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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING APPEAL BOARD

Michael C. Farrar, Chairman
Dr. John H. Buck
Dr. Lawrence R. Quarles

In the Matter of	)	SERVED OCT 13 1977
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC. and POWER AUTHORITY OF THE STATE OF NEW YORK	)	Docket Nos. 50-3 50-247 50-286
(Indian Point, Units 1, 2 and 3)	)	

Messrs. Harry H. Voigt, Leonard M. Trosten, Patrick O'Hare and Eugene Fidell, Washington, D. C., and Mr. G. S. Peter Bergen, New York, New York, for the licensees, Consolidated Edison Company of New York and Power Authority of the State of New York.

Ms. Joyce P. Davis, New York, New York, for the licensee, Consolidated Edison Company of New York.

Mr. James L. Woods, New York, New York, for the licensee, Power Authority of the State of New York.

Messrs. John Clemente, Michael Curley and John Rosenberg, and Ms. Sandra Mitchell Caron, Albany, New York, for the New York State Atomic Energy Council.

Mr. David S. Fleischaker, Washington, D. C., for the intervenor, Citizens' Committee for Protection of the Environment.

Messrs. Joseph Gallo, Frederic Gray, Myron Karman, Thomas Bruen, Michael W. Grainey and Richard C. Browne, and Ms. Colleen Nissl for the Nuclear Regulatory Commission staff.

DECISION

October 12, 1977

(ALAB-436)

Opinion of the Board by Dr. Buck and Dr. Quarles:

This special proceeding on the seismic and geological aspects of the Indian Point nuclear reactor site near Peekskill, New York, was initiated by the Commission in its memorandum and order of August 4, 1975. CLI-75-8, 2 NRC 173. That memorandum and order was prompted by seismic and geologic questions raised during the operating license proceedings for the Indian Point 2 and Indian Point 3 nuclear reactors. The complete history of the proceeding to the date of the memorandum and order is outlined therein and need not be repeated here. See also ALAB-319, 3 NRC 188 (1976).

This Board[1/] on August 5, 1975 issued a "Notice of Public Hearing on Seismic Issues, and Order in Connection Therewith"[2/] and convened a prehearing conference on September 25, 1975 to discuss with the parties the formulation of the issues and other matters. As the result of this conference and later suggestions from the parties,

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1/ The initial Board Chairman, John B. Farmakides, left the Commission in November 1975 and was then replaced by the present chairman (see Reconstitution of Atomic Safety and Licensing Appeal Board, November 28, 1975).

2/ 40 Fed. Reg. 33498 (August 8, 1975).

we issued a prehearing conference order on October 17, 1975 setting forth the issues to be covered and outlining a schedule for discovery and submission of testimony.

The issues there stated were:

1. Does the Cape Ann earthquake of 1755, or any other historic event, require the assumption, in accordance with 10 CFR Part 100, Appendix A, of a Safe Shutdown Earthquake for the Indian Point site greater than a Modified Mercalli intensity VII?

2. Should the ground acceleration value used for the design of Indian Point Unit 1, 2 or 3 be increased?

3. Is the Ramapo fault a capable fault within the meaning of Appendix A, 10 CFR Part 100?

The 35 days of hearings on these issues commenced on April 21, 1976 and ended on July 25, 1976.

On August 27, 1976 the licensees forwarded to us "Licensees' Motion to Modify License Condition". The condition involved was contained in Amendment 2 to the Unit 3 operating license, which had been issued on April 5, 1976 just two weeks before the commencement of the hearings on the three issues. This amendment, inter alia, permitted the licensees to operate the Indian Point 3 reactor to 91% of rated power. However, section 2(C)(4) of the amendment required the

licensees to "conduct a program of geological and seismological investigations" of the Indian Point site and the Ramapo fault system. Included in this program was the requirement that the licensees expand the then existing microseismic monitoring network "southward to include the Pompton Lakes, New Jersey, epicenter area and northward to include the Fahnstock region." Amendment 2, §2(C)(4)(c).

Although the amendment was relevant to the issues in these hearings, the NRC staff neglected to inform this Board about it. We first became aware of the license condition on the last day of the hearings on the three issues when licensees' counsel brought the matter to our attention in his cross-examination of the staff on the purpose behind the requirement for an enlarged micromonitoring system.

The condition imposing the micromonitoring extension required the licensees to obtain two years of data on the expanded system by April 5, 1979. In its motion the licensees in essence requested this Board to examine the need for an enlarged monitoring system and extend the completion of the two-year investigation with such an expanded monitoring system until three years after the final Commission and judicial action on our decision.

On September 14, 1976 we stayed the installation of the new system pending our review of the problem. This allowed time for us to give the motion full consideration without requiring the licensees to take irrevocable action before we rendered a decision. On November 10, 1976 we issued a decision (Chairman Farrar dissenting) further postponing the time limits for compliance with the license conditions and calling for submission of evidence from all the parties, with the expectation that a hearing on the issue would be held early in 1977. ALAB-357, 4 NRC 542.[3/]

Six days of hearings on the expanded monitoring system were held in Bethesda, Maryland, between March 15 and March 23, 1977. Testimony was submitted by the licensees, the NRC staff and the State of New York while CCPE participated only in the cross-examination. The questions involved in this phase of the hearing are discussed in this decision as Issue 4.

