Two of the most interesting archaeological ventures now being conducted in Egypt illustrate at its most dramatic the application of modern science and technology to the problems of antiquity. Their common denominator is the use of computers, the best instrument, if not the only one, to handle the enormous dimensions of both projects. One is the biggest jigsaw puzzle in the world, the other the biggest "X-ray examination" in both cases, bigger by a factor of a million or so than anything of the sort ever attempted.

The developments of twentieth century archaeology have accustomed us, almost to the point of yawns, to seeing science in its service in the glamorous role of discoverer (magnetometers, infra-red photography, for instance), exp post facto medical diagnostician, chronology detector (carbon-14, thermoluminescence), retroactive weather reporter (fossilized pollen, dendrochronology) and in a dozen other sophisticated functions. In the two Egyptian inquiries, however, the computer is called into play as a drudge, but what is that does best is reduced. If you will, to the humble role of file clerk, but exalted in that service to a veritable prodigy of file clerk, with elephantine memory, instant recall, total space perception and mathematical transcendence.

In the mid-1960's Nobelist Luis Alvarez conceived the audacious notion of exploring the burial chambers of the pyramids of Chephren (Herodotus' name for Khafre, which has persisted in common: Western names are about 2590-2560 B.C., standing next to the Great Pyramid of Cheops [Khufu] and only slightly smaller. The purpose was to discover whether it contains, as does the Great Pyramid, a complex of hitherto undiscovered chambers and passages.

Only two corridors, joining in a vertical fork, and two chambers are known in the Chephren pyramid, discovered in 1816 by the Italian explorer Belzoni. Why, asked the famous cosmic ray scientist at the University of California, should Chephren have settled for a relatively uninteresting pile of almost solid limestone when the huge mortuary monuments of his father Cheops and son Mycerinus (Menkaure) a few yards distant were constructed with many passages and rooms? If there were other chambers in Chephren's monument that escaped the inevitable grave robbers (who tunneled through the Pharos' tomb probably soon after his death, but whose tunnel was lost just to the ages) they are presumably intact; they would be a prime more valuable—being much older, than Tutankhamun's tomb.

It must be noted at the outset that most Egyptologists believe that Alvarez cherished a vain hope, and that no further chambers exist. They argue that over the almost five millennia since the death of the 4th Dynasty, grave robbers have searched and snooped, tapped every likely stone for a tell-tale hollow sound and left it if there were anything there they would have found it.

Dr. Alvarez chose to end speculation once and for all by applying a method analogous to X-ray photography. The technique is nothing more than measuring the density intervening between a radiation source and sensitized recorders. The denser the material, the more the radiation is blocked.

Soft X-rays, obviously, cannot penetrate stone, much less millions of tons of it, but other radiation particles can, notably one of the collision products of the constant bombardment of the earth by cosmic rays. This particle, the mu meson, muon, traverses an atom with an average fragmental weight of an atomic nucleus about one-fifth the weight of the hydrogen atom, is born when a cosmic ray splits an atom in the earth's outer atmosphere. Traveling at about one-tenth the speed of light, scores of muons strike every square yard of the earth's surface some thousand times every second. In that planet-crossing course, some are stopped by incoming obstacles early, others late or never; a few are stopped simply by the first stone to penetrate to recorders placed in the Chephren's burial chamber, at the base and almost dead center of the recorder (or counter) is a standard. If infinitely complex and sophisticated laboratory device consisting of a scintillator of about 1 mm, apart, forming a mesh, the whole sealed in a chamber of gas. If a muon enters the chamber, its electric charge ionizes the gas, sets up an electric potential in it, and a spark on a wire ensues at that spot.

In a joint Egyptian-American project, supported by the National Science Foundation, a double-deck spark chamber was installed in 1967 in the burial chamber. It was no mean feat, for much of the entrance passage is only four feet square, necessitating a tedious crouch on the part of anyone traversing it, the spark chamber and counting devices weigh some 35 tons.

The two-layer chamber of counters, each segment about five feet square and mounted one a few inches above the other, locates the angle of entrance of muons coming through the walls of the pyramid (several every second although the machine can only read only about one two per second). As the moon enters the top chamber, the resulting spark marks the exact spot. A fraction of a microsecond later it does the same thing in the lower chamber. The difference between the two impact times reveals the angle at which the moon was traveling. The data are fed automatically onto a recording tape, which in turn is put through a computer at Ein Shams University in Cairo, manned and interpreted by young graduates. If a significantly large number of "events," read from one direction, the deduction is that there was less of an obstacle for the muons to traverse the stone surrounding that particular course. Ego, a hole, an empty spot, a room.

The equipment was initially operated for about a year, facing directly upward and scanning a cone-shaped segment in the pyramids over and on of arc 35°. No discrepancy in the number of penetrating muons (taking into account the volume of stone being traversed at each point) was found, indicating that the section scanned was uniform with no cavities therein. There was nothing amiss with the equipment. From the computer tallies, the analysts were able to verify exactly the known height of the pinnacle of the pyramid and to demonstrate that the burial chamber below was 3' off the vertical from the peak.

