ENCLOSURE 3

Review and Comments

on the

February, 1982, Report by Weston Geophysical Corporation

to

Consumers Power Company

on

"Description and Evaluation of Bedrock Surface Structures in the Vicinity of Midland Plant - Units 1 and 2 Midland, Michigan"

by

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SUMMARY

1. This extensive report and compilation of surface and subsurface data for the central portion of the Michigan Basin is the most complete compendium of information which I have seen for such an area in Michigan. Though there are some areas (particularly south and southwest of the Power Block Site) which have less data than might be desirable, I believe this data base is about as complete as possible at this time. It is complete enough to make reasonable postulation of the geologic characteristics of the region.

2. The geologic interpretation is, for the most part, quite logical and adequately documented.

3. I agree with the basic conclusions concerning the stability of the area. It is my opinion, and it is adequately documented in this report, that tectonic structures, including a variety of folds, faults, and flexures, in this area are pre-Pennsylvanian in age and none have been identified as penetrating or otherwise modifying the continuity or attitude of the Pennsylvanian and overlying Jurassic or/and Pleistocene deposits.

4. In my own judgement, Weston Geophysical's conclusions demonstrate this area of Michigan to be tectonically inactive.

5. It seems unproductive to recommend further data-gathering for the area surrounding this site to demonstrate more strongly the geologic stability of the Power Block Site.

Aureal T. Cross

PART I ASSESSMENT OF BEDROCK STRATIGRAPHY AND STRUCTURE IN THE VICINITY OF THE MIDLAND PLANT SITE

The pattern of two systems of structural trends, a principal SE-NW trend and a subordinate trend SW-NE has beendocumented for the central Michigan Basin area. The report has demonstrated that some of these structures are coincident with others in strata above or below, thus appearing "stacked" or superimposed. Some of these are accurately identified as being at high angle or near-vertical and probably directly related from the middle Devonian to the upper pre-Pennsylvanian sections studied, i.e., from the Dundee Formation through the Bayport.

The major structures are probably in part coincident with and derived from basement structures, which may have been reactivated during various episodes of the early and middle Paleozoic era, and in part due to basinal subsidence and attendant compressive and tensional stresses.

Some of the structures which are identified with the two aforementioned tectonic trends in this part of the Michigan Basin are not apparently"stacked". They are not directly superimposed or coordinate with or, in some instances, continuous through the several major named units of strata studied here. The reasons for considering that these are not stacked are:

1/ Some which are in the same general area in successive strata and are in proximity with or coordinate with the general structural trend above or below, are too far apart areally (1/8 to 1-1/2 mi) to be directly related vertically;

2/ some of the structures, particularly postulated faults, do not have the same azimuthal direction as faults in strata above or below, i.e., they are 3° to 12° apart;

3/ some are not of corresponding length;

4/ some are evident in strata lower or higher in the section but no "fault" (or significant flexure) is evident at the proper location in strata in between, as when faulting is identified or postulated in the Dundee below and the Marshall above but it cannot be found in the Traverse between. Some of these offsets in superposition (or "stacking") are of considerable distance, as noted, with presumed faults being from 1/8 to 1-1/2 miles offset from the Dundee up to the Traverse or / and from the Traverse up to the Marshall, as mapped in Plates II, III, and IV. There is no possibility that fault structures on these trends which are spatially dislocated by such

distances in strata which are only 1000-2000' apart stratigraphically (vertically) could be assumed to be superimposed, and thus considered to be part of the same high-angle fault. Faults may be offset through successive strata but this type of intermittent horizontal transfer has not been demonstrated here, and I do not believe it is a major characteristic of the faulting in this part of the Michigan Basin.

Such aberrations (flexures, folds, faults) of tectonic origin may, in some instances actually be intrastratal response (deformation, displacement, etc.) to stresses exerted by compressive forces, and in some instances, to depositional non-uniformity (bars, channel-fills, carbonate-bank build-ups, etc.), or even to subaqueous or subaerial erosion locally in alternate or occasionally superposed layers of sediment (bedrock).

