trons for the dark-adapted eye of a careful observer to detect this phenomenon. It remains for future research to characterize the relationships of flash brightness and shape with charge, momentum, and trajectory.

THOMAS F. BUDINGER
Donner Laboratory and *Lawrence Radiation Laboratory, University of California, Berkeley 94720*
HANS BICHSEL
Department of Radiology, University of Washington, Seattle 98105
CORNELIUS A. TOBIAS
Donner Laboratory and
Lawrence Radiation Laboratory

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Mechanisms Controlling World Water Chemistry: Evaporation-Crystallization Process

Gibbs's (*1*) stated intention in writing his report was "to elucidate the major natural mechanisms controlling world water chemistry." The three natural mechanisms that he cited are the following: (i) atmospheric precipitation, (ii) rock dominance, and (iii) the evaporation-crystallization process. The argument, in brief, was that some streams, especially those draining well-leached, tropical basins, have water compositions dominated by Na^+ and Cl^-, an indication that the composition is controlled by airborne salt with strong oceanic affinities [figure 2 in (*1*)]. Another end-member is dominated by Ca^{2+} and HCO_3^- with generous contributions from K^+ and SiO_2, an indication that the composition is controlled by mineral components leached from the rocks of the drainage basin. The third type of water, also dominated by Na^+ and Cl^-, but with a high concentration of dissolved solids, reflects "evaporation, which increases salinity, and . . . precipitation of $CaCO_3$ from solution, which increases the relative proportion of Na to Ca both from the tributaries and in the mainstream" (*1*, p. 1090). The Pecos River and the Rio Grande were cited as typical examples of the evaporation-crystallization process.

Inasmuch as specific data points were not given, it is impossible to examine Gibbs's (*1*) conclusions rigorously. Examination of his figure 4, however, suggests that the choices of examples of the evaporation-crystallization process are questionable. Gibbs's figure 4 shows "total dissolved salts" in Pecos River water increasing from slightly more than 1000 parts per million (ppm) to nearly 6000 ppm; the increase in total dissolved salts in the Rio Grande is from a little more than 300 ppm to nearly 900 ppm.

There is no argument with the proposition that concentration by evapotranspiration and irrigation return water contribute to the mineralization of Pecos River and Rio Grande water progressively downstream. But the major increments of increased mineralization to the Pecos are from groundwater inflows, some of which are brines nearly saturated with respect to sodium chloride.

Hale *et al.* (*2*) reported that in a reach of only about 3 miles (4.8 km) in the Malaga Bend south of Carlsbad, New Mexico, seepages and springs added about 420 tons (380,000 kg) of dissolved minerals to the Pecos daily, of which about 370 tons is common salt (NaCl). Since the Pecos is tributary to the Rio Grande, it is reasonable to infer that the increase both in the mineral concentration and in the proportion of Na^+ among the cations in the Rio Grande shown by Gibbs [figure 1 in (*1*)] is accounted for largely by a comparison of the analyses of water from the Rio Grande taken above and below the junction of the Pecos.

Gibbs's (*1*) reliance on the deposition of $CaCO_3$ to explain increased Na^+ percentages in waters dominated by the evaporation-crystallization process is unsupported by any evidence that in those waters the solubility limit of $CaCO_3$ is exceeded. Nor is evidence given that, if supersaturation does occur, it will be succeeded by nucleation and precipitation of $CaCO_3$.

Gibb's figure 4 (*1*) also shows the Sacramento River to have a concentration of dissolved solids of between 4000 and 5000 ppm, and a high percentage of Cl^- among the anions. For the years 1950–1957 Van Denburgh and Feth (*3*) calculated an average concentration of dissolved solids of 168 ppm for the Sacramento at Knights Landing, California, the farthest downstream sampling station on the river that is still above the intrusion of seawater. The concentration indicated by Gibbs can occur in the Sacramento only in the delta reaches where mixing with seawater increases both the overall mineral concentration and the percentage of Cl^- among the anions. In light of the foregoing, one views with some hesitation the Jordan River example as well. The sample site is not indicated, but it is possible that the site is downstream from material saline inflows from springs in the vicinity of Lake Tiberias.

