The Polytechnic School is a 12 or 14 year old one-story school with saw-tooth roof shop buildings constructed of burned clay brick walls, concrete columns and bond beams, parallel chord wood roof trusses, wood purlins and subpurlins, and roof of corrugated asbestos cement. That portion of the brick wall above the bottom chord of the truss closing in the saw-tooth ends of the building was dislodged and fell. This masonry was unreinforced and no anchors were placed in the top of these unreinforced brick walls to connect the corrugated asbestos cement to the walls for their lateral support. No roof diaphragm was provided.

No damage was apparent to the remaining masonry walls nor to the wood trusses; however, several panels of the corrugated asbestos cement were destroyed, probably as this material attempted to act as a roof diaphragm.

The Regional College was dedicated in April, 1970, and was not yet completely operational. Here again the short reinforced concrete columns were seriously damaged and the longer columns on the opposite side of the buildings were not damaged except at one location where a rock pocket existed in the column.

Upon a cursory review of the plans at the site it was obvious that the rigid frames in the sawtooth roofed shop buildings and the rigid frame in the auditorium were designed for some lateral forces. The frames of both these buildings had little damage. There was, however, damage to the masonry walls in the auditorium but to a much lesser extent in the shop walls. Several light fixtures in the shop buildings fell to the floor. They were anchored with a single bolt about 1/4" diameter located at the center of the fixture.

The Colegio Mundo Mejor is a two-story reinforced concrete frame, concrete block infilled wall school, approximately two years old. It was located in a neighborhood where there was considerable settlement of buildings and soils. Homes nearby were in one to two feet of water; see Fig. 28. Local residents reported that prior to the earthquake the water table was 1½' to 2' below the surface of the ground. They also reported that the surface of the level of the ground appeared to have settled.

This school had no significant damage to the frame or to the walls. There was, however, some slight spalling damage at the expansion joints located in each wing.

The ground floor of each classroom was bulged up in the center about 16". Apparently, the whole building settled uniformly thereby merely bulging the ground floor slabs upward.

The Convent of the Dominican Mothers of Columbus, Ohio, was a two-story reinforced concrete building about three years old with unanchored, unreinforced concrete block walls. The building was a total collapse.

The unreinforced concrete block school for the handicapped, operated by these nuns adjacent to this convent, was seriously damaged to a point where it may be demolished.

The hospital Obrero is a complex of brick bearing wall buildings. The exterior walls were cracked throughout and much glass damage occurred. This hospital continued to remain in operation.

The Banco Nor Peru is a four-story reinforced concrete building. At the rear of the building is a mezzanine floor which gives lateral support to the rear columns at mid-height. Failure occurred at the stiffest elements, namely, the rear wall and the rear columns that were braced at mid-height by the mezzanine floor.

The Sogesa Steel Mill is the largest installation in Chimbote. It consists of a large two crane ore unloading structure and conveyor system, a furnace building, a rod and angle mill, a new light gage plate mill, an oxygen building, and other auxiliary buildings and administration building.

At the new Steel Light Gage Plate Mill, a plant that was to be opened a few weeks after the quake, the floor slab (a slab on ground) suffered settlement. A close inspection showed that these settlements occurred near and adjacent to deep pits built in the floor. These pits were 25 to 30 feet deep. These settlements were attributable to the consolidation, during the quake, a backfill placed around these pits. In one area two large steel rolls weighing between 60,000 and 75,000 pounds caused the slab to settle more than the usual settlement. This particular area settled about 4 inches. The north end of the pickling line had settled about 12 inches. Realignment of cranes and machinery will doubtless be a time consuming task. A considerable amount of the corrugated asbestos cement roofing and siding broke at the hook-bolt connections and fell to the ground.

A reinforced concrete storage building located at the Steel Mill site had several fractured columns, the most severe fractures occurring in the clerestory portion.

The ore-handling dock of the Corporacion del Santa, serving the steel mill, shifted laterally. Hydraulic fill adjacent to the east side of the dock, settled on the order of six feet and the outer half of the pier shifted laterally about three feet. A horizontal separation of 21 inches occurred between the wharf structure and an electric substation at the outer end of the wharf. Several concrete pilings in the two bents closest to shore were cracked just below the pile cap.

Essentially all of the approximately 10 fish plant finger piers suffered damage due to settlement and lateral movement. These piers were not loaded at the time of the earthquake. One pier under construction suffered damage similar to the other piers and the outer 180 feet completely collapsed.

A new pier for handling fish boats at a repair yard did not suffer noticeable vertical movement but moved longitudinally approximately 6 inches.