For the reasons given below we find that:

3/ This decision was affirmed by the Commission in its memorandum of January 14, 1977 (CLI-77-2, 5 NRC 13).

1. In accordance with Appendix A, 10 CFR 100, neither the Cape Ann earthquake nor any other historic event requires the assumption of a Safe Shutdown Earthquake for the Indian Point site of greater than a Modified Mercalli intensity VII.

2. The ground acceleration value used for the design of Indian Point units 2 and 3 should remain at 0.15g. Indian Point unit 1 was designed for a lesser value, but the reactor is currently shut down and the fuel removed. If it should be reactivated it must be backfitted to sustain an acceleration of 0.15g.

3. The Ramapo fault is not a capable fault under Appendix A, 10 CFR Part 100.

4. The extended micromonitoring system required by §2(C)(4)(c) of Amendment 2 to the operating license of unit 3 is unnecessary and will not add to the assurance of public health and safety. The NRC staff is therefore instructed to delete that section of the license amendment requiring the enlarged monitoring system.

Additionally, in section III of Issue 1 (pp. 55-61, infra) we have specifically agreed with certain findings of fact

proposed by New York State and given our view of the need for the NRC staff to supply more definitive guidelines for the use of Appendix A to 10 CFR 100.

It will be noted that, other than for the above noted findings of fact, we have not attempted to deal specifically with any of the proposed findings submitted by the parties; but we believe we have covered the substantive subject matter of all of them in our decision.

ISSUE 1.

Does the Cape Ann earthquake of 1755, or any other historic event, require the assumption, in accordance with 10 CFR Part 100, Appendix A, of a Safe Shutdown Earthquake for the Indian Point site greater than a Modified Mercalli intensity VII?[4/]

As we have noted in our preliminary statement, questions about the adequacies of the licensees and staff review of the Indian Point site seismic issues were brought up in hearings in both the Indian Point 2 and Indian Point 3 reactors. In the present proceeding, New York State (State)[5/] continues to claim that the Indian Point facilities should be built to withstand an intensity VIII earthquake.[6/] Evidence on this issue was received during a total of 18 days of hearings from April 29 through June 11, 1976. The licensees, State and the Nuclear Regulatory

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4/ Appeal Board Prehearing Order, October 17, 1975. We note that in its Proposed Findings of Fact and Conclusions of Law dated October 15, 1976 New York State at p. vi misquotes this order by using Modified Mercalli intensity VIII in place of VII -- no doubt a true Freudian slip.

5/ The New York State intervention was made by the New York State Atomic Energy Council with principal witnesses from the New York State Geological Survey.

6/ See Charles F. Richter "Elementary Seismology" (W. F. Freeman and Company, Inc., 1958) at pp. 136-138 for a full description of the Modified Mercalli (MM) intensity scale. That scale uses a subjective description of an earthquake's effects on people, buildings and the surroundings to assign a ranking of between I and XII to the impact experienced at any particular location.

Commission staff (staff) participated fully but the Citizens Committee for the Protection of the Environment (CCPE) was excused by the Board from participation on this issue.

This issue centers upon the concepts of "tectonic provinces" and "tectonic structures", as used in Appendix A to 10 CFR Part 100 to determine the safe shutdown earthquake for a site.[7] Among other things, Appendix A states that all "historically reported earthquakes which have affected or which could reasonably be expected to have affected the site" must be listed. Id., §IV(a)(5). "The epicenters or locations of highest intensity" of those earthquakes are, where possible, to be correlated "with tectonic structures any part of which is located within 200 miles of the site"; where correlation with tectonic structures is not reasonably possible, "the epicenters shall be identified with tectonic provinces any part of which is located within 200 miles of the site". Id., §IV(a)(6). Using that information, the vibratory ground motion at the site of each earthquake is determined by assuming (1) that the epicenters of earthquakes related to a tectonic structure

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7/ For Appendix A purposes, "tectonic province" refers to "a region of the North American continent characterized by a relative consistency of the geologic structural features contained therein". A "tectonic structure" is "a large scale dislocation or distortion within the earth's crust". Appendix A, §§III(h) and (i).

are situated at the point on the structure closest to the site; (2) that the epicenters of earthquakes identified with the tectonic province in which the site is located (albeit not with structures) are located at the site; and (3) that the epicenters of earthquakes identified with other tectonic provinces are situated at the closest point to the site on the boundary of the respective tectonic provinces. Id., §V(a).

All parties agreed that some seismic events resulting in earthshocks of intensity VIII or greater had occurred in the eastern United States. State maintained that at least some of these historic earthquakes were in what it considered to be the same tectonic province as Indian Point. On the other hand the licensees and the staff, for somewhat different reasons, delineated tectonic provinces such that none of the earthquakes above intensity VII was in the province in which Indian Point is located or near enough to affect the site significantly.

I. Testimony of the Parties

We will first discuss the theories of the parties on the proper method of designating tectonic provinces, then we will examine the historic earthquakes which must be considered in making the decision of the proper value for the Safe Shutdown Earthquake (SSE) for the Indian Point facilities.