I am of the opinion that a significant number of the tectonic structures indicated on Plates II, III, and IV are folds, rolls and flexures only, and are not faulted. Faults are certainly associated with some of the structural trends, but evidence is lacking to assign faults to most of them.

Even where closer control is available, such as in the Porter and Kawkawlin oilfields, or in coal areas which have been extensively explored with cored test holes, the large number of faults postulated is not demonstrated here or in other non-proprietary works to date. The postulated faults are generally anticlinal, synclinal, or monoclinal folds or flexures of moderate or even low amplitude. Most of the structures mapped have dips of only a few feet per mile on either limb of such folds.

PART II EVIDENCE FOR POST-MISSISSIPPIAN FAULTING IN CENTRAL MICHIGAN

This section of the Report reviews geological evidence for the tectonic folding and faulting in east-centralMichigan Basin and concludes there was no post-Mississippian tectonic disturbance, and none of the earlier faults have been identified as having propagated to the surface in post-Mississippian time.

In general, I concur with these conclusions on the bases of both the evidence presented in this report and prior knowledge. However, one cannot say categorically that there may not have been minor tectonic activity during the Pennsylvanian, but if it did occur, it has not been identified in quarry and mining operations and has not been demonstrated in drilling the subsurface. If any such Pennsylvanian tectonic activity did occur, it was apparently neither widespread nor significant.

Soft-sediment deformation (slump-faulting, local folding and flexing) has been observed locally in stratified Pennsylvanian age strata at several clay-pit quarry sites and local coal strip-mining pits (Figure 1). Some of this soft sediment deformation may have been the result of gravitational readjustment of then-poorly consolidated Pennsylvanian sediments, or deformation during unequal compaction and dewatering caused by anomalous distribution of virtually non-compacting sediments (sandstone channels, bars, irregular carbonate-bank buildups either within the sequence or in shallower substrate) above, below or laterally between soft, muddy siltstones and claystones and peat deposits (which lose 50% to 90% volume during compaction). Many of these silty shale and mudstones were deposited on very-low-angle, seaward sloping, coastal plains and marginal bays or shelves which would have had adequate slope to allow water-saturated sediments, particularly under some hydrostatic head, to slide seaward or channelward, even without triggering by earth tremors. The alternating succession of diverse types of sediments (sandstones, siltstones, shales, limestones, limy-muds, peat, organic muck, etc.) in lower alluvial plain, delta plain, foredelta, lagoons, embayments, and broad swamps (lateral to levees or behind barrier beaches or bars and dune-banks) of typical depositional sites of the Michigan Basin, should generally be expected to be characterized by extensive occurrences of locally limited soft-sediment deformation.

The locations of the sites of such soft-sediment deformation in the

Pennsylvanian strata do not appear to be coordinate with the pre-Pennsylvanian fault and fold systems. It is possible that some reactivation along old fault lines might have occurred during Pennsylavnian time and, in such hypothetical instances, the post-Mississippian sediments which had accumulated should have been deformed or faulted. However, such sites, if present, have not yet been identified with certainty even in areas of considerable stratigraphic control (quarries, surface and subsurface mines, coal fields which have been drill tested, oil fields with densely spaced drilling with good geophysical and lithologic logs). It is extremely difficult to "prove" the presence of any fault with subsurface drilling without close spacing of holes, diverse geophysical logs, lithologic and paleontologic control, or cores. Even the close spacing of 400 to 600 foot centers is insufficient to prove that faults are or are not present, but such control would reduce the uncertainty.

This report establishes with reasonable certainty that the depositional attitude of the Pennsylvanian strata of east-central Michigan, and in the area of the plant Site, has been retained, with only minor aberrations, and that these strata have not been involved with the pre-Pennsylvanian faults, folds and flexures.