But if there are, in fact, other chambers in the great structure and they are thought more likely to be in the sides than directly above the burial room, consequently, after the experiment was suspended for a year, the spark chamber was reassembled to permit its insertion to scan all four sides of the pyramid, one after the other, each for several months, to obtain the requisite number of "events"—perhaps two—by full comparison of the recorder (or counter) is a standard. If infinitely complex and sophisticated laboratory device consisting of a scintillator of about 1 mm, apart, forming a mesh, the whole sealed in a chamber of gas. If a muon enters the chamber, its electric charge ionizes the gas, sets up an electric potential in it, and a spark on a wire ensues at that spot.

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Nevertheless, such is the indestructibility of the stone hewn from the Egyptian quarries, none pieces remain. Indeed, of the Pharaoh’s magnificent tombs at Karnak, some 35,000 decorated pieces remain: as such, blocks, most of which were not yet cut out of the stone and painted. There also remain many un-decorated blocks. When the gigantic buildings were carved, the stone was re-used, principally as fill for the foundations of the temples. At least three of the ten monumental pylons at Karnak erected by later Pharaohs. Thereby, the successors of those restorers of religious orthodoxy were served: the blocks, neatly cut and dressed in uniform sizes, made ideal building material, and, as fill, the engraved and painted heroes were successfully hidden from view deep inside the two-meter thick walls of the pylons.

But what they achieved at the time, today’s archaeologists are in some measure able to reconstruct the Aten temple at Karnak are now in full swing. The aim of both to re-compose the thousands of stones into their original scenic designs—not physically or literally except for a few showpieces—but by matching thumb-nail size photographs of the blocks and thus reassembling pictorially the composition and his historical, descriptive, religious and artistic entity.

Akhenaten was initially titled Amenophis IV, one of the later Pharaohs of the glorious XVIII Dynasty, contemporary with his father Amenophis III from about 1370 to 1367 B.C., and Amenophis IV, adopting a new name to conform with his new religious, ruler until 1362. He came to power when Egypt’s sway extended by alliances, vast kingly and viceroyal through the Northern Sudan, Palestine, Syria and far into Upper Mesopotamia. On his death and the ascent of his son-in-law, Tutankhamun, imperial control over the dominant god of Egypt, Amen, the sun, with Aton, the sun-disk, was also a totally new religious order.

But what began with Akhenaten’s studied ignoring of other gods in the huge Egyptian pantheon developed into his reign into the principal element of the Great Hery: the virulent suppression of the other objects of worship and the insistence on Aton as the one and only deity. This was unique and unprecedented, the first Egyptian monotheism, preceding that of Moses, although certainly not monothelism in any like the Judeo-Christian-Islamic sense.

It has long been taken for granted that in expressing the worship of other gods and particularly of Amun, Akhenaten provoked furious religious warfare, led by Amen’s now designated priests, and that on his death it was they who set about eradicating his memory and his works, and restoring the orthodoxy quo. Mr. Aldred believes matters were not all that simple, and that it may have been the Ramesses II, who were more responsible for wrecking Akhenaten’s new capital at Tell el-Amarna and his temples, and for destroying all his name wherever it was found, than was the man conventionally credited with the job, Horemhab, last Pharaoh of the XVIII Dynasty.

But one aspect of Akhenaten’s rule and times admits of no doubts or disputations: during his period Egyptian art underwent a revolutionary change. The rigid, conventional style, with the idealized representation of every Pharaoh, the changing of the individual portrait, and to individualistic portraits. What is perhaps seen more remarkably than the famous bust of Akhenaten’s queen, Neferiti, as a living, breathing beauty, is the representation of Akhenaten himself as an ugly man with a receding forehead, long nose, pendulous over-sized jaw, ponderous belly, and small buttocks and thighs, his hair short. These attributes, plus a monstrously elongated skull and the fact that on one statue he is shown with a genitalia whatever were, led to a general conclusion that he suffered a serious endocrine imbalance. One frieze and some hieroglyphic evidence suggest that he was a homosexual.

What makes the recovery of the decorated blocks of the Karnak temple doubly interesting is that they show unmistakably this departure from the conventional, millennia-long, Egyptian art style. They reflect and perhaps anticipate the change so seen abundantly in the arts at the king’s new capital, built from scratch, at Amarna. The Karnak blocks were first brought to light by the French archaeologist, Henri Chavrier, in 1926, 54 x 24 x 20 cm, splendidly incised of about 20,000 blocks (later increasing to about 25,000) each of which was individually finished and then repositioned to match, Smith concluded that only by means of a computer could an accurate chart of the pictorial contents of each block be attempted. He presented his ideas to the University Museum of the University of Pennsylvania, which agreed to sponsor it. The resulting Amarna Temple Project has been supported by the Museum, the Smithsonian Institute, and the National Geographic Society. A preliminary report by Mr. Smith appeared in the Fall, 1967, issue of Expedition and also in the National Geographic of November, 1970. Today, the Project is being carried on under the direction of Prof. Donald Redford of the University of Toronto, and with about ten gifted young Egyptian specialists, many originally recruited by Mr. Smith. Dr. Edward Tureau, formerly of the Boston Museum of Fine Arts, is acting as consultant.