A. The Tectonic Provinces

1. Testimony of the State of New York

a. The State of New York maintained that tectonic provinces should be delineated on the basis of consistency of the style of deformation of the rocks. On this basis according to the State's witness, Dr. Hall,[8] if rocks of "two distinctly different ages that have been subjected to the same deformation, and responded to that deformation in a similar fashion, * * * those two ages of rocks would be part of one consistent regime of deformation and part of one province, the ages notwithstanding". Tr. 3309. Further explaining this understanding of tectonic provinces, Dr. Davis, New York State Geologist, emphasized that the State would consider only "first" order characteristics in describing a tectonic province.[9] He agreed, however, that such provinces could be subdivided into sub-provinces on

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8/ Dr. Leo M. Hall, Associate Professor, Department of Geology, University of Massachusetts, Amherst, Massachusetts.

9/ In using first, second and third order characteristics the State was following the terminology of Hadley and Devine (Hadley and Devine 1974 Seismotectonic Map of North America) to distinguish structural characteristics in terms of size. Dr. Davis agreed that this usage is informal and not universally accepted. Tr. 2139. The Jarvis P. Hadley and James P. Devine "Seismotectonic Map" was marked as State Exhibit 14 at Tr. 3444 and entered into evidence at Tr. 3688.

the basis of the similarity of smaller structural features. Tr. 2138-40.

Using only first order characteristics, the State would divide the eastern United States and Canada into four tectonic provinces which closely match the physiographic provinces of the area. The State's four tectonic provinces are shown in the proferred testimony[10/] of Davis, Fakundiny and Pomeroy as Exhibit 1 (following page C-25 of Appendix C), a reproduction of which is included in this decision as Figure 1 (p. 62, infra).

As can be seen from the map, the Atlantic Coastal Plain province runs northward along the coast from Florida to New York and includes those sections of Georgia, North and South Carolina, Virginia, and New Jersey east of the Appalachians. Also included are Long Island and the eastern sections of Cape Cod. The boundary north of Cape Cod is undefined but is assumed by these witnesses to be far enough off shore for the Cape Ann earthquake to be included in the Folded Appalachian province. Tr. 2220-22. The Folded Appalachian province includes the Appalachian

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10/ State Exh. 9. "Testimony of Dr. James F. Davis, Dr. Paul W. Pomeroy, and Dr. Robert F. Fakundiny (Panel) on Behalf of the New York State Atomic Energy Council on Issue I."

Mountains from northwestern Georgia north to the Canadian maritime provinces as well as the Gaspe Peninsula east of Quebec City. Starting in northern Alabama, the province includes the Blue Ridge Mountains, then narrows in the region of Harrisburg, Pennsylvania. The western border then turns northeast to the Hudson River Palisades, then north to include the Green Mountains. Thus essentially all of New England is included in this province. The line of separation between the Atlantic Coastal Plain and the Folded Appalachian provinces is not delineated north of Cape Cod. The third province identified by the State, the Appalachian Plateau, adjoins the western boundary of the Folded Appalachian province and extends from the Gulf Coastal Plain province in northern Alabama to approximately Albany, then in a northwesterly direction to the eastern tip of Lake Ontario, thence westerly to Lake Huron and south-southeast to the Gulf Coastal Plain in northern Alabama. The final tectonic province identified by the State, the Grenville province, adjoins the northern boundary of the Folded Appalachian province from Albany north. The province covers southern Ontario, most of Quebec Province and a small triangle in the U. S. between Albany, Lake Champlain and the east end of Lake Ontario.

According to the State, each of these tectonic provinces "has a distinctive set of consistent geological structural features" (N.Y. PFC,[11] p. A-5; also see State Exh. 9 at 3) and with regard to seismicity in the Folded Appalachian province "on a gross pattern there appears to be a general [seismic] density that is greater than in the contrasting areas outside of the fold belt." Tr. 2196. Later Dr. Davis did say some people divide this fold belt or province into four subprovinces (Tr. 2198), but he believes that the State's use of the overall province is "the most defensible application of the siting appendix." Tr. 2196.

b. In addition to the general testimony on its proposed tectonic provinces, the State presented four other witnesses[12] on specific phases of New England geology and seismology. Dr. Lynn R. Sykes of the Lamont-Doherty Geophysical Laboratory of Columbia University and Dr. William H. Diment of the United States Geological Survey, Menlo Park, California, presented testimony on the so-called Boston-Ottawa seismic trend and its possible

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11/ Abbreviation for New York State Proposed Findings and Conclusions.

12/ All four appeared as witnesses representing themselves and not their respective employers.

interpretations under Appendix A. Dr. Hall discussed this seismic trend in connection with a review of seismic frequency contours in the eastern United States. Dr. Charles L. Drake, a professor of geology at Dartmouth College, discussed the difficulty of applying Appendix A, given the present incomplete knowledge of tectonics.

Dr. Sykes[13/] stated that he accepts as a "working scientific hypothesis" that there is "a zone of activity in New England and adjacent parts of Canada [which] appears to be associated spatially with rocks whose age is younger than that of opening of the present Atlantic Ocean". State Exh. 7, p. 1. Both Dr. Sykes and Dr. Diment[14/] said that hypothesis has not been sufficiently proven to be used in making decisions on nuclear siting. They do agree that there is a spatial correlation between earthquake activity and a line of plutons[15/] running north through New Hampshire

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13/ State Exhibit 7, "Testimony of Dr. Lynn R. Sykes on behalf of the New York State Atomic Energy Council".

