al. was not representative of the general population on the island in that it consisted of outpatients from the Noumea Hospital laboratory. Individuals observed in an outpatient clinic, and treated for medical reasons, tend to have more medical problems than people who do not visit such a clinic. Therefore, differences in control and study groups tend to be lessened. But, as noted, in retrospective studies there are inherent difficulties in evaluating cancer incidence. However, the study by Lessard *et al.* made the important contribution of calling attention to a potential problem.
5. Exposure to many agents has been implicated, as in the etiology of lung and sinus cancers in nickel workers. Cancer of the sinus has been considered by some a result of exposure to nickel carbonyl; the lung cancers are associated with more complex exposures. These are reviewed in Mastromatteo's paper (*1*); among the suggested agents are arsenic compounds. Morgan (*1*) stated that "workers showing an increased incidence of respiratory cancer were those involved in dusty operations rather than those exposed to nickel as a gaseous compound." The question of identifying the carcinogens has not yet been resolved.
6. An overview of the silica problem was described by A. M. Langer in *Maxcy-Rosenau Public Health and Preventive Medicine*, J. Last, Ed. (Appleton-Century-Crofts, New York, ed. 11, 1980), pp. 637–641. A study by B. Gylseth and T. Norseth implicated fibrous amphibole gangue minerals in their case reports (*Am. J. Ind. Med.*, in press).
7. A. M. Langer, A. N. Rohl, I. J. Selikoff, G. E. Harlow, M. Prinz, *Science* **209**, 420 (1980).
8. G. Troly, M. Esterle, B. Pelletier, W. Reibell, in *Proceedings of the American Institute of Mining, Metallurgical, and Petroleum Engineers Laterite Symposium* (American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 1979), pp. 85–119. This detailed geological report is at variance with the assertion of Meininger *et al.* concerning the absence of chrysotile in the ore as a result of the weathering process. The island peridotites (used in the generic sense) are totally serpentinized along major thrust plates and fault zones. Moreover, diffuse bodies of serpentine appear within the mafic body with no visible structural control. Essentially, serpentine may occur anywhere; the major portion of the peridotites is referred to as *facies normale*, which is 40 to 79 percent serpentinized; the serpentines in the ultramafic bodies consist primarily of lizardite and chrysotile; the "surficial weathering" of the serpentinized peridotites (the process that accounts for the nickel concentration) follows a five-stage gradational series in which an end product contains completely destroyed chrysotile. However, serpentine minerals are not attacked before stage 3; the nickel ore, with a tenor between 2.0 and 3.0 percent, occurs throughout the alteration zone and includes a 3 percent nickel zone associated with unaltered to slightly altered serpentine (including chrysotile) in stage 3. This is to be anticipated in an alteration continuum; x-ray diffraction analysis of the weather ore zone, called saprolite, shows line-broadened serpentine peaks present, with changes in intensity that could be explained on the basis of particle size and orientation as well as a change in crystallinity; saprolite ores have been shown to contain abundant residual serpentine minerals (lizardite and short chrysotile fiber); within the saprolite ore body are nickeliferous serpentines and a range of "garnierites," a material that is optically homogeneous and nickel-enriched. Garnierite from this island has been shown by Troly *et al.* to consist of serpentine veinlets in saprolite; although the nickeliferous garnierites are essentially lizardite, the magnesium-rich varieties contain a great proportion of chrysotile; the degree of weathering in the four types of saprolitic ores on New Caledonia ranges from complete to incomplete; the peridotites range from highly to weakly serpentinized. Extensive tectonic activity has thrust a number of highly serpentinized zones into weakly serpentinized zones and vice versa, so that they are often juxtaposed. Superimposed fracturing and topographic factors have produced an enormously complex ore body in which chrysotile fiber contamination may range significantly.
9. A general review of chrysotile and its biological effects in man may be found in *Asbestos and Disease*, I. J. Selikoff and D. H. K. Lee, Eds. (Academic Press, New York, 1978).
10. See, for example, the chrysotile data for human populations in the following: *Evaluation of Carcinogenic Risk of Chemicals to Man*, vol. 14, *Asbestos* (International Agency for Research on Cancer, Lyon, 1977); I. J. Selikoff and E. C. Hammond, Eds., *Health Hazards of Asbestos Exposure* (New York Academy of Sciences, New York, 1979); J. C. Wagner, Ed., *Biological Effects of Mineral Fibers* (International Agency for Research on Cancer, Lyon, 1980).
11. There are unconfirmed reports that during the past few years, mesothelioma and lung cancer have occurred in the nickel workers. These reports were not compared to any incidence base, nor were they independently verified clinically or pathologically. Clearly, it would be advantageous to evaluate the entire clinical situation.
12. J. C. Cochrane and I. Webster, *S. Afr. Med. J.* **54**, 279 (1978); *ibid.* **59**, 848 (1981).

5 November 1981

Deforestation and Increased Flooding of the Upper Amazon

In their report on deforestation and flooding in the upper Amazon basin, Gentry and López-Parodi (*1*) draw a number of hydrologic conclusions that are not supported by their evidence.