The general continuity of the various layers of rock in the coal-bearing strata is always difficult to establish, because of the considerable interfingering of the various types of sediments which were deposited in the diverse environments of the coastal margins. Even the coals, which were deposited in a variety of swamp sites (ox-bows, lagoons, sag-basins on delta surfaces, low areas behind natural levees along watercourses, etc.) lack the desirable continuity for tracing over wide areas. The coals are locally discontinuous (degradation was more extensive in some parts of swamp or bog environments than others, fires occasionally destroyed peat accumulations locally, channels of seaward meandering streams cut through the swamps removing some or all of the peat, etc.) and of variable thickness. Interspersed river floods or inundations from the sea brought muds,silts and sands,and even limestone deposits,which intermittently interrupted the continuous accumulation of peat and resulted in so-called partings or splits of the coal seams. The Report has adequately reviewed these vagaries of interdigitated sediments. It concludes, and I concur, it is possible to use larger composite units of several lithologies, i.e., packets or sequences, here referred to as cyclothems, as stratigraphically identifiable and correlatable units. One

factor valuable in the use of "cyclothems" is the repetetive order of occurrence of successive lithologies in successive cyclothems. Though some lithologic units may be missing from a cyclothem locally, where they occur they seem to occur in their proper sequence. The control for such orderly sequential deposition is rise and fall of sea level (transgression-regression cycles), or periodic stream-switching. Within these types of variables, the Report has demonstrated continuity of Pennsylvanian sedimentary rocks and their present distribution across pre-Pennsylvanian tectonic aberrations without discontinuity or change of attitude.

This Report, then, proposes correctly, that the general continuity of Pennsylvanian strata indicates little or no post-Mississippian tectonic disturbance, and no evidence of reactivation of faults present in earlier strata. The upper and lower surfaces of the Pennsylvanian strata are uneven. The determination of the nature of the pre-Pennsylvanian surface is complicated by internal inconsistencies of thickness of various layers of the Pennsylvanian strata and by the unevenness of the erosional surface at the top of the Pennsylvanian. However, it is clear that some previously deposited sediments of Mississippian age were removed in this area prior to the deposition of the Pennsylvanian sediments. It is also established that some, and in places nearly all,of the Pennsylvanian strata were removed by erosion in the long interval (130 m.y. ±) before deposition of the coastal plains Jurassic "Redbeds", or the 260 m.y. later Pleistocene drift. These irregularities of thickness do not,however, obscure the identification of continuity of Pennsylvanian strata continuously across the region, including the Power Block Site.

It should be noted that many of the apparently abrupt changes in lithology in the Pennsylvanian and Pleistocene sediments,depicted on the cross-sections, are not real. Rather, they are artifacts derived from the use of dissimilar data recorded in test holes; differencesin description of the lithologic units encountered by different drillers, and data from different types or qualities of logs. Therefore, the descriptions given to strata penetrated in even adjacent holes may (and do) vary considerably.

PART III LINEAMENT ANALYSIS IN SOUTHERN MICHIGAN

I am not a specialist in lineament analysis or interpretation but I have used it in various ways in oil and coal exploration and interpretation of coal-bearing rocks in three areas of western United States. It is a useful tool in some areas for the establishment of fault patterns in the subsurface. However, where thick, or even thin, deposits of unconsolidated sediment conceals the bedrock, the value of this tool is questionable and disputed. It seems that a subsurface pattern of faults depicted by the Geospectra Corp on Figure 2 in the area of the Power Block Site may be in accord with other subsurface evidence for faults, folds or flexures or even trends of such structures, but there is no evidence presented which would indicate the reliability of lineament analysis as the prime evidence of such a pattern. Considering that the extent of displacement or amplitude of folding is a few tens of feet in the pre-Pennsylvanian strata near the Site, and that there is no evidence of disturbance of tectonic nature in the Pennsylvanian sedimentary rocks here any lineament pattern at the surface would have to be reflecting, in some manner unknown or untested at the present time, structures deeper than the Pennsylvanian, perhaps even basement structures.