14/ State Exhibit 5, "Testimony of Dr. William H. Diment on Behalf of the New York State Atomic Energy Council on Issue I".

15/ A pluton is defined as a body of igneous rock that has been formed beneath the surface of the earth by consolidation from magma. See "Glossary of Geology," American Geological Institute, second printing, 1973, at p. 550.

from the Boston area, or perhaps even from the Kelvin seamounts in the Atlantic Ocean.

Dr. Hall[16] approached the New England seismicity on the basis of the frequency of earthquakes in various areas. By drawing iso-frequency lines about areas of seismicity,[17] Dr. Hall finds that there are three isoseismic areas: (1) one running east-northeast from New York City to eastern Connecticut, (2) a second of much higher frequency running north from Boston through New Hampshire to the White Mountains, and (3) a third running approximately east-west along the St. Lawrence River near Montreal. The latter two regions are separated by an area of very low seismicity running north-northeast through central Vermont. The witness agreed that the New Hampshire seismicity spatially correlates with the ring dike or pluton series running south from the White Mountains but does not correlate with the Monteregion Hills of Canada. State Exh. 13, pp. 6, 7. Finally, Dr. Hall concluded that while "there

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16/ State Exh. 13, "Testimony of Dr. Leo M. Hall on Behalf of the New York State Atomic Energy Council on Issue I".

17/ Seismicity as used here is frequency of earthquake occurrence regardless of size.

are many tectonic subdivisions in New England that can be made through detailed study * * * the intensely deformed and metamorphosed rocks throughout the region characterize it as a tectonic province." Id. at p. 15.

Dr. Drake's direct testimony[18] was largely limited to criticisms of Appendix A, particularly the difficulty of applying such a regulation with the incomplete knowledge of tectonics that we have today. However, under cross examination he stated that the licensees had proposed "structural provinces", i.e., "provinces in which a kind of deformation can be recognized, and that there is a continuity of this throughout this province, these are reasonable things". Tr. 2873-74.

Dr. Drake further agreed that these provinces meet the requirements of the regulatory criteria as stated by Appendix A (Tr. 2874) and that the licensees had properly outlined the present interpretation of the tectonic history of the East Coast. Tr. 2869-70. Following the trend of his direct testimony, he stated:

18/ State Exhibit 11, "Testimony of Dr. Charles L. Drake on Behalf of the New York Atomic Energy Council on Issue I".

> where I get into problems is when you start to divide the area up into specific tectonic provinces and then to associate the earthquake activity that is occurring today with these specific tectonic provinces. [Tr. 2870.]

2. Testimony of the Licensees

a. The licensees developed their primary tectonic provinces by using current plate tectonic theory together with their geologic and petrographic studies. A panel of witnesses[19] from the firm of Dames and Moore (D & M), consultants to the licensees, presented the testimony on the plate tectonics theory and its relationship to the tectonic provinces.[20]

Plate tectonics as described by these witnesses traces the motion of the African and American plates from Precambrian time (600 million years (600 m.y.)),[21] when they were joined together as one continent, to their present positions. The initial continental divergence took place during the Appalachian orogeny in late Precambrian-early Paleozoic time[22] and formed an ancient eastern boundary of the American plate.

19/ The panel consisted of Joseph A. Fischer, Matthew L. Werner, III, and Jerzy S. Szymanski.

20/ Lic. Exh. 15, "Testimony of Dames & Moore (Panel) on Behalf of Licensees on Issue No. 1".

21/ This terminology denotes 600 million years ago.

22/ For geologic time charts see, Geology, Richard M. Pearl, Barnes & Noble, 3rd ed., p. 191.

This separation of the North American and African plates eventually formed a proto-Atlantic Ocean with a long depositional trough being formed which developed an ocean crust. In mid-Ordovician time (450 m.y.), the continental motion reversed with the development of a subduction zone system -- eventually leading to a continent-continent collision. Witnesses described this collision as occurring first with the closing of the proto-Atlantic Ocean along the southern portion of the Appalachians in what is known as the Allegheny orogeny. This was followed by a translation motion or possibly localized convergence of the continents and gradual closing of the proto-Atlantic along the entire ancient coastline of the American plate.

In the late middle Triassic time (200 m.y.), the continents again separated, but well east of the original line of separation, eventually producing the North American coastline as we now know it. This divergence formed the present Atlantic Ocean, which is still widening.

It is from a detailed study of these continental motions and of the geologic formations produced that the licensees derive the basis for their tectonic provinces which are shown in Licensees' Exhibit 15, Figure 3-1.[23/]

23/ It will be noted that the licensees' tectonic province map goes southward only to 200 miles from the Indian Point site. The reasons for this are discussed at p. 27, infra.

(This plate is reproduced as Fig. 2 of this decision at p. 63). As we develop below, although Fig. 2 shows nine provinces we need make a decision on only four of them.

b. We have already noted that the original divergence of the American and African continents formed an ancient coastline along the North American continent. The later convergence and finally the continental collision (300 m.y.) resulted in an eastern belt of great anticlinoria[24] on the American continent. The eastern portion of this belt, termed the Highlands province by the licensees, is characterized by Grenvillian rocks. Lic. Exh. 15, pp. 3-3, 3-4. To the immediate west of the Highlands province is a series of tightly folded Paleozoic sediments with an absence of basement involvement. Ibid. This is classified as the Fold and Thrust Belt whose western boundary is the limit of the Paleozoic thrusting and marks the eastern boundary of the Stable Interior province. In the Stable Interior province, the intense deformation of the provinces to the east is absent. Ibid.

