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Computing in China: A Travel Report

Computer technology advances rapidly in China with no external aid.

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In July 1972, at their invitation, we visited the People's Republic of China for 3 weeks to tour computer facilities and to discuss computer technology with Chinese experts in Shanghai and Peking. Officially, the trip was seen by the Chinese in two lights: as a step in reestablishing the long-interrupted friendship between the two nations and as a step in opening channels for technical dialogue. We, less bound to national purposes than our hosts, had our many individual motives for taking part, not least among them curiosity.

The project was initiated by Severo Ornstein, who, on an informal basis, got in touch with a small number of interested computer scientists at universities and research institutions in the United States and subsequently applied for visas on behalf of the group to the Embassy of the People's Republic of China in Canada. After a 9-month period of discouraging silence, the embassy, in April 1972, transmitted an invitation from the Chinese government for a delegation of six scientists and their wives to visit China for 3 weeks in July, with all expenses within China to be covered by the host country.

While no group of six can fairly represent the young and as yet loosely organized field of computer science, our group did bring interests and competence in computer systems and computer design, programming languages, systems theory, management science, artificial intelligence, and computer science education. A representative of the computer manufacturing community with more competence than ours in computer components and device engineering would have been a valuable addition to the group (*1*).

We were received in China with open arms. A greater cordiality and solicitude, a more earnest effort to satisfy our wishes (within practical and policy limits) would be hard to imagine. "You have brought your wives; next time you must bring your children too," they said. Egalitarian convictions in no way inhibited them from offering their American guests, on a very full and

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well-arranged schedule, the choicest foods, accommodations, transportation, amusements, and services—in short, the "curious mixture of exaggerated privilege and strict control" familiar to recent Western visitors to China (*2*). While it was clear that these considerable attentions were largely a matter of official policy, in many of our contacts we sensed a personal warmth.

Officially the guests of the China Association for Travel and Tourism, we spent a good part of our time on sightseeing and visits to cultural, social, and educational institutions. The technical and scientific aspects of our visit were firmly under the aegis of the Chinese Academy of Sciences. A representative of the academy traveled with us throughout, and, toward the end of our visit, the most formal of many banquets was given in our honor in the Great Hall of the People by Kuo Mo-jo, chairman of the academy (*3*). Some 50 percent of our time was given to discussions with technical people, visiting factories and research institutions, and viewing computing machinery. The American group had considerable opportunity to lecture before Chinese audiences, to entertain their questions, and to hear them present and discuss their achievements in computer design and programming (Fig. 1). We assume, on the basis of the attitudes we sensed and the consistency of the evidence, that our hosts gave us a representative picture of their most advanced nonmilitary computer technology.

We have attempted to keep in mind the following questions: What is the present state of Chinese technical knowledge about computer construction and use? How is this knowledge institutionally distributed? What is their capacity to produce computers and programs? How and why did they reach their present state, and in what direction are they proceeding? In respect to these questions, what we have to say is, at best, fragmentary. Nevertheless, we hope it will be valuable to future travelers (*4*).

Fig. 1. Informal discussion at the Shanghai Computing Research Institute.

The Role of the Institutes and Universities

As far as we could determine, the focus of computer design and systems programming knowledge is to be found in the computer institutes of the Academy of Sciences. The Shanghai Computing Research Institute has about 300 members, the Institute of Computing Technology in Peking, about 1000. Apart from the Shenyang Institute of Computing Technology (which we did not visit), we do not know how many more institutes of this general style are now in operation.

The computer institutes appear to take the lead in computer design and prototype development, working closely with associated factories that subsequently manufacture variants of the resulting machines. Programming research and development is also carried out within the computer institutes, but responsibility for specific computer applications seems to lie elsewhere.

Chinese computer scientists are very well read. Although at present there are no Chinese professional publications in the computer field, the Western literature is carefully collected and thoroughly processed. Institute scientists and technical personnel were eager to learn from us the very latest research results we could offer. "Don't tell us what you have already published, tell us only what has not been published," they requested. This suggested to us that we were meeting some of the workers in the field who were at the forefront of their society's computer efforts.