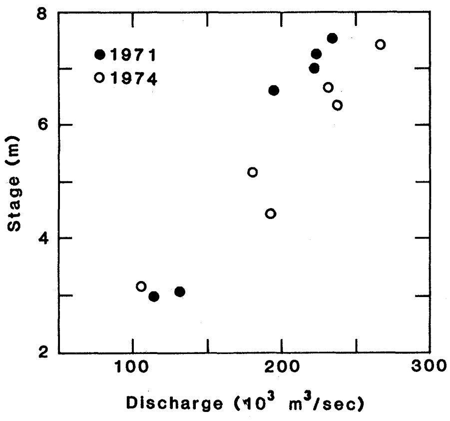
For example, by comparing the mean flood stage (*2*) for 1962 to 1969 with the mean for 1970 to 1978, they conclude that ". . . the runoff of water from upper Amazonia has increased during the last decade." This conclusion requires the assumptions that river stage correlates directly and consistently with river discharge, and that the peak stage is some index of runoff. The relation between water discharge and stage has never been established for the gage at Iquitos, and therefore neither assumption is supported by data. Rivers with beds of fine sand where the bed configuration changes with time and discharge usually have unstable stage-discharge relations. Farther down the Amazon, frequent changes in the configuration of the sandy stream bed are at least partly responsible for the shifting relation between stage and discharge observed at Óbidos, Brazil (Fig. 1) (*3*). The bed of the Amazon at both Óbidos and Iquitos consists of highly mobile fine sand (*4*), so the stage-discharge relation at Iquitos probably is no more stable than that at Óbidos.

Stage-discharge relations also can change as a result of changes in channel cross section. For the Mississippi River at St. Louis, Belt (*5*) has reported that the river stage at a discharge of 24,100 m^3/sec was 3 m higher during 1973 than it was during 1881. He attributed this change to the artificial constriction of the channel. The Amazon has not been subjected to artificial control, but the channel thalweg at Iquitos has shifted appreciably during recent decades. Much of the flow of the Amazon has shifted from the far side of Padre Island to the side nearest Iquitos, the apex of the meander upon which Iquitos is located has slowly migrated downstream, and the impinging flows have accelerated erosion of the riverbank (*6*). The possibility that the stage-discharge relation was affected by the shifting thalweg and bank erosion should be considered.

Gentry and López-Parodi dismiss the possibility that the apparent increase in annual peak stages at Iquitos for 1970 to 1978 is due to an increase in precipitation during the same period, even though all eight stations show higher average annual precipitation for 1970 to 1978 than for 1961 to 1969. They draw their conclusion partly from the observation that 1978

Table 1. Average annual flood stage for the Rio Negro at Manaus; S.D., standard deviation.

Period	Years	*N*	Mean	S.D.
1	1942–1956	15	28.06	0.74
2	1957–1969	13	27.27	0.63
3	1970–1980	11	28.42	0.92
Record	1903–1980	78	27.69	1.17



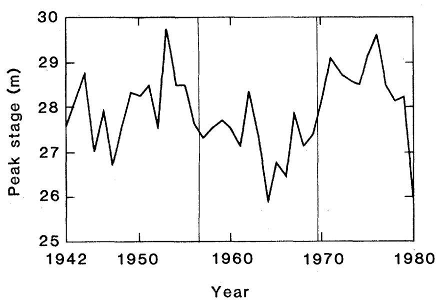


Fig. 1 (left). Relation between stage and discharge, Rio Amazonas at Óbidos (*3*). Fig. 2 (right). Peak stage of the Rio Negro at Manaus, 1942 to 1980 (*3*).

was a dry year, yet the peak stage was still relatively high. In this, they ignore carry-over storage from one year to the next; carry-over storage is characteristic of large drainage basins. Furthermore, the highest stage of the year should not be expected to correlate with the total annual precipitation or even with seasonal or monthly point values as much as with the temporal and spatial distribution of precipitation over the drainage basin (*7*). The spatial distribution of rainfall is likely to be very important, considering the large differences in precipitation recorded at stations only short distances apart. Gentry and López-Parodi report that the average rainfall at Yurimaguas is twice that at Tarapoto; these two stations are only 75 km apart, and their difference in elevation is only about 100 m. Until some of the effects of spatial and shorter-term temporal distribution are taken into account, no firm conclusions can be drawn about the relations between river stage at Iquitos and precipitation in the upper Amazon basin.

Finally, we believe that the *t*-test should not be applied to these kinds of hydrologic data. Most hydrologic time series have some degree of autocorrelation and exhibit the "Hurst phenomenon," a long-term persistence not found in independent sequences (*8*). One manifestation of persistence is a tendency for clustering of high values and of low values as observed in the Iquitos record. In geophysical time series, this sort of persistence is the rule rather than the exception. Samples drawn in their order of occurrence are not independent, so a major assumption implicit in the *t*-test is violated.