24/ Anticlinorium is defined as a composite upward folded structure of regional extent composed of lesser folds, the core of which contains stratigraphically older rocks. See the definitions of anticline and anticlinorium in the "Glossary of Geology", second printing 1973 (American Geological Institute), at p. 30.

Going now to the present coastline, the licensees agree with the State on the line of demarcation between the Coastal Plain province and the adjoining provinces to the west, as far north as Long Island Sound. But there agreement ceases. The licensees divide the northern part of the State's Folded Appalachian province (shown in State Exh. 9, Exhibit 1, p. C-25) into primarily four provinces (two additional sub-provinces are described in northern Vermont). See Fig. 2 at p. 63, infra.

The easternmost of these provinces, the Avalon Platform, was described by the witnesses as "crystalline continental crust which is younger than the Grenvillian orogeny". Lic. Exh. 15, pp. 3-11, 3-12. Witness Szymanski indicated that the term Avalonian referred to a specific age of the late Precambrian (approximately 600 m.y.). Tr. 2810. The western boundary of the Avalon Platform in eastern Massachusetts and northern Rhode Island is, according to the licensees' witnesses, marked by a change in magnetic signature[25/] which roughly outlines the area of the Avalonian age basement. Tr. 2812-13. On this basis

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25/ Magnetic signature is a record of the magnetism and magnetic gradients of the terrain in a given area.

the Avalon Platform boundary runs southwest from the region of Ipswich Bay, Massachusetts, to Worcester, then south near the Connecticut-Rhode Island border to Long Island Sound. It would then appear that the southern border extends eastward beyond Cape Cod and then turns northeasterly, so the Cape is within this province. The record is unclear as to the exact boundaries to the east and north of Massachusetts Bay, but witness Fischer cited the paper of Ballard and Uchupi to describe the boundaries in the Bay of Fundy area. Those boundaries are such that the Bay of Fundy earthquake (see item 6 in Table 1, p. 32, infra) location is almost midway between them. Tr. 2998-3003.

Licensees witnesses emphasized their belief that the Avalon Platform is actually a segment of the African plate left attached to the American plate following the closing of the subduction zone, and the final divergence of the two plates. They reached this conclusion not only on the basis of geologic similarity between the Avalon Platform rocks and African rocks, but also on the evidence they found in ocean floor deposits to the west of the platform. (See Lic. Exh. 15, sections 2.2 through 2.5 and Tr. 2847-48). We consider this evidence in our discussion of the licensees' provinces which lie between the Avalon Platform and the Highlands provinces.

North of Long Island and east of the New York-Connecticut border licensees proposed two tectonic provinces between the Avalon Platform and the Highlands. They call the western one the Inner Piedmont and the eastern one the Central New England. The dividing line between the two provinces runs from Long Island, northeast across Long Island Sound, and then turns north, passing just to the east of Hartford, Connecticut. It continues north and generally traces the Vermont-New Hampshire line northeastward into Canada. (See Fig. 2, p. 63, infra.) The southern boundary of the Central New England province runs east through Long Island Sound from just east of New Haven to the southwest corner of the Avalon Province and is part of the northern boundary of the Coastal Plain. Ibid.

The licensees' panel depicted the two provinces as part of a mobile belt formed in the final convergence and translational movement of the North American and African plates. The Inner Piedmont and the Central New England provinces are considered to be sedimentary areas covering part of the original North American plate and the remains of the ocean floor which was present following the initial divergence of the American and African plates. Lic. Exh. 15, sections 3.3.1 and 3.3.2.

In differentiating these provinces, licensees witnesses pointed out that (a) the Central New England province has a thick dense mafic crust and eugeosynclinal sedimentary rocks[26/] while (b) the Inner Piedmont province has a Grenvillian[27/] basement with miogeosynclinal sediments.[28/] As a result of the change in basement rock across the boundary between the two provinces there is, according to the licensees, a distinct gravity gradient in this area. Tr. 2937. The boundary line is thought to correspond to the ancient eastern margin of the American plate. Tr. 2807.

The final province near the Indian Point site proposed by the licensees panel is the Conestoga Valley province

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26/ Mafic rocks are dense, dark-colored rocks usually containing large amounts of iron. Tr. 2456. The eugeosynclinal sediments contain remnants of ocean crust. See fn. 28, below.

27/ The Grenvillian basement rocks are primarily silica and alumina. Tr. 2528.

28/ Simplistically, miogeosynclinal sediments are relatively thin sediments deposited in shallow water while eugeosynclinal sediments are thicker and deposited in deeper water. However licensees' witness Szymanski emphasized that the panel was using the term miogeosynclinal to cover sediments older than the subduction zone which existed between the continents. The miogeosynclinal deposits of the Inner Piedmont contain the great carbonate bank along the eastern edge of the province. Tr. 2447. There is no known Grenvillian crust east of the eastern boundary of the Inner Piedmont province. Lic. Exh. 15, p. 3-8.

which basically lies between the Inner Piedmont and the Highlands provinces southward from a point in mid-eastern Connecticut. The reason given for separating it from the Inner Piedmont province is, to say the least, less than clear in the licensees' written testimony. Lic. Exh. 15, pp. 3-10, 3-11. On cross-examination the licensees witnesses emphasized the extreme complexity of the structures along the line between the Inner Piedmont and Conestoga Valley provinces and stated:

> Originally we had a large province which was composed of two provinces, one was the Inner Piedmont and the other one was the Conestoga Valley and we had them together. But after we had recognized that these provinces are not characterized by uniformities in geological structures, we thought that for the purpose of this report and this proceeding it would be fair to put this line, since it divides in our judgment the two different structural domains. [Tr. 2960.]