China's universities, such as Futang University in Shanghai and Tsinghua University in Peking, seem to play a secondary role in computer development. At Tsinghua, China's most important technically oriented institution of higher learning, we saw a pair of small computers that had been built entirely—including the transistors themselves, we were told—by students as part of their educational program. All this had taken place before the Cultural Revolution. The operation of these machines was demonstrated to us by students, but we saw no examples of new machines under construction. Indeed, our hosts declined to give us any substantive information about present activity in computer science and engineering education, saying that the matter was "being studied." Perhaps the curriculum is in some disarray.

It is by now well known that the Cultural Revolution (1966 to 1969) profoundly affected the universities, along with virtually every other organized activity in China. Tsinghua was essentially closed during the upheaval (*5*), and enrollment, which began again in 1970, is now at about one-third of the former level of 12,000 students. Under the administration of a Revolutionary Committee, as are all other enterprises, the university's admissions policy emphasizes maturity in politcal and social understanding, dedication to the aims of the revolution, and practical experience more than academic achievement (*6*). The traditional facilities of the university, such as lecture halls, libraries, and laboratories, have been supplemented by workshops, factories,

Fig. 2. Workers mounting components on printed circuit boards at the window handle factory in Shanghai.

and even farms, in an effort to stress the "three-in-one" approach—that is, teaching, research, and production combined. Members of the faculty were sent to factories and farms for a period of "reeducation" and, in some cases, are still being assigned elsewhere to help increase production competence. We met one former professor of electrical engineering who is now assigned to a factory that produces computers, although, interestingly enough, he is still accorded quasi-professorial status in formal gatherings (*7*).

The course of study, now combined with much practical work, has been shortened to 3 years, and at present there is no formal graduate program. The research institutes, such as the Peking Institute of Computing Technology, now provide postgraduate training in the computer field, we were told.

Computer Manufacturing

The new factories we visited were varied both in size and in manufacturing technology. At one extreme is the factory associated with the Shanghai Computing Research Institute. One of China's numerous neighborhood factories, it is staffed by people in the neighborhood and is therefore small. It occupies a comfortable old wooden building with an inner courtyard, formely a residence, about 2 miles away from the institute. The American visitor is struck by its good order; generous spacing of work tables; extreme simplicity of facilities; the quiet movement of engineers and other workers in the course of their hand work, study, and discussion; sunshine; and incense.

In September 1970, the factory that previously produced handles for doors and windows, with housewives as workers, reorganized in cooperation with the institute in order to produce an integrated circuit digital computer. In all of our discussions, the Chinese referred to the factory as "the window handle factory," and it was pointed out that most of the 90 employees in its electronic workshops were the same housewives who had been there in the handle days (Fig. 2). Institute members spend considerable time at the factory, and they gave us the impression that they try to help the workers progress with their own understanding of the work and, whenever possible, gather suggestions from them.

Not surprisingly, the level of mechanization is lower than one would find in a comparable American situation. There was a relative dearth of even such simple aids as magnifying lenses for the workers assembling ferrite-core memory planes. Some attention, however, appeared to have been given to elementary principles of motion economy in various assembly operations.

At the other end of the scale, the largest and oldest of the factories we visited, the Telecommunications Factory in Peking, gave much more evidence of attention to industrial engineering considerations. Several devices for the mechanization of particular processes, such as bending electronic component leads and threading cores, had been invented locally. In answer to direct questions, we were told that these innovations had been made by workers collaborating with specialists on manufacturing methods (that is, with industrial engineers). Yet here, too, manual assembly methods still predominate. We saw no evidence of flow-soldering for mounting components to circuit boards and no wire-wrap technology for interconnecting circuit boards. We did, however, find manual methods for core testing being replaced by excellent automatic testers in both Shanghai and Peking.

It was difficult to obtain information about scheduling or inventory management. Output of computers and other devices at the Telecommunications Factory were evidently determined by planning units at higher levels of the government. "What happens when two products compete for the same component?" we asked. The possibility of such a conflict was not admitted. We could not get specific data on production rates, but we estimated (on the basis of throughput at various assembly stages) that the Telecommunications Factory is producing standard computers at a rate of one or two per week. The main task of that factory, however, is the production of communication switchgear. The Shanghai Radio Factory No. 13, where we were told that we were the first foreign visitors, we estimated to be capable of producing about ten machines per year.