The peak-stage record for the Rio Negro at Manaus provides an excellent example to compare with the Iquitos data. Records are available from 1903 through 1980. The average flood stage for the period of record is 27.69 m. A segment of the record from 1942 through 1980 (Fig. 2) shows three distinct "clusters," high stages from 1942 through 1956, low stages from 1957 through 1969, and high stages from 1970 through 1979. A statistical summary of these data is shown in Table 1. Applying the *t*-test in the manner of Gentry and López-Parodi, we find that the mean values between periods 1 and 2 or 2 and 3 are significantly different. Examining only the data from 1957 through 1980, one not familiar with the persistence of hydrologic records might indeed conclude that runoff has ". . . increased during the last decade." Consideration of the data from 1942 through 1969, however, would lead to a different conclusion: that the period 1957 through 1969 reflects a drought.

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References and Notes

1. A. H. Gentry and J. López-Parodi, *Science* **210**, 1354 (1980).
2. Gentry and López-Parodi, as well as others, report the river stage at Iquitos as "depth." However, our own observations of the river gage at Iquitos, supported by information from Eduardo García, manager of Linea Amazonica S.A., convince us that the available records are of stage (elevation of the river surface above an arbitrary datum) rather than of depth (distance from river surface to riverbed). In this context, we also should point out that the low-water elevations that Gentry and López-Parodi quoted from the ONERN report [reference 19 in (*1*)] for 1962 to 1972 are not the lowest elevations for the years cited but the highest elevations during the months of lowest stage. The differences amount, for example, to errors of 1.8 m, 1.4 m, and 1.7 m for 1970, 1971, and 1972, respectively. We presume that similar errors are present in the low-water elevations they cite for 1962 to 1969, but we have no independent data against which we can check our presumption.
3. The data shown in Figs. 1 and 2 were provided by Flavio M. Costa Rodrigues, Hidrologia S.A., Rio de Janeiro.
4. C. F. Nordin, Jr., R. H. Meade, W. F. Curtis, N. J. Bósio, P. M. B. Landim, *Nature (London)* **286**, 52 (1980).
5. C. B. Belt, Jr., *Science* **189**, 681 (1975).
6. A. Martínez Vargas, *Revista Vialidad de Ministerio de Obras Publicas, Dirección de Caminos (Peru)* **7**, 124 (1967).
7. E. M. Wilson, *Engineering Hydrology* (Macmillan, London, 1963).
8. H. E. Hurst, *Trans. Am. Soc. Civ. Eng.* **116**, 770 (1951); B. B. Mandelbrot and J. R. Wallis, *Water Resour. Res.* **4**, 909 (1968).

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We feel that technicalities of how river stage is measured at Iquitos do not pertain to our thesis for two reasons. First, although the Iquitos data set may be subject to hydrologic constraints imposed by unstable stage-discharge relations, the phenomenon of an increased flood crest in recent years is a widespread one, and not at all limited to the Iquitos area. Our attention was first called to the increase in high-water levels by the complaints of residents along the banks of the Amazon from as far downriver as the mouth of the Javari that the higher annual flood levels were forcing them to abandon their homes during high water for the first time in memory. These houses are built on stilts on raised riverside alluvial terraces well above the influence of shifting channels. Second, if changes in riverbed configuration are responsible for the high-water changes in river stage observed at Iquitos, as implied by Nordin and Meade (*1*), the low-water values should be similarly affected; that the low-water values remain constant while high-water values increase suggests that greater runoff rather than changes in stage-discharge values is responsible for the recent flooding. Thus we conclude that, for whatever reason, there has been increased flooding along the upper Amazon in the last decade.

The second point of Nordin and Meade (*1*) is that precipitation patterns in Amazonia are so complex that firm conclusions about the relation between river stage at Iquitos and precipitation in upper Amazonia cannot be drawn. In our original paper (*2*) we noted the frustrations of trying to draw conclusions from the inadequate data base available. While increased precipitation could also explain the observed changes in Amazon flood stage, there is no evidence that precipitation has systematically increased in the Amazon basin, while the land-use changes we reported in our article are well documented.

Finally, while the lack of long-term records makes it impossible to tell to what extent the Iquitos peak-stage data reflect normal climatic cycles as suggested by Nordin and Meade for the Rio Negro data from Manaus, our interpretation [figure 1 in (*2*)] predicts that annual high-water levels will continue to increase while the alternative explanation does not. The 1981 flood crest was the second highest one ever recorded, falling inches short of the all-time record, and this year's changes in the Amazon's channel and the location of sandbars along it were the most pronounced ever (*3*).

Whether land-use changes or natural phenomena are responsible, significant changes appear to be taking place in the Amazonian water balance. The potentially devastating hydrological effects of changing land-use patterns suggest that a thorough system of environmental monitoring is in order.

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1. C. F. Nordin and R. H. Meade, *Science* **215**, 426 (1982).
2. A. H. Gentry and J. López-Parodi, *ibid.* **210**, 1354 (1980).
3. P. Jenson, personal communication.

26 October 1981