Hotel Chimu, a three-story structure located on the water front, was undamaged. Cracks in the ground running parallel to the shore line were evident in the street end in front of the hotel building.

Trujillo

Trujillo, about 85 miles from the epicenter, suffered far less damage than other coastal towns in the stricken area, but many adobe buildings collapsed partially or completely and some brick and reinforced concrete buildings with infilled walls were slightly damaged. The quality of construction in Trujillo was without doubt better than in other towns described in this report, and had a much older and much more established appearance to it.

A reinforced concrete elevated water tank just being completed in the south part of the city was undamaged.

An adobe sign, also at the south end of Trujillo, suffered no damage; it was 16" thick, 13'-6" wide and about 20' high above the first step of the footing. It is amazing such a structure remained standing, whereas many adobe buildings nearby collapsed.

At the Clarianca Seminario Religioso (a Catholic School) four identical classroom dormitory units had been constructed. Only the Southwest unit suffered minor damage.

At the College St. Vincent de Paul, a typical two-story school building dedicated in 1960, little damage occurred to any of the school buildings. In the new large auditorium a few acoustical ceiling tile under the balcony were loosened but did not fall.

Many other buildings in Trujillo of reinforced concrete framing with infilled masonry walls resisted the quake with little or no damage including some buildings that had little evident strength to resist lateral forces.

The parapets and part of the top story of the Municipalidad (City Hall), a brick building adjacent to the Plaza de Armas, fell to the street.

The cupola of the main dome in the 350 year old cathedral fell through the dome onto the altar structure below, thus causing it to collapse. One of the sub steeples became dislodged and fell through the main roof to the floor below.

A large hospital suffered only slight damage in the main structure due to pounding of adjacent sections at a construction joint and re-entrant corner. More damage occurred at the nursing school, which had been built on a fill that settled during the earthquake. Unreinforced clay brick walls were cracked and one foot high glass windows in the demonstration-lecture room were broken.

Salaverry

Salaverry, about 75 miles from the epicenter, had negligible damage. Many buildings in the town are wood frame buildings with wood siding. Neither the sugar warehouse nor the adjacent loading dock equipment at the marine terminal appeared to have suffered any structural damage. Concrete slabs on the fill at the shore end of the loading dock settled a few inches.

MOUNTAIN REGION

The Callejon de Huaylas, frequently referred to as the Callejon, is the beautiful valley formed by the Santa River as it flows north from Lake Conococha for a distance of about 100 miles, thence into the Canyon del Pato, a very steep walled canyon about 65 miles in length, and then out to the Pacific Ocean.

The towns and villages in the Callejon have many adobe buildings of one or two stories with a few three-story dwellings. The adobe generally appeared to be of better quality than that of the coastal cities. Throughout the Callejon more than half of the adobe buildings collapsed, or were seriously damaged. Most of the brick and reinforced concrete frame buildings with brick filler walls survived, many of them with little structural damage. All buildings within the debris flow were completely wiped out. The following towns are located in the Callejon de Huaylas.

Huaraz

Huarez, about 95 miles from the epicenter, was the location of severe destruction from vibrational effect. Almost every adobe building in the south portion of the town was completely destroyed. Most of the buildings in the north portion, consisting of one and two-story brick or adobe construction, were rebuilt after an avalanche in 1941 resulting from the collapse of a natural dam of a lake above Huaraz. The buildings in this rebuilt area of Huaraz in general, suffered little damage.

The situation in Huaraz was perhaps the worst in Peru. Because most of the adobe dwellings were two and a few three-storeys in height and the streets were so narrow (maybe 15 feet or so) people who had run out into the streets were crushed by buildings falling on top of them.

One nun explained as she was pointing to her school, that four nuns and perhaps 300 children lay under the rubble that once was their school. Also that probably 400 or so people were buried in the collapse of the theater. Certainly hundreds of other people lay beneath the rubble of the many demolished buildings.

The steeples of the cathedral opposite the Plaza de Armas, collapsed. Yet in the midst of this devastation there were buildings of reinforced concrete frames with brick filler walls and brick buildings that survived very well. Apparently the earthquake vibrations were less severe in Huaraz than in the coastal towns of Huarmey, Casma and Chimbote because comparable construction which had some lateral force resistance suffered less in Huaraz.

The city hall, opposite the Plaza de Armas, a two-story reinforced concrete frame building with brick walls and tile roof, showed strong evidence of motion but did not appear to be seriously damaged.

The library building of the Corporacion del Santa adjacent to the city hall was dedicated in May 1968. It is a one-story building constructed with reinforced concrete rigid frames and brick walls. Damage to this building was limited to dislodged roof tiles and nominal cracks in the brick walls. There was essentially no structural damage.