Components

The Chinese have been manufacturing integrated circuits, at least in limited quantities, since 1968—reportedly the same year in which integrated circuit production began in the Soviet Union (*8*). In several of the computers we saw, circuits of the transistor-transistor logic (TTL) family with rise-times of 20 to 30 nanoseconds are in use (*9*). Emitter-coupled logic (ECL) circuits, in ceramic packages, with rise-times of 3 to 4 nanoseconds are in pilot production at the Shanghai Metallurgical Research Institute, which is also developing ion implantation techniques and is using a small computer of its own design to generate integrated circuit masks. The ability to make high-performance ECL integrated circuits is an impressive accomplishment in device engineering, and we were told that plastic package versions were "in large-scale production at another factory." Apart from the metal oxide semiconductor (MOS) development work we glimpsed at Tsinghua University (in the excellent "clean room" facilities of the Integrated Circuits Laboratory), we saw no evidence of large-scale integration, now so widely used in the United States. In memory components, ferrite cores with switching times of about 1 microsecond are in common use. We also saw examples of a read-only memory using ferrite rods and of a small magnetic film memory with a read-write cycle time of 0.66 μsec.

Printed circuit boards very similar to ours were in all of the computers we saw. Typically they had a relatively low component packing density on boards 1.6 millimeters thick having copper circuit paths etched on both sides and hand-drilled holes. In at least one machine, laminated boards of four layers (that is, four circuit planes) were employed, but we did not learn whether plated-through holes were used to interconnect layers. We found connector technology to be not as well developed—possibly a bottleneck in computer production capability.

Computer Architecture

We found the Chinese examples of computer design to be relatively conservative, as exhibited in both prototype and pro-

Table 1. Principal characteristics of some Chinese computers.

Name	Year	Circuit type	Speed (1000 operations per second)	Number form	Core memory: Word length (bits)	Core memory: Size (1000 words)	Core memory: Cycle time (μsec)	Magnetic drums: Number	Magnetic drums: Size (1000 words)	Magnetic drums: Word time (μsec)	Equipment and features
					Shanghai Computing Research Institute						
C2	1968	Transistor	25	?	42	?	?	2	?	?	Two 50-column line printers
709	1971	Integrated	110	Floating	48	32	2.4	4	15	10	800-character-per-second paper tape reader; two instructions per word
					Shanghai Radio Factory No. 13						
TQ-3	?	?	100	Fixed	24	8	3	2	40	100(?)	Line printer and high-speed paper tape reader; eight in-out channels with analog-digital conversion at 100 samples per second; five priority interrupt levels; used for process control
TQ-11	?	Integrated	50	Fixed	36	16	?	?	?	?	Two 5-bit-per-millimeter, 1 m/sec, three-channel magnetic tapes; 80-column, 10-line-per-second printer; two high-speed paper tape readers; double indexing used in addressing memory
					Shanghai Metallurgical Research Institute						
?	?	?	50	Fixed	18	8	8				Cathode-ray tube unit, used to display masks for integrated circuit manufacture
					Peking Institute of Computing Technology						
109C	1965	Transistor	115	Floating	48	36	6	4	32	18.4	Four 260,000-word, 150-μsec-per-word magnetic tapes; two 72-column, 7.5-line-per-second printers; four 1000-character-per-second paper tape readers; two instructions per word; 128 19-bit index register memory (2-μsec core); 6000-word magnetic rod read-only memory for fixed Algol routines
111	1970	Integrated	180	Fixed and floating	48	32	2	1	64	9.2	Two 20-bit-per-millimeter, 300-μsec-per-word, 16-channel magnetic tapes; two 10-line-per-second printers; two 1000-character-per-second paper tape readers; cathode-ray tube scope shares 4000-word buffer with drum; 18 in-out channels; 30 priority interrupt levels; 256-word, 0.66-μsec cycle time; 5-μsec floating point addition
					Peking Telecommunications Factory						
DJS-7	1965	Transistor	3	Serial fixed	21	4	15				Variant has 32,000-word memory, 5.4-μsec cycle time; complement of in-out equipment not recorded
DJS-6	1966	?	?	Fixed and floating	48	16	5.2	?	?	?	Line printer, paper tape reader, XY-recorder; described as a "mini-computer"

Fig. 3. Console of the 109C at the Peking Institute of Computing Technology. The Chinese inscription is a quotation from Chairman Mao.

