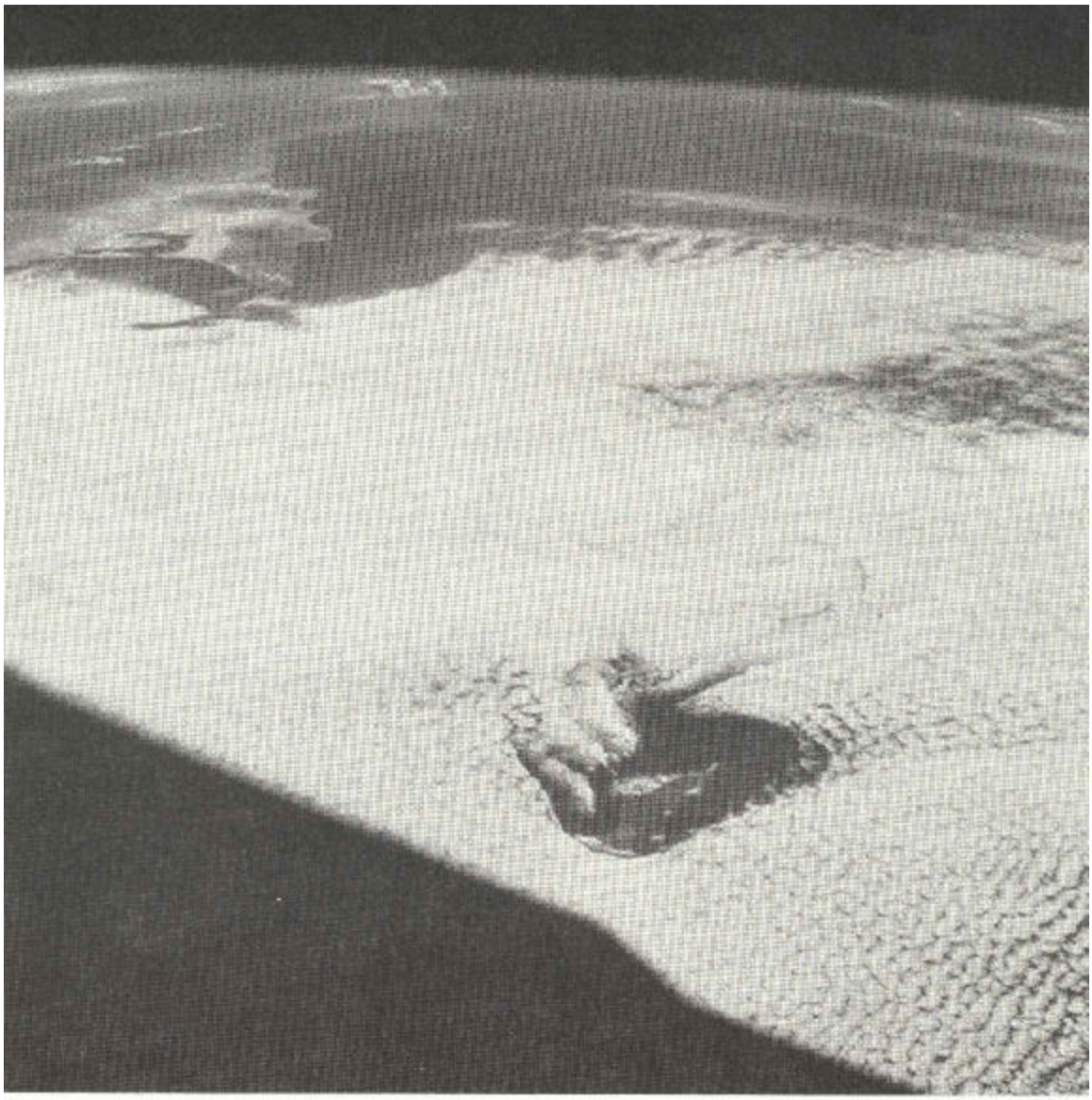
The Red Sea lies in one of the major rift zones of the earth's crust and is well delineated by the sharply faulted boundaries. Faulting activity is quite evident also around the gulfs of Suez and Aqaba. In geologic parlance the Red Sea is a textbook example of a graben -- a region of crustal tension. It is postulated that this is the rift for continental drift.

The fertile Nile Valley can be seen on the right and the huge Aswan Dam appears as a small light dot south of the great bend.