It appears, further, that Gibbs (*1*) used data on precipitation chemistry from the Mojave Desert to calculate the percentage of several cations in the Rio Grande derived from rainfall. The difficulties associated with the derivation of mass balances for chemical loads of streams have been discussed by Van Denburgh and Feth (*3*). One of the dangers they mentioned arises from extrapolations of incomplete data across large regions. The mass balance for the Rio Grande must, in consequence of its data input, be regarded as a first approximation at best.

The above comments imply that Gibb's selection of data was not wholly sound and that some data were inappropriate to his argument. Unfortunately, the visible flaws suggest that the conclusions presented should have been supported with more rigorously screened data.

J. H. FETH
U.S. Geological Survey,
345 Middlefield Road,
Menlo Park, California 94025

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Feth's questions (*1*) regarding the evaporation-crystallization process in arid regions provide an opportunity for the elaboration of several points which the brevity of my original report (*2*) did not allow. Contrary to Feth's initial observation, the sources of the specific data for all rivers named were clearly identified in the second paragraph of my report (*2*) as a readily available U.S. Geological Survey publication by Livingstone (*3*); the source for the Amazon data is a paper in preparation (*4*).

Examination of Livingstone's data (*3*) indicates that the choice of the Pecos River, the Rio Grande, and the Jordan River as examples of rivers controlled by the evaporation-crystallization process is far from questionable. Rather, Livingstone's data (*3*) strongly support the inclusion of these three rivers as arid-region rivers exemplifying this process. Unfortunately, a drafting error in figure 4 (*2*) is responsible for the misplacement of the name of the Sacramento River with the group of rivers controlled by the evaporation-crystallization process. Livingstone's data (*3*) show the correct grouping of the Sacramento River with those rivers exemplifying control of composition by rock dominance.

Feth's attempt to discredit the grouping of the Pecos River and the Rio Grande with those rivers controlled by the evaporation-crystallization process is based on two erroneous assumptions: that groundwater was not considered as a part of the process and that the trend of the Rio Grande toward increased salinity and a higher ratio of Na to (Na + Ca) is based solely on the mixing of the Pecos with the Rio Grande.

In my original discussion of the evaporation-crystallization process, consideration of groundwater was certainly implied in my statement (*2*, p. 1090) that the change in composition and concentration along the length of the arid-region rivers is due to evaporation "and to precipitation of $CaCO_3$ from solution,"—including, naturally, both surface and ground solutions—"which increases the relative proportion of Na to Ca both from the tributaries and in the mainstream"—with the phrase "from the tributaries and in the mainstream" again inferring consideration of the entire basin, of which groundwater is an integral part. Figure 1, which is based on data of both Livingstone (*3*) and Love (*5*), clearly shows that the shift in chemical composition along the entire length of the Pecos is a steady one, with none of the spectacular variation that, according to Feth's implication, occurs with the addition of groundwater at Malaga Bend.

Feth's further assumption that the increased-salinity trend of the Rio Grande results solely from the mixing of the Pecos with the Rio Grande is contradicted by the data of Livingstone (*3*). These data give clear identification of the four Rio Grande data points in figure 1 of my report (*2*). Three of these points, located in the upper portion of the Rio Grande, give evidence that the trend toward increased salinity and a higher ratio of Na to (Na + Ca) is already well defined prior to and independent of the mixing of the Pecos with the Rio Grande. Figure 1, based on Love's compilations (*5*) [which substantiate Livingstone's work (*3*)] further supports the inclusion of the Rio Grande —entirely apart from the tributary contribution of the Pecos—as an example of an arid-region river having its chemical composition controlled by