duction versions of the machines we saw (Table 1). Like most of the world's digital computers, they are essentially organized as systems of the von Neumann type, considered "classic" by Western computer scientists. The most ambitious of the machines, the well-designed Model 111 (completed in 1970) at the Peking Institute of Computing Technology, employs straightforward organizational devices to increase speed and efficiency. It embodies features such as concurrent operation of memory units, central processors, and input-output equipment without excessive complexity. The Model 111, described to us as a prototype, is a computer of intermediate size by both Chinese and Western standards, and our hosts deflected queries about their plans to build machines of a larger and more complex variety. Nonetheless, we found them to have a lively and knowledgeable interest in the assessment of technical issues involved in the design of very large scale computer systems. Finding no evidence of time-sharing, we pressed (somewhat naively) for clarification of their understanding of this rather elaborate technology and were politely told: "We would like to know what problems you have had with time-sharing. The concepts of time-sharing are understood."

China's scientific and industrial needs have lead to a heavy emphasis on numerical computation, thus far; the attention of machine designers has, therefore, focused heavily on the central processor and lightly on input-output technology. This is especially striking to American computer scientists, since in our country so much attention is now directed toward input-output devices and systems that emphasize convenience of access to the central machine.

We found punched paper tape rather than cards to be the prevailing medium for program and numerical data entry; in fact, we saw no punched card equipment anywhere. Paper tape readers with speeds of 800 to 1000 characters per second appear in the larger machines, but we saw no high-speed punches for output; paper tapes, we were told, are punched by hand on the equivalent of

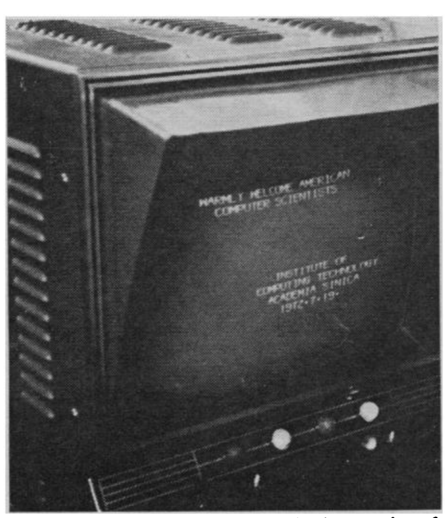

Fig. 4. Cathode-ray tube display unit of the Model 111 at the Peking Institute of Computing Technology.

teletype machines. Operating consoles are similar to those used in the United States (Fig. 3). Of the computers we saw, only the Model 111 used a cathode-ray tube display unit for the presentation of output text (Fig. 4). Impact or electrostatic line printers with speeds of about 10 lines per second and modest print quality are used with the larger machines. All printing is in Arabic numerals and Roman letters.

We saw no magnetic disk systems. Fixed-head magnetic drum units of at least four different designs are in use in as many machines (Fig. 5). Magnetic tapes on what appeared to be well-designed transports were also in operation on some of the larger machines; again there is evidently no "industry standard."

Programming and Applications

As far as we could determine, the Chinese use their computers almost entirely for scientific and engineering calculations. Problem areas specifically mentioned in our presence included lens design, weather prediction, mechanical structure analysis (as in bridge or dam building), and artificial insemination studies. The Chinese showed themselves to be aware of other application areas, such as information retrieval, traffic control, and report generation and other business applications, but gave no evidence of having invested much effort in these directions. At the Peking Computer Institute, there exised some years ago a small project on information retrieval that was abandoned in favor of work on computer languages. We were told on several occasions, in fact, that computers are *not* now used in accounting, inventory control, or similar management applications. This is consistent with the relatively primitive stage of development of input and output devices and with the apparent lack of any easy way to handle a standard set of several thousand Chinese characters. Of course, such applications could, to some extent, use preprinted forms and numerical output, but no evidence of the use of such forms came to light during the visit.