Three remaining provinces to the north were proposed by the licensees' panel. The first is the Ottawa Basin which appears to be identical to the State's Grenville province. The remaining two are merely northeasterly extensions of the Fold and Thrust Belt and the Inner Piedmont provinces and are of not particular importance in this proceeding.

c. Another licensees witness Dr. H. James Dorman[29/] covered part of the same ground as State's witnesses Sykes, Diment and Hall, i.e., the geologic structures and seismic activity in the southern segment (New Hampshire) of the "Boston-Ottawa trend".[30/] While the State and NRC staff referred to this area as a seismic trend, Dr. Dorman proposed that, within the context of Appendix A, it be classified as the Cape Ann-New Hampshire tectonic province.

Under Board questioning (Tr. 2663-2672), Dr. Dorman outlined the approximate boundaries of this province. He did not define the boundary on the Atlantic Ocean side. The southern border passed north of Cape Cod, thence westerly beyond the 71st meridian, northwesterly to the Massachusetts-New Hampshire border, north along a line slightly east of the 72nd meridian to cover the granitic intrusive in Quebec at a latitude of about 45.5° North. The province line would then loop eastward to approximately the 71st meridian and south to the Maine-New Hampshire border, thence southeast out into the Atlantic. Tr. 2668-72; also see Fig. 2, p. 63, infra.

29/ Dr. H. James Dorman, Professor of Geophysics, University of Texas, Marine Science Institute, Galveston, Texas.

30/ Lic. Exh. 17, "Testimony of Dr. H. James Dorman on Behalf of Licensees on Issue NO. 1".

In his testimony (Lic. Exh. 17 at p. 4) Dr. Dorman testified that such a province would include:

(1) A series of granitic intrusive complexes of the White Mountains and extending offshore to the southeast; and

(2) Active faults indicated by earthquakes occurring in an area partially coextensive with the igneous complexes.

It was Dr. Dorman's contention that the province includes "the largest historic earthquakes of the northeastern U. S., including the Cape Ann earthquake of 1755 * * *". Id. at p. 5. Dr. Dorman also pointed out that this system appears to be colinear with the Kelvin Seamounts (id. at pp. 14, 15) and the Atlantic fracture zone which are probably related to a "rearrangement of the relative movement of the plates about 80 million years ago." Id. at p. 17.

d. As we have previously noted at p. 19, supra, the licensees did not develop specific provinces south of the Pennsylvania-Maryland border. It is their thesis that the northern and southern Appalachians developed differently with different alignments and stresses (Lic. Exh. 15, p. 1-5, para. 5; Tr. 3015-21) and the major earthquakes south of the Pennsylvania-Maryland border were below the transverse break line between the north and south Appalachians.

3. Testimony of the Staff

In its very brief direct testimony,[31] the NRC staff stated:

> In our review we determined that six tectonic provinces lie partially within 200 miles of the Indian Point site. These are: (1) Piedmont - New England, (2) Northern Valley and Ridge, (3) Appalachian Plateau, (4) Central Stable Region, (5) Southeastern Platform, and (6) Atlantic Coastal Plain. [Id. at p. 2]

Since no map was presented, and the province names did not match the province names used by either the State or licensees, it was necessary to develop approximate locations of the provincial boundaries used by the staff through cross examination. By this means a map showing the staff provinces was developed on a seismotectonic map by Jarvis B. Hadley and James P. Devine (1974), identified as State Exhibit 14. See Tr. 3338-40 and 3443-45 and p. 11, supra. This map is reproduced in this decision as Figure 3 (see p. 64, infra).

In a general way the staff map matches that of the State with regard to the Grenville, Appalachian Plateau,

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31/ Staff Exh. 5, "NRC Staff Testimony on Issue No. 1 and Issue No. 2"; J. C. Stepp, D. R. Budge, S. M. Coplan, R. B. McMullen, G. A. Robbins.

and the Atlantic Coastal Plain provinces. However where the State used one large province called the Folded Appalachian Province, the staff divided the area into three parts. The two westernmost regions next to the Appalachian Plateau are the Northern and Southern Valley and Ridge provinces. These are split in western Virginia and the northern province appears to coincide roughly with the licensees' Fold and Thrust Belt. Staff witness Robbins explained that the Appalachians have "a significant structural break" along a zone lying between Roanoke and the James River. Tr. 3522. The witness noted also that the region south of this break has major seismicity with thrust faulting as the dominant style of deformation, while the province north of it is virtually aseismic with folding being the dominant structural style. Tr. 3448-49.

Staff's Piedmont-New England province runs between the Atlantic Coastal Plain and the two Valley and Ridge provinces. In the north this seems to coincide with that area which licensees have split into the Highlands, Conestoga, Inner Piedmont and Central New England provinces. Finally the staff identified its Southeastern Platform province in Massachusetts and Rhode Island.