First each of the 25,000 blocks was photographed on a film. Then the team “translated” the details and designs of each block onto a computer card. Together with the blocks the project assigned to the stone by the Project (which includes its warehouse location) the card notes its color, whether signed or unsigned (the block was built for the most part in alternating layers) and, most importantly, the incised design fragment contained, under a score of different classifications. A leaflet may contain some hieroglyphic writing, the cartouches of Aten or Nofretti, or a part of a human or animal figure, a portion of a chair or chariot, a ceremonial fan, a religious symbol, a palaquin, an offering, part of a procession, etc. Hap hazardly yet—would be expected given the official worship of Aten—show descending sets from a sun disk above. On the other, none classified by the angles of the lines.

Some years were spent in photographing the stones and transcribing their contents into forms manageable. The problem was to devise a system for recording the computer read-outs under the appropriate classification for other picture of chairs or chariots, they could come up with a number of prospective
matches. Their procedure was quite analogous to what a jigsaw puzzler does in seeking to expand a scene from one piece the design on which he has identified, except that here almost the only guide is the design itself with no reciprocally fitting jagged edges to confirm the proper match.

The team, working in offices in Cairo, has now assembled, which is to say matched in larger or smaller scenes, some thirty per cent of all the stones photographed, and has mounted the remaining on glass plates according to subject matter. The grand panorama of the temple walls is beginning to take shape, with its processions, representations of court scenes, festivals, religious occasions and scenes of offering and worship.

Mr. Smith entertains no doubts about the essentiality of the computer as the instrument that made the project possible. Other archaeologists, admittedly not as close to the work as he was, are not so certain. They argue that the same thing could have been done by dropping each photo into a filing folder, by classification, or mounting it on plates according to subject matter. But in the early stages of the program, the computer read-outs certainly produced the information sought more easily and quickly.

Yet it is true that as of today, the assembly team of young university graduates is relying much more on their own personal memory banks than on that of the computer. If you ask how it is possible for the human brain to remember the contents of 25,000 tiny photographs, there is no answer but an empirical one: they are doing it. Their immersion has been so profound that they can recall, say, a familiar pattern on one postage-stamp sized photo that will fit next to one on the glass plates in front of them.

Dr. Redford estimates at least two more years of work before the project will be completed.

At Karnak itself, 360 miles up the Nile from Cairo, a French-Egyptian team, directed by Drs. Jean Lauffray and Serge Sauvion, is working on another portion of the same jigsaw puzzle, with 10,000 talatat, but without a computer. The French were lucky enough, because of the way their finds were concentrated, to need it.

The happy chance came in 1964 when the Egyptian Antiquities Service began to dismantle the western wing, or half, of the Ninth Pylon at Karnak to consolidate it and prevent its threatened collapse. They discovered, as Chevrier had in the Second Pylon, that the fill consisted of talatat, laid down—as was later determined—in 34 regular layers. Three years later, the Franco-Egyptian Center made common cause in the project of removing the stones. About half the pylon is now emptied. With good Gallic logic, the French team concluded that the workmen charged with destroying Akhenaten’s temple would have carried the stones from the walls into the interior of a new pylon more or less sequentially, which would have been the natural and most efficient way to do it. If so, one would expect one stone in a given layer in the pylon to lie adjacent to its original neighbor in the temple wall. In actually, matters were not so simple, but a pair of ingenious French archaeologists figured out the patterns of demolition and deposition, so that the present system of removals more or less follows that pattern in reverse. Whatever the irregularities, the problem of matching the stones is made easier by the element of their geographical concentration: the perimeter of search is notably narrowed.

Besides the matching of photographs in the Karnak offices, proceeding as with the American project, the Franco-Egyptian Center this spring (1973) has accomplished a tour de force (literally, for one talatat weighs from 90 to 100 pounds) in physically assembling about 500 incised and painted blocks into a rebuilt wall, for display in the new Karnak Museum. The recreated scene is delicious. In three rooms, apparently authentic renderings of a palace, dozens of animated figures are preparing a great feast, carrying the cooked delicacies along streets toward a banquet. As distinct from so many Egyptian mural scenes, this one is bustling and alive, almost buccaneering. Except for the most ebullient dreamers, no one really expects that after the pictorial reassembly of the temple walls is completed a project can be mounted to haul the stones themselves from the storage sheds where they are jumbled and reconstruct the temple—except for sample walls, such as the one just described. The cost—and the required labor force—would be immense. Mr. Smith has calculated from the talatat now known that the temple complex was a mile in extent and, if the interior walls were also decorated, there must have been about two miles of bas-relief murals, 15 feet high. If his figure seems excessive, there can nevertheless be no doubt that the structure was enormous, at least hundreds of yards in length.

For the present, there is enough reward in assembling the structure, or part of it, photographically. The result should disclose a treasure of information and illustration of the life, times and artistic conceptions of one of the most interesting periods of Egypt’s three thousand years of dynastic history.