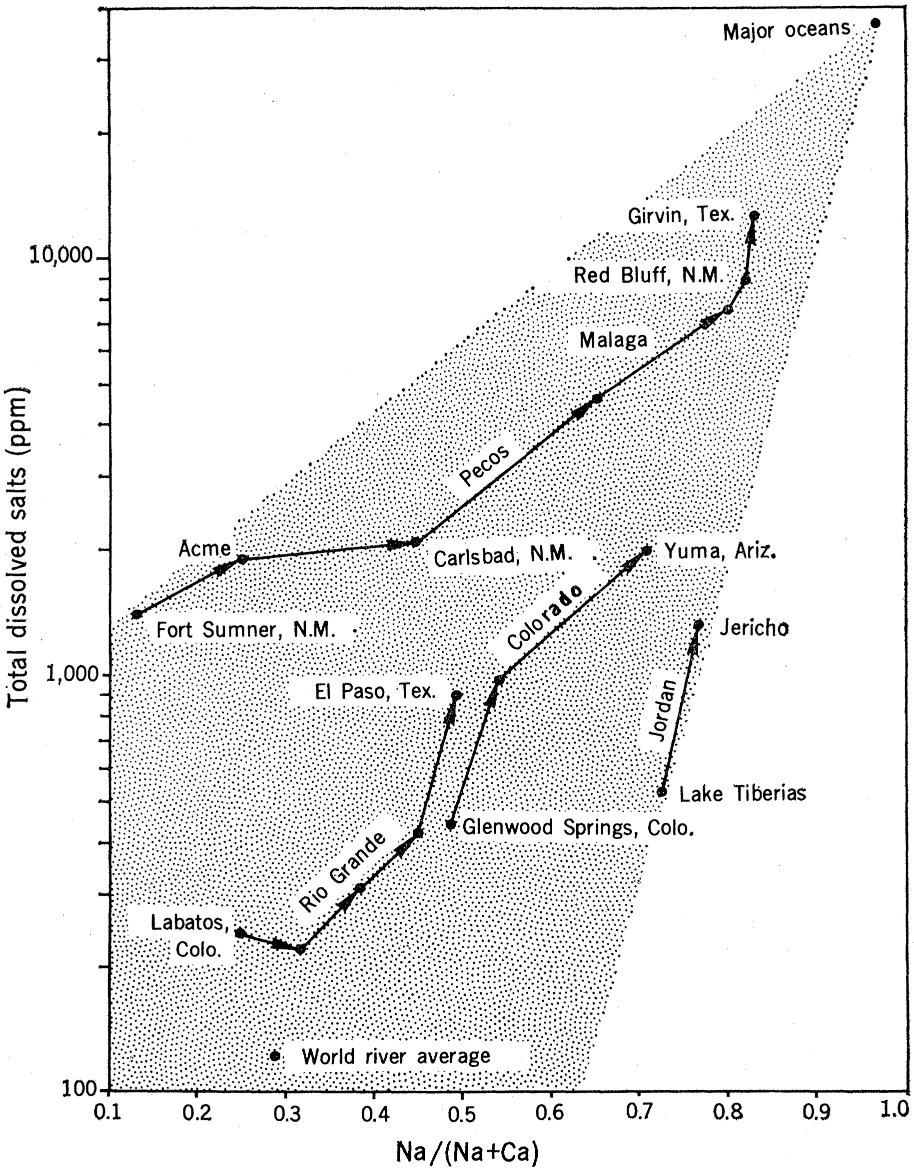

Fig. 1. Variations of the weight ratio Na/(Na + Ca) as a function of the total dissolved salts of arid-region surface waters.

the evaporation-crystallization process.

The basis for Feth's objections to the inclusion of the Jordan River as an arid-region river in the evaporation-crystallization grouping—that "the sample site is not indicated"—is also unfounded. Feth hypothesizes that the Jordan sampling site is dominated by groundwater seepage. The sampling point at Jericho (*3*) does, indeed, reflect the "saline inflows from springs in the vicinity of Lake Tiberias" (*1*) resulting from the fact that most of these springs enter Lake Tiberias (*6*) which serves thus not only as a mixing basin, but also as the source of the Jordan. However, as shown in Fig. 1, the 507-ppm salinity of Lake Tiberias (*6*) [also given by Livingstone (*3*)], serves as the base point for the steady increase in the salinity of the Jordan to 1310 ppm at Jericho (*3*) after the water flows through a region that is without major springs (*6*). This increasing salinity and the changing ratio of Na to (Na + Ca) are evidence in support of the inclusion of the Jordan River as an arid-region river in the evaporation-crystallization process grouping.