One three-story building with brick filler walls next to the Plazs de Armas remained standing, but was severely damaged. That building, as well as several others in Huaraz, employed brick as the principal structural material with reinforced concrete columns and bond beams.

The hospital, built in 1963, is a complex of one and two story wings. It suffered some nominal structural damage to the brick infilled walls and reinforced concrete frames. The roof tile on all of the wings was dislodged.

In each instance the tile slipped or was bounced down the roof slope to such an extent that there was no tile within about three feet of each roof ridge. It was reported that many injuries resulted from the roof tile falling on the occupants as they attempted to escape from the buildings. In Huaraz there was a large amount of dislodged roof tile.

At the hospital a reinforced concrete water tank supported on four columns braced by intermediate horizontal beams did not collapse; however, there was some nominal cracking at the intersection of the beams and columns and at the column bases.

The hospital power house was built with corrugated iron roofing supported by steel purlins on steel trusses and reinforced concrete columns. Walls were of adobe. The roof was braced with steel rods about ½" in diameter. Several rods were broken and many were deformed so that they sagged. Damage in this building was very nominal and limited to the rod bracing and cracks in the walls.

A two-story school building was under construction at the time of the earthquake. Little damage occurred to the building. This school had a roof of corrugated iron supported by wood trusses. The walls were of plastered infilled masonry and frame of reinforced concrete. The second floor was constructed of reinforced concrete slab formed by spaced clay tile so commonly found throughout the earthquake area.

A five-story reinforced concrete frame building with infilled walls was nearing completion at the market area. Some of its brick filler walls were cracked. The three-story school, probably was constructed after the 1941 mud flow which covered this portion of Huaraz. This school building had frames of reinforced concrete, infilled walls of unreinforced brick masonry, wood roof trusses, and a roof of corrugated transite. Half of one wing collapsed and the adjoining portion of the same wing was on the verge of collapsing. An expansion joint separated the collapsed and the standing portions of the wing. The concrete frames at the expansion joint apparently could not resist the induced torsional forces.

Yungay and Ranrahirca

Yungay and the neighboring town of Ranrahirca were wiped out by the debris avalanche from Mount Huascaran. This earthquake will be recorded in history, not only for the damage to man made structures and the related loss of life, but also for the huge debris avalanche originating on Mount Huascaran which probably took 20,000 lives.

Mr. Mateo Casaverde, a geophysicist at the Geophysics Institute of Peru, was an eyewitness to the event and gave the following account. He stopped in Yungay near the cemetery about 3:00 p.m. Sunday, May 31, the afternoon of the earthquake, to photograph Mount Huascaran. Through his telephoto camera lens he observed a series of rather deep horizontal cracks in the glacier on the face of the mountain and commented to his companions about the possible danger associated with those cracks. They returned to their car and proceeded in a southerly direction a short distance to the end of the curve in the road opposite the cemetery, when the earthquake occurred.

The vibrations were so violent that he stopped the car. He saw several adobe homes fall and the small bridge ahead of them collapse. Knowing of the imminent danger and of the past history of avalanches or debris flows in Ranrahirca in 1962 and in Huaraz in 1941, they ran for the cemetery hill about 150 to 200 yards away. At this time there was a strong blast of wind accompanied by a continuous deafening rumble. Upon arrival at the base of the cemetery hill, Mr Casaverde turned to look back toward Mount Huascaran and saw a huge wave of debris above Yungay. He ran up to the third tier of the cemetery just as the mud flow reached this highest level. Two women about 12 feet behind him did not reach the safety of this level and were swept away to their death.

Much discussion centered around the velocity of the flow. Consensus of opinion placed the velocity at approximately 200 miles per hour.

The speed and time of travel for this avalanche also coordinates closely with the avalanche which covered Ranrahirca on January 10, 1962. A very good report of that avalanche is given in the June 1962 issue of the National Geographic magazine.

The debris flow originated from a large block of ice and rock about one half mile wide and about a mile long at an average elevation of about 18,000 feet on the side of the north peak of Mount Huascaran, approximately 9 miles from Yungay. This peak's elevation is given as 21,860 feet, whereas the south peak at Mount Huascaran is at 22,205 feet.