The Chinese have concentrated heavily on the use of Algol (algorithmically oriented language), an internationally developed computer language competitive with the IBM-developed Fortran so familiar in the

United States. In addition to Algol compiler programs, they have, of course, also developed assembly languages and the usual array of service and maintenance programs. There is also considerable interest in the development of programs to support compiler writing in general. The Model 111 has an operating system that allows the machine to run some 30 problems a day, with a turn-around time of 1 to 2 hours. All "general-purpose" Chinese computing, as far as we know, is in the batch-processing mode on problems that do not demand many concurrent input-output operations. It is important to remember, however, that our group heard nothing about, and saw nothing of, military applications.

The Growth of Computer Technology

Proper treatment of the question of how the Chinese reached their present stage of computer development is beyond the scope of this article, but a few remarks and observations are in order. First, it is known that the basic directions in computer technology were set forth in 1956 in the formulation of the Twelve-Year Plan for the Development of Sciences and Technology, which established 57 priority fields, including electronics, computer technology, and automation and remote control. Research institutes were subsequently established in support of these priorities, and the pattern of combining industrial enterprises with the research and development processes of the institutes and universities became evident (*10*).

Second, withdrawal of scientific and technical support by the Soviet Union in 1960, following a period in which many thousands of Chinese engineers and scientists were trained in Russian universities (*11*), left China determined to "go it alone." In the words of Kao Ling, Responsible Member of the Revolutionary Committee of the Peking Institute of Computing Technology, in his introductory remarks to us at the institute (*12*, p. 12):

> In old China we were oppressed by feudalism and bureaucratic capitalism. At that time we had nothing to say about computers, science, or technology. By 1959 the electronics industry had developed. We began to set up our institute in 1956. At the beginning we had only a little more than 100 people. Now there are more than 1000 people in our institute. . . . We have 10 laboratories and one factory, all in the same place. . . . We follow the policy of self-reliance and keep developments in our own hands. . . . In the beginning, Russian scientists came to give us help. In 1960 they withdrew all their people. The transistor and integrated circuit computers were all done by ourselves. Because of the blockade imposed by social imperialism and other capitalist countries, we have to work by ourselves and we have brought up a generation of scientists. Except for transistors and integrated circuits, everything else is done by ourselves [at the Institute]. Of course, compared with an advanced technology there is a gap. But we will follow Chairman Mao's teachings; we have determination and ability and will catch up in the future. We hope you will give us your opinions and suggestions.

This speech contained a number of elements that we heard often and that seemed to us, despite the manifest political zeal, to be valid reflections of Chinese reality: the theme of self-reliance ("We did it by ourselves as a nation and as an organization"); the coupling of research, development, and manufacturing through close organizational links; and the importance of belief in the goals of the Revolution. We were being told, in effect, that China has reached its present computer capabilities not primarily with university-trained computer scientists, but with workers engaged in sink-or-swim practical efforts in relation to well-understood social goals that they believe in.

Third, it appears that the computer development work of the Peking Institute, and perhaps of other institutes, was relatively unaffected by the upheaval of the Cultural Revolution. (The Shanghai Institute was not established

Fig. 5. One of the four magnetic drums of the 109C. Each drum holds 32,048-bit words.

until April 1969 and therefore did not have to weather the worst of the storm.) The Model 111 is an example of a machine whose design and construction took place largely during this period, and others have been reported (*13*). Several of the computers we saw, including those of the Tsinghua battleground, were pre-Revolution machines; they remained undamaged. Perhaps the priority given to computer work was sufficient to dampen the excesses of the Red Guards.

There is very little meaningful crystal ball gazing we can do about the future of Chinese computing, yet a few remarks in this vein seem appropriate. First, the Chinese we talked to indicated a strong interest in what they called the "super computer"—that is, very big and very fast machines such as the CDC Star computer and the Burrough's B6700. One guesses they will continue the trend toward bigger and faster computers, perhaps attempting a very large step next. By way of contrast, they showed little interest in mini-computers, which have become prevalent in the United States in recent years and which, because of their simplicity and economy, have made possible many new applications. The smallest computer we saw in China was physically the size of a large desk and thus bore little resemblance to the portable units we think of as mini-computers in the United States.

Although the Chinese have concentrated so far on numerical computing, there is no reason that this must continue. Overall economic planning is probably the main influence here, rather than limited understanding of the potential of other forms of information processing. New probings are discernible—for example, two small projects at the Peking Institute, one in speech recognition and the other in proving theorems. While China is clearly not the equal of the United States in computing, we believe that evaluations of the "China is *N* years behind the United States" sort are most hazardous. The Chinese have demonstrated the ability to reach very high levels of technology in a very short time. The state of technical and scientific knowledge is expanding rapidly. Much will depend on present and future national priorities in China and on the broadening base of interaction with the Western world.