Figure 1 shows the distinct trends of the Rio Grande (upstream from the Pecos junction), the Pecos, the Colorado, and the Jordan rivers toward steadily higher salinities and higher Na values relative to Ca, based on data compiled by Love (*5*) and Bentor (*6*), which substantiate that of Livingstone (*3*). For each of these rivers the site sampled farthest downstream is far from either oceans or seas and, therefore, is not at all influenced by seawater.

Feth also desires elaboration on the precipitation of $CaCO_3$. It is common knowledge that the soils in arid-region river basins have an abundance of $CaCO_3$ precipitate in the form of cäliche which, in some instances, produces a limestone-like layer in the soils.

With regard to the mass-balance calculation shown in table 1 (*2*) for the Rio Grande (as an evaporation-crystallization river type), the rainfall data used are of the best quality available for the area. Although this calculation is, indeed, a first approximation, it does vividly demonstrate the contribution of Na, K, Mg, and Ca cations from rocks (99.9 percent) to the evaporation-crystallization river types. Further calculations based on additional data would not change the significance of the conclusion already drawn.

R. J. GIBBS
Department of Geological Sciences,
Northwestern University,
Evanston, Illinois 60201

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Precautions with Alkyl Mercury

This technical comment has been written in response to inquiries concerning recommended safety precautions in the handling of alkyl mercury compounds. In 1865 Edwards first reported that two laboratory technicians died from intoxication caused by methylmercury (CH_3Hg) while studying valencies of metallic compounds (*1*). Although the lethal effects of the volatile compounds in this case were communicated from one laboratory technician to another, additional cases of poisoning of laboratory personnel caused by alkyl mercury have been reported. In these cases, inhalation was thought to be the mode of contact with the organic mercurial (*2*). Hunter *et al.*, in 1940, described intoxication caused by CH_3Hg in four individuals in a seed-dressing factory (*3*). All had taken some precautions in handling the reagents (for example, masks and gloves). They developed subacute illness with initial symptoms of cerebellar ataxia, paresthesias, disturbances of the visual field, dysarthrias, increased salivation, and dysphagia. The disease progressed to more severe neurological symptoms, including deafness, blindness, spasticity, paralysis, urinary incontinence, and seizures.

Some alkyl mercury compounds are very volatile. The saturated vapor concentration of methylmercury chloride at 20°C is 94,000 μg per cubic meter of air as compared with 5 μg per cubic meter of air for phenylmercury chloride and 14,000 μg per cubic meter of air for metallic mercury (*4*). The high volatilities of alkyl mercury compounds increase the risks to those handling the compounds.

The International Committee to Determine Maximum Allowable Concentrations of Mercury met in Sweden in 1968 and recommended that no one should be exposed to more than 0.01 mg of alkyl mercury per cubic meter of air over an 8-hour period and that the mercury concentration in whole blood should not exceed 10 μg per 100 ml (as total mercury) (*5*). For laboratory work we suggest that the following precautions be taken:

1) All handling of CH_3Hg should be done in a well-ventilated hood. Syringes should be filled in a hood; if the solution is spilled, cysteine or some other sulfhydryl-rich solution must be mixed with the spilled alkyl mercurial in order to decrease the volatility. All treatments of animals should be performed in a hood.

2) Methylmercury, when not in use, should be stored in disposable, closed, glass containers (for example, a penicillin ampoule) at refrigerator temperature. Feces, although a major metabolic excretion pathway for alkyl mercury in rats, contain CH_3Hg in nonvolatile, bound form, thus minimizing the danger from this source.

3) Concentrations of mercury in the blood of all those working with these substances should be measured periodically. If the concentration exceeds the recommended maximum blood concentration, the individual should be immediately removed from the area of further exposure to alkyl mercury, and his handling techniques should be evaluated for carelessness or other flaws.

4) Women of childbearing age, and especially pregnant women, should not work with alkyl mercury compounds because of possible teratogenic effects on the central nervous systems of the unborn children (*5*).

RONALD KLEIN
SHELDON HERMAN
National Institute of Environmental
Health Sciences, Research Triangle
Park, North Carolina 27709

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