My experience in the Appalachian Plateau area, the Colorado Plateau area and the northern Great Plains has resulted in mixed results from the use of lineament analysis. I concede that in some instances there appears to be some type of emanation from the deeper subsurface which appears to be giving some well-defined linears at the surface of unconsolidated sediments but what it may be is still a conjecture. There is evidence that lighter hydrocarbons do migrate to the surface in minuscule quantities from deeper oil-bearing strata. There is also some evidence that gaseous emanations from coal seams, perhaps methane, also reach the surface. In some instances such gases reach the surface through fractures; in some they follow updip on tilted strata, but such emanations also appear to reach the surface directly above the hydrocarbon reservoir or coal seam irrespective of attitude of the strata, presence of fractures, or multiplicity of lithologic types in the interval to the surface. The quantities of such gases(?) are usually too minute or too difficult to collect directly for measurement. However, it is known that certain bacteria and fungi are specific for the support of their metabolism on certain lighter hydrocarbons. Such organisms (microflora) may

be used to identify the areal pattern of such emanations and thus may define certain geologic structures as well. It may be that the amount of gaseous concentration in the vicinity of fractures (perhaps lineaments) is greater than that which has diffused upward through the strata irrespective of lithologic barriers, and therefore a concentration of such microfloras might be found to alter the heat sensitive record found on certain spectral wave-lenths by remote-sensing cameras. Whatever it is, one would normally expect the record to be diffused where unconsolidated sediments intervene between the top of the bedrock and the present surface. However, I am inclined to agree that some linears on photos appear to fall into a pattern which sometimes reflects or coincides with known fracture patterns. I do not believe that the lineament patterns are necessarily coincident with major faults or other tectonic structures which might be propagated to the surface. It is apparent that many of the faults or fractures which are apparently coincident with lineaments are deep faults, even basement faults, which do not reach within a few hundred or even a few thousand feet of the present surface.

Lineaments, therefore, do not necessarily indicate positions of active faults to the surface. Though it has been stated here that lineaments have been correlated in some instances with known tectonic features and other geologic features, it has not been established here that these are clearly associated with geologic features in the upper thousand feet or more of strata in this part of the Basin. Some appear to be more nearly correlated with deeper structures.

One very strong argument against these being recognized through the unconsolidated drift deposits in the Michigan Basin is the fact that in southern Michigan, in the vicinity of several major structures which are rather generally accepted as being faulted , with throws of several hundred feet, no linears or other features which might be construed as lineaments can be identified at the surface. Where the folds or faults(?) in the vicinity of the Power Block indicated on Geospectra's map (Figure 2 of report) are only a few tens of feet, or at the most a little over a hundred feet, in magnitude, it seems highly unlikely that what is being recorded at the surface is faulting to the surface.

PART IV STRESS IN THE BEDROCK IN THE VICINITY OF THE PLANT SITE

From the evidence currently available, it is my estimation that the Power Block Site is on one of the least-stressed areas which could be identified in the Great Lakes region.

It is my opinion that this is an essentially inactive area, tectonically. This particular site is not on any major fault or flexure. It is regionally on a very stable segment of crust which lies about intermediate in position between any regional trends, flexures, folds or faults. In such a position, there should be a very low level of either internal natural tension or compression.

Introduced tensions or pressures (compressive forces) from active extraction of liquids or solids from on or near the Plant Site are not apparently present at this time. However, no further extraction of liquid or solid materials (oil, brine, salt, coal, etc.) from the vicinity of the Plant Site should be permitted, probably within at least one mile of any significant structures.

The significance of injection of liquid solutions (waste water, unused brine, etc.) into the subsurface through holes penetrating various types of strata beneath or in the vicinity of the Plant Site has been adequately considered in the report. Again, it is wise that no such injections shall be continued if they are now not discontinued. Prior injections at somewhat below Formation pressures should have not affected the stability of the Site.