The debris avalanche came down the Llanganuco River Valley from Mount Huascaran, buried Ranrahirca killing its 3,000 to 4,000 residents, then plunged down the Santa River apparently in a single long large wave all the way to the ocean. A small lobe of the debris topped a ridge and flowed over Yungay killing an estimated 17,000 people. As the debris flow hit the west, or opposite, bank of the Santa River at Ranrahirca, the avalanche washed up the opposite bank about 400 feet or more. The depth of the flow at Huallanca was 200 feet and about 8 or 10 feet where the Chimbote - Trujillo road crosses the Santa River. Judging from the height of an uprooted palm tree at the Plaza de Armas in Yungay and comparing the height above grade of the palms remaining in the Plaza, the depth of the debris is estimated to be 11 feet.

A rough estimate of the amount of material in the whole debris avalanche is about 75 million cubic yards.

The material in the flow ranged from large boulders estimated to weigh about 700 tons to fine silts. Craters formed by chunks of ice were found in the mud at Huallanca, 35 miles below Yungay; this was evidenced by a crater up to a foot across with clean rocks in the bottom of the crater.

The debris flow took out the dam and a bridge to the power house at Huallanca. No evidence of either was found.

CONCLUSIONS AND OBSERVATIONS

1. The earthquake was not a good test of modern construction as used in the United States of America because too few buildings designed in accordance with contempoary U.S. standards were within the area of its effect.

2. It is probable that had structures designed and constructed according to lateral force requirements of California been subjected to this earthquake, minor damage could have occurred, but the structures would not have collapsed.

3. This earthquake again demonstrated that in addition to building failures, utilities, bridges, and highways will also suffer considerable damage.

4. Most of the collapses occurred in areas where structures had been constructed on alluvial deposits.

5. It is possible the high degree of reported vertical vibrations increased the amount of consolidation of loose soils in Chimbote. This condition would apply to both alluvial and man-made fills.

6. Where concrete columns are the means of lateral resistance, concrete outside of the column cage should be ignored in both shear and bending.

7. Brick bearing walls and brick filler walls generally fared better than adobe bearing walls and adobe filler walls. All were unreinforced.

8. Since many concrete columns failed at the beam soffits, some additional research work appears to be necessary utilizing simulated earthquake loadings rather than mere stress reversals.

9. Exterior concrete columns tended to "walk out" from under concrete beams, where beam-column failures occurred.

10. Column ties were generally widely spaced and had 90° bends at the corners. The "opening" of these ties was very evident in some columns. Had 135° bends been used this "opening" might not have occurred.

11. Concrete generally appeared to be of low quality, with large aggregates in small columns, unwashed aggregates, low strengths (probably 750 p.s.i. to 2000 p.s.i) and over-sanded mixes.

12. Torsional resistance and relative stiffness of all members in the whole building must be given consideration. This includes the stiffness of each column in each direction and the stiffness of all walls. This was apparently overlooked in the few engineered structures that failed.

13. The structural integrity of all infilled walls must provide for all loads normal and parallel to the plane of the walls.

14. Unreinforced and unanchored masonry should not be used in areas of seismic activity.

15. The installation of glass must be consistent with the stiffness of the structural frame of the building or the support of the glass. The stiffness of the frame should be sufficient to prevent glass breakage or details of sash and glass installation must be provided which will allow the frame to move without imposing load on the glass.

16. The nature of the soils and their behavior under static and seismic conditions must be considered in the design of a structure.

17. All elements of a building such as partitions, fixtures, veneer, sash, railings, roof tile, etc. must be designed for the lateral forces to which they are subjected.

18. Beam bars and column bars, throughout their joint intersections, must be held in place by means of column ties and closed beam stirrups.

19. For a uniform level of safety of construction, proper building regulations must be adopted and enforced. Continuous construction inspection by competent personnel is required for compliance with the design concepts and drawings.