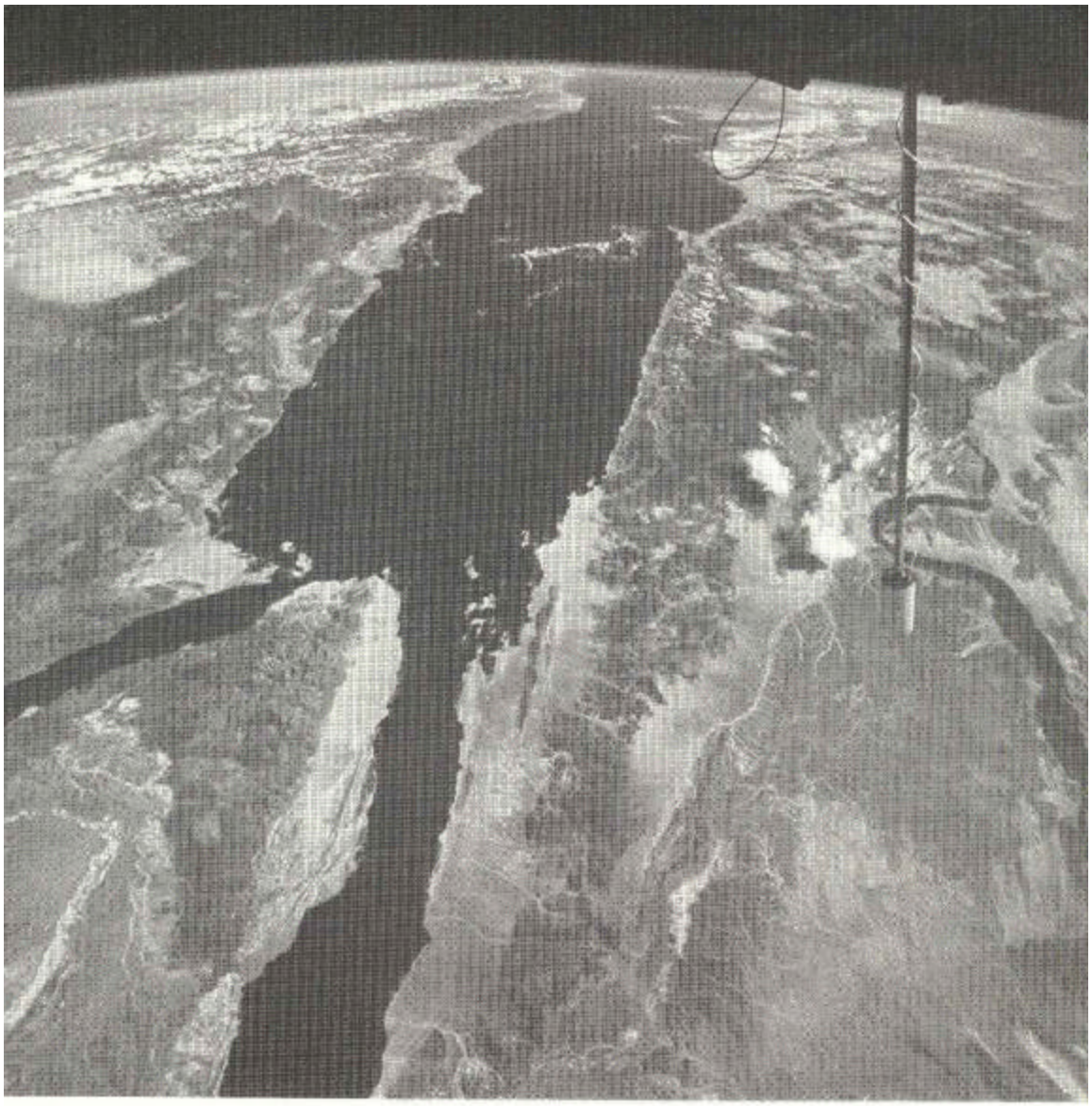
Conclusions

From these photographs, the usefulness of viewing the ocean, earth, and atmosphere in the visible part of the spectrum is clear. Furthermore, there can be little question concerning the greater suitability of information were sophisticated systems available.

Hopefully, these evaluations and the interpretation of existing photography will act as stimuli to the development of realistic sensor equipment for the study of earth resources from space.



Bēnard Cells and Baja California (Figure 2) -- National Aeronautics and Space Administration/Manned Spacecraft Center Color No. S65-45967 taken on August 21, 1965 during Gemini flight V by astronauts Col. L. G. Cooper and Cdr. Charles Conrad, Jr. with a Zeiss Planar, 80 mm. lens.



Faulting and the Red Sea (Figure 3) -- National Aeronautics and Space Administration/Manned Spacecraft Center Color No. S66-63481 taken on November 13, 1966 during Gemini flight XII by astronauts Capt. James A. Lovell, Jr. and Lt. Col. Edwin E. Aldrin, Jr. with a Biogon, 38 mm., wide-angle lens.