Respectfully submitted

Aureal T. Cross
March 4, 1982 (Final Revision)

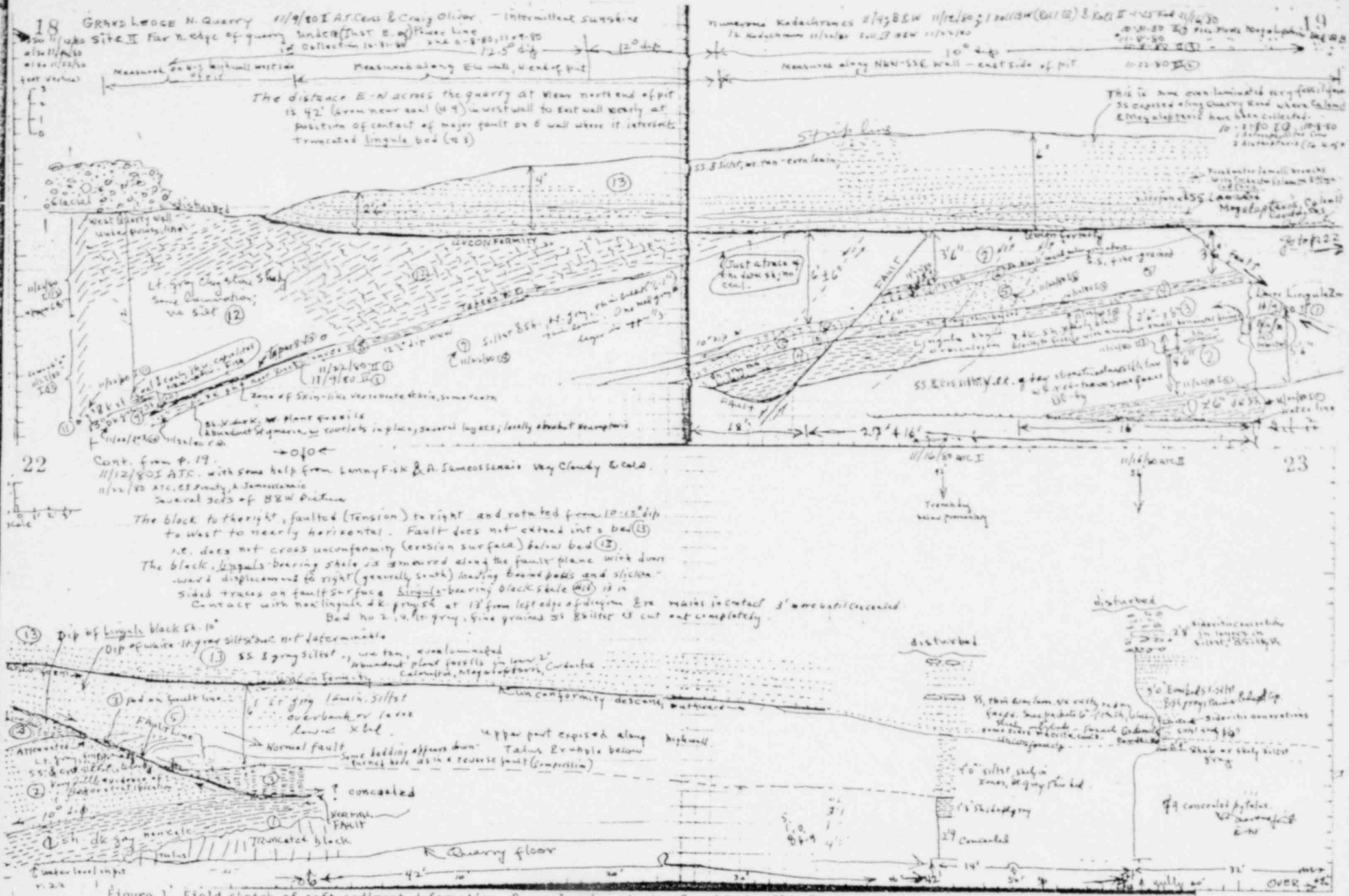

Figure 1. Field sketch of soft-sediment deformation, Pennsylvanian strata, Grand Ledge Clay Products Co. quarry, November 1980. Aureal T. Cross
(Section is continuous from left to right, p.18-19, above and p. 22-23 below. Right margin figure above overlaps slightly left edge of Figure below)