For this final province the staff explained that the United States Geological Survey (USGS) had advised it by correspondence in late 1975 that USGS considered that "the New England part of the Avalonian belt forms a tectonic province in the larger New England-Maritime Province and is called the Southeastern Platform in Massachusetts". Tr. 3472-73. As we shall see later, this area is essentially the same as the licensees' Avalon Platform province.

In addition to its determination of provinces the staff, in accordance with Appendix A, section V, designated two areas as "tectonic structures" with which seismicity is related. In its testimony the staff stated:

> (1) within the Piedmont-New England and Southeastern Platform Provinces we conclude that the 1727 southeastern New Hampshire earthquake of maximum intensity VIII, the 1755 Cape Ann, Massachusetts earthquake of maximum intensity VIII and the 1817 Woburn, Massachusetts earthquake of maximum intensity VII-VIII can be reasonably correlated with the White Mountain Intrusive Complex; and (2) within the Central Stable Region, we conclude that the 1929 Attica, New York earthquake of maximum intensity VIII can be reasonably correlated with the Clarendon-Linden structure. [Staff Exh. 5, p. 3.]

B. The Seismic Events to be Considered

In its direct testimony, the State of New York presented a list of intense earthquakes the effects of which,

under its view of the tectonic provinces, should be considered at the Indian Point site.[32] Since this list encompassed all of the earthquakes suggested for consideration by the other parties we include it in this opinion.[33]

Both the licensees and the staff objected to consideration of most of these earthquakes for one or both of two reasons: (a) the earthquake occurred in a province so far removed from Indian Point that the resultant intensity would not have been greater than MM VII at the site and (b) the intensity used by the State is too high.

All of the events listed by the State and other parties will be analyzed on the basis of our decision on the applicable tectonic provinces (see section II.B, infra).

32/ State Exh. 9, pp. B-1, B-2.
33/ See Table 1, p. 32, infra.

Table 1 */

	Date	Location	MM Intensity	Coordinates
The Atlantic Coastal Plain				
1.	1886, Aug 31	Charleston, S.C.	X	32.9°N 80.0°W
The Folded Appalachians				
1.	1638, Jun 11	Off Cape Ann, Mass.	VIII	42.5°N 69.0°W
2.	1727, Nov 9	Newbury, Mass.	VIII-IX	42.8°N 70.8°W
3.	1755, Nov 18	East of Cape Ann, Mass.	VIII	42.5°N 70.0°W
4.	1791, May 18	Connecticut	VIII	41.5°N 72.5°W
5.	1817, Oct 5	Woburn, Mass.	VII-VIII	42.5°N 71.2°W
6.	1869, Oct 22	Bay of Fundy	VIII	45.0°N 66.2°W
7.	1897, May 31	Giles Co., Virginia	VIII	37.3°N 80.7°W
The Appalachian Plateau				
1.	1929, Aug 12	Attica, N. Y.	VIII	42.9°N 78.3°W
Grenville				
1.	1663, Feb 5	St. Lawrence River	X	
2.	1732, Sep 16	St. Lawrence Valley	IX	45.5°N 73.6°W
3.	1860, Oct 17	Northeast of Quebec City-St. Lawrence Valley	VIII-IX	47.5°N 70.0°W
4.	1870, Oct 20	St. Lawrence Valley	IX	47.4°N 70.5°W
5.	1944, Sep 5	Massena, N. Y.	VIII	44.9°N 74.8°W

*/ State Exh. 9, pp. B-1, B-2; column entitled Intensity Source omitted.

II. Discussion of the Testimony

A. Tectonic Provinces

As is obvious from the testimony, the interpretations of 10 CFR 100, Appendix A, vary widely between the parties. The variations are attributable to section III(h) in which a "tectonic province" is defined as "a region of the North American Continent characterized by a relative consistency of the geologic structural features contained therein."

On the basis of our review of the entire record covering this issue, we must conclude that the approach taken by the licensees in formulating their provinces is the correct one. Our reasons for this conclusion will be outlined in the following discussion of the provinces proposed by the State, the NRC staff and the licensees.

1. The State takes the definition of "tectonic province" to mean that consideration will be given only to "first order characteristics."[34/] As a result it claims that the entire United States between the western edge of the Appalachians and the western edge of the Coastal Plain and from Alabama to the St. Lawrence River is one big province (see Fig. 1, p. 62, infra). It is inconceivable

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34/ See p. 11, supra.

to us that the formulators of Appendix A to the siting criteria intended that only first order characteristics be considered in delineating tectonic provinces. If this had been the type of province that was being considered for siting, it is reasonable to suppose that Appendix A would have said so explicitly. It is our conclusion that the licensees and NRC staff have made a proper showing that some smaller provinces are justified within the requirements of Appendix A. (See also the testimony of State's witnesses Sykes, Hall and Drake, pp. 15-18, supra.)

