Press Abstract

ANCIENT OCEANS AND MARTIAN PALEOHYDROLOGY

by

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Solving the Puzzle

Science strives to make sense from the bewildering complexity of Nature. Its processes have been likened to a kind of puzzle solving in which the solution is an enhanced understanding of the natural world. Certainly one of the most perplexing puzzles of nature is that posed by the evidence of ancient water processes on the planet Mars. A century ago the fuzzy images of Mars in telescopes led some astronomers to speculate that putative intelligent inhabitants had transformed a desert planet to productive agriculture through systems of canals. During the 1960s and 1970s the high-resolution pictures returned from orbiting spacecraft revealed that the Martian "canals" were really the products of combining imperfect observations with hopeful imaginations. Nevertheless, the reality of the Martian landscape revealed by modern spacecraft pictures proved even more intriguing than the imagined scenarios.

The heavily cratered, ancient highlands of Mars are dissected by networks of valleys. Huge outflow channel systems, tens of miles wide, emanate from zones of massive collapse. Water flows are clearly indicated by the landforms associated with these features. Additional landforms indicate processes related to frozen ground ice. Such observations have led to many fascinating questions. Why did some portions of the Martian surface seem to have very low erosion rates, while other areas have forms indicating intense degradation by erosional processes? Why did numerous valleys and channels form during the Martian past, when the modern climate is too cold and dry for active water flow? How could water have moved to replenish ancient streams when the modern atmosphere has less than 1/100 the pressure of that on Earth?

In 1990, at the 21st Lunar and Planetary Science Conference, we reported on a conceptual scheme that tied together the diverse water-related landforms of Mars. Our work partly derived from that of others who hypothesized the existence of large bodies of water on Mars during its ancient past. Evidence for a great northern ocean, which we named Oceanus Borealis, was most impressively assembled in 1989 by T.J. Parker, R.S. Saunders, and D.M. Schneeberger of the Jet Propulsion Laboratory, California Institute of Technology. Stimulated by their work and by a vast array of studies by many planetary geologists, we developed the following global model of ocean formation on Mars.

Mars Climate Model

Models are theoretical simplifications of how scientists perceive the operation of phenomena. Our model arose intuitively from experience with Martian phenomena and from hypothesizing the origin and consequences of an ocean. The following events are not yet conclusively proven, but we find them scientifically compelling.

During later Martian history huge amounts of molten rock (magma) were concentrated at one local region of the planet, the Tharsis volcano area. Massive and rapid emplacement of magma beneath this bulging hot spot melted huge amounts of ground ice, driving it into fractures on the margins of the Tharsis bulge. The water burst on to the surface at great outflow channels heading at these fractures. Driven by volcanic heat, the cataclysmic outburst floods of water eventually reached the northern plains of Mars, inundating low-lying areas to form a temporary water body, the Oceanus Borealis.

The cataclysmic ocean formation led to profound climatic changes. Dissolved carbon dioxide was released from ground water and melted ground ice. Additional carbon dioxide was released to the Martian atmosphere as relatively warm water soaked into cold soils containing adsorbed carbon dioxide. Carbon dioxide previously frozen in the northern polar cap would also enter the atmosphere. This cataclysmic release of carbon dioxide profoundly changed the atmospheric heat balance, allowing the penetration of solar radiation but trapping much of the resulting heat released by the planetary surface. The planetary warming that ensued is exactly of the sort presently exacerbated on Earth because of the burning of fossil fuels to release carbon dioxide. On Mars, however, this "greenhouse effect" was further enhanced by massive evaporation of water from the ancient floods and the transient ocean.

Water vapor is also an extremely potent greenhouse gas. As Martian temperature rose, water, frozen in upland permafrost, was released to flow into lakes or the Oceanus Borealis. The climate moved to a maritime state, with precipitation possible. This maritime state was a temporary warm, wet interval, perhaps lasting only thousands or a few million years. When the oceans gradually evaporated or froze, the planet returned to its cold, dry conditions with its water trapped as ground ice in underground permafrost. It is this cold, dry mode which presently characterizes Mars.

During the late phase of ocean formation, much of the precipitation fell as snow. Particularly near the south pole and in upland areas, the snow accumulated and was transformed to ice. As the snow and ice built up to sufficient thickness, it eventually flowed as glaciers. The epoch of glacier formation was probably relatively short on the planetary time scale of billions of years.

We hypothesize that Oceanus Borealis was probably a persistent feature during the first billion years or so of Martian history. At that time the planet was experiencing a relatively high rate of impacting objects. The dense water and carbon dioxide atmosphere allowed precipitation as rain, resulting in the widespread valley networks of the Martian uplands. However, water was being lost because of dissociation in the upper atmosphere of the planet. The hydrogen was lost to space while the oxygen contributed to the red color of the planet by oxidizing various materials. Eventually water loss and precipitation of the carbon dioxide as carbonate rock reduced the atmospheric pressure below the greenhouse level for maintaining the ocean. Most of the water was sequestered into the very permeable rocks of the planet where it comprised ice in a permafrost.

The ocean was able to reform much later in the planet's history because of the Tharsis volcanism described above. This cataclysmic ocean was smaller than the original because of the water loss by hydrogen escape. However, it was big enough to temporarily modify the climate, producing the enigmas that had bothered us about the Martian surface.

Outrageous Hypotheses

Sometimes science is viewed as a monolithic enterprise of computers, laboratory equipment, and individual theorists. We forget that science is a group exercise in which people make sense, a kind of common sense, out of the world in which they live.

We feel that the above model makes sense out of what previously seemed to be perplexing problems of past environmental change on the planet Mars. Our model is really an elaborate scientific hypothesis that is contrary to previous theories of climatic change and geological evolution for Mars. Thus, it is an "outrageous hypothesis," but the outrage is not upon factual observations but rather to theoretical beliefs held by many Mars scientists. Whether or not this new view prevails will depend upon how well it explains otherwise enigmatic phenomena.

Our studies of impact crater densities on certain Martian landforms show that late in Martian history there could have been coincident formation of (1) glacial features in the southern hemisphere, (2) ponded water and related ice features in the northern plains ("Oceanus Borealis"), (3) fluvial runoff on Martian uplands, and (4) active ice-related mass-movement. The numerous landforms could, of course, be ascribed to unique, separate causes. However, our model of transient ocean formation ties these diverse observations together in a long-term cyclic scheme of global planetary operation. Geologists long ago demonstrated that Earth processes follow such cyclic operation, and we extend that concept to Mars.

If our "outrageous hypothesis" proves correct, it will provide a new confidence on how Mars works as a planet. It will especially illuminate how Martian water-related systems have evolved through time. We need a similar confidence for Earth. Rather than idealized future "scenarios" given to us by computers, we need an understanding of how the whole planet works. If we can figure this out for a slightly smaller, slightly colder version of Earth known as Mars, that process of common sense should allow us the same revelation about Earth and its global changes. As the philosopher William Clifford once said of science, "... the truth at which it arrives is not that which we can ideally contemplate without error, but that which we may act upon without fear."