Although we believe that a useful beginning has been made in the establishment of appropriate channels of communication between Chinese and American computer specialists, a proper assessment can only be made in terms of the quality and degree of further exchanges of knowledge. The recent visit to this country by a delegation of Chinese scientists, one of whom is a specialist in computing technology, is a hopeful sign (*14*), but the matter is still largely in the political arena. At the banquet held in the Great Hall of the People, Kuo, elder statesman of the Chinese intellectual community and vice chairman of the Standing Committee of the National Peoples Congress, discussed the inevitable ties between science and politics. Privately he spoke of the political gulf that still separates our countries, but he toasted our friendship publicly and said that China has much to learn from the United States.

Finally, an important factor in determining the shape of the technical future of the Chinese lies in how they will solve the problem of administering higher education. Asked what they regarded as the most serious problem facing their new experiment in higher education, the Chinese singled out two: the uneven educational backgrounds of the new university entrants and, perhaps more significant in the context of this article, finding the proper modes of combining theory with practice. China is officially committed to a course that does not permit the establishment of a scientific-technical elite. The educational policies now in force, especially in view of the educational hiatus of several years, may have a profound influence on the future development of science and technology in China, computer technology and practice included. In every part of the world the relationship between science and society has become a matter for soul-searching in the quest for new understanding. China is, in this regard, a special laboratory, looking for a viable way into the future.

References and Notes

1. An informative account of the burgeoning development of high technology in China from the point of view of a solid-state physicist is given by R. Tsu [*Sci. Amer.* **227**, 13 (December 1971)]. Tsu, traveling in China at approximately the same time we were, generally corroborates many of the points and impressions noted in this article.
2. B. W. Tuchman, *Notes from China* (Macmillan, New York, 1972), p. 57. Tuchman goes on to comment that "The effect of all this gracious attention was not so much to make one feel oneself an object of friendship as of manipulation" (p. 62).
3. *Jen-min Jih-pao* [*People's Daily*, Peking] (26 July 1972), p. 3.
4. See also: T. E. Cheatham, *Comput. Autom.* **21**, No. 11, 16 (1972); Industry and World News Department, *Comm. Assoc. Comput. Mach.* **15**, 937 (1972); A. Pantages, *Datamation* **18**, 109 (1972).
5. See, for example, W. Hinton, *Hundred-Day War: The Cultural Revolution at Tsinghua University* (Monthly Review Press, New York, 1973).
6. Six admission criteria were enumerated for us by the Responsible Member of the Tsinghua University Revolutionary Committee. The candidate must: (i) have determination to serve the people; (ii) have completed middle school; (iii) have 2 or 3 years of practical experience; (iv) be in good health; (v) be about 20 years old; (vi) be unmarried.
7. L. A. Orleans [*Science* **177**, 864 (1972)] points out that such assignments are not permanent, usually requiring only a few weeks or months away from the home base.
8. M. Macioti, *New Sci. Sci. J.* **50**, 636 (June 1971).
9. A typical set of package configurations consists of a five-input NAND gate with fan-in of 24 and fan-out of 8, supplemented by three other package types: an AND extender, an OR extender (three separate two-input AND circuits in OR combination), and a power driver.
10. P. R. Nyberg, *Datamation* **14**, 39 (February 1968).
11. M. Kapitsa, quoted by Nyberg (*10*, p. 41).
12. K. Ling, quoted by M. A. Clark, *Wash. Univ. Mag.* **43**, 18 (Fall 1972).
13. Nyberg, commenting on an announcement of a new transistorized, large, general-purpose digital computer that was trial-produced at the Peking Institute—one of several preproduction models that had been studied and built "mostly during the period of the Cultural Revolution" [*Jen-min Jih-pao* (*People's Daily*, Peking (7 October 1967), p. 2]—found ". . . every reason to believe that the social, political, and economic upheaval caused by the Cultural Revolution left unscathed workers engaged in activities associated with computer technology" (*10*, p. 43).
14. D. Shapley, *Science* **178**, 289 (1972).

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