2. It is our opinion that the licensees, in their determination of tectonic provinces, have made the only consistent attempt to utilize a range of scientific data in their interpretation of the requirements of 10 CFR 100, Appendix A. A major basis for their approach is the present tectonic plate theory model of past movements of the American and African continents which their witnesses in this proceeding considered to represent the current "state of the art".[35/] We have summarized in section I.A.2 the currently accepted history of the two continents and the provinces

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35/ Staff witnesses also accept the hypothesis of plate tectonics (Tr. 3638) as do some of the State's witnesses (e.g., Sykes and Drake, State Exh. 7, p. 1 and Tr. 2870). On the other hand State witness Davis branded the use of the tectonic plate theory to explain the deformation of the Appalachians as "supposition and speculation." N.Y. PFC, pp. A-12 & A-13; Tr. 1810-11.

that have been proposed by the licensees. While the model which led the licensees to their selection of tectonic provinces may not be completely correct, we find the geologic evidence that they present for the differentiation between many of their provinces to be convincing. We will now discuss our reasons for accepting or rejecting the various provinces proposed by the licensees and the staff.[36/]

a. The Grenville or Ottawa basin and the Stable Interior or Appalachian Plateau Provinces

Since all parties agree on these provinces we will not discuss them further.

b. The Fold and Thrust or Valley and Ridge Provinces

The NRC staff divided its Valley and Ridge province into northern and southern sections. The boundaries the staff proposed for the Valley and Ridge province follows a 1970 map developed by Rodgers and no geologic reasons for the eastern and western boundaries were presented. Tr. 3447 and 3749. However, with respect to the boundary which separates the northern and southern sections of the province, the staff showed convincingly that in the Southern

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36/ The provinces discussed are shown on the attached maps: Fig. 1 - N. Y. State; Fig. 2 - Licensees; Fig. 3 - Staff, pp. 62, 63 and 64, respectively.

Valley and Ridge thrust faulting is the "dominant style of deformation" (Tr. 3448-49) and the province has high seismicity (Tr. 3526-27). On the other hand the Northern Valley and Ridge is primarily folded and is "virtually aseismic". Tr. 3449; 3522-23.

The licensees for their part identified the Northern Valley and Ridge (their Thrust and Fold Belt) as a series of tightly folded Paleozoic sediments with an absence of basement involvement. We have noted in section I.A.2.b, (p. 20, supra) that the western boundary of this province is the limit of the Paleozoic thrusting and marks the eastern boundary of the Stable Interior province. To the east of the Thrust and Fold Belt, however, is an area characterized by Grenvillian rocks (licensees' Highland province).

The licensees did not consider the Southern Valley and Ridge province specifically since it is their view that the geologic movement and development south of a line roughly between the 39th and 40th parallels have been entirely different from the development to the north. This view would of course split the Valley and Ridge as well as the lower Piedmont and Highland provinces at this line. Lic. Exh. 15, p. I-5 and Tr. 3014-17. State witness Drake tended to agree with this interpretation of the break between the North and South Appalachians which he considers to run from the New Jersey coast southwesterly to the western part of West Virginia. Tr. 2884-88.

We accept the Southern Valley and Ridge and Northern Valley and Ridge (or Thrust and Fold Belt) as two tectonic provinces.

c. The Highlands Province

The licensees have described this province as the eastern belt of the anticlinoria on the American continent. This zone of Grenvillian rocks is bounded on the west by the Fold and Thrust Belt and to the east by sedimentary rocks over a Grenvillian basement (as we have noted at pp. 20, 24, supra). Licensees witness Szymanski described the rock formation as being structurally different from the surrounding areas. He stated

> * * * this is an uplifted block of the basement, a block which broke through the Paleozoic cover. And since it did so, it has a very specific structural assemblage which we call up-thrusts, that is to say there are faults which bound this great anticlinoria on either side. [Tr. 3049.]

This type of consistent style of deformation of the rocks is a feature we have already discussed in connection with the separation of the Valley and Ridge area into two distinct provinces, one being primarily folded and the other characterized by thrust movements. We note also that State witness Hall, when asked what characteristics -- such as

age of rocks, basement rock types and the like -- could be used to define the boundaries of a tectonic province, answered:

> The age of the rocks involved would not, in my opinion, be an overriding concern in defining the tectonic province. I would say the overriding concern would be the consistency of the style of deformation of the rocks. [Tr. 3309.]

We conclude that the Highlands province as outlined by the licensees is a valid tectonic province.

d. Inner Piedmont, Central New England and Avalon Platform Provinces

As we have seen in section I.A.2.b. (p. 24, supra), the licensees described the Inner Piedmont province as Grenvillian basement surmounted by miogeosynclinal sediments (including the great carbonate bank). The Central New England province however was described as mafic rocks covered by eugeosynclinal sediments.

The licensees emphasized that the boundary line between the Central New England and the Inner Piedmont provinces indicates the location at which an area containing Grenvillian age rocks changes to an area which holds the "remnants of a defunct ocean." Tr. 2807. The division line or zone is indicated by a change in rock chemistry, a gravity gradient and seismic velocity changes. Tr. 2807-09.

We have noted (p. 21, supra) that crossing the line from the Central New England into the Avalon Platform province the crust changes to a "crystalline continental crust" which is younger than the Grenvillian orogeny. The boundary line chosen by the licensees is located along the change in magnetic characteristics between the crust of the Avalon Platform and that of the Central New England province.

The staff's proposed province called the Southeast Platform agrees very closely with the Avalon Platform province, the difference being that the staff chose a series of faults running closely parallel to the magnetic changes for its province boundary.

The State of New York, in its Proposed Findings of Fact and Conclusions of Law, objected strongly to the division of