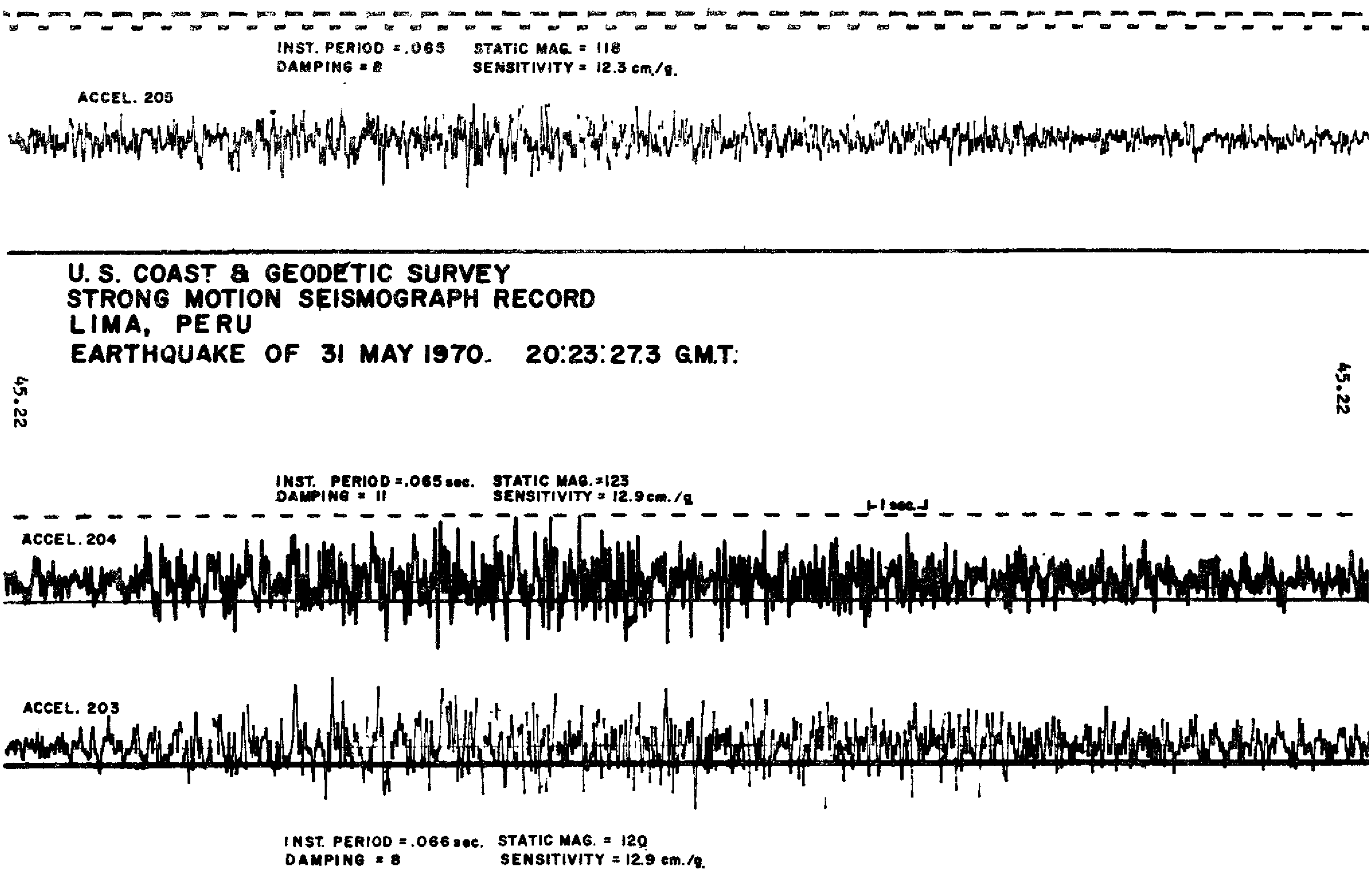
20. Where a concrete frame is designed to resist lateral forces and then a weak masonry filler wall is placed within this frame, a strong possibility arises that the concrete columns may fail in shear when the weak masonry fails in shear. Placing a weak masonry filler wall within a reinforced concrete frame may result in a weaker unit than without the filler wall.

STRONG MOTION SEISMOGRAPH RECORD

The strong motion seismograph record was provided by the Seismological Field Survey, United States Coast and Geodetic Survey, Environmental Science Services Administration, Department of Commerce, 390 Main Street, Room 2067, San Francisco, California 94105. This record was obtained from the United States-Peru Cooperative Station in Lima, Peru.

Attention is directed to the high frequency content of the accelerogram which was recorded approximately 380 km. (240 miles) from the epicenter. The top record is the vertical component, the middle record is the longitudinal, and the bottom record is the transverse. The directions of the horizontal, longitudinal and transverse records is not known at this time since the instrument was moved from its original installation. Preliminary analysis of the record indicates that the maximum acceleration recorded was approximately 1/10 G in Lima, Peru.

CCMS No. 9


INST. PERIOD = .065
DAMPING = 8
STATIC MAG. = 118
SENSITIVITY = 12.3 cm./g.
ACCEL. 205
U. S. COAST & GEODETIC SURVEY
STRONG MOTION SEISMOGRAPH RECORD
LIMA, PERU
EARTHQUAKE OF 31 MAY 1970. 20:23:27.3 G.M.T.
45.22
45.22
INST. PERIOD = .065 sec.
DAMPING = 11
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SENSITIVITY = 12.9 cm./g
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ACCEL. 204
ACCEL. 203
INST. PERIOD = .066 sec.
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SENSITIVITY = 12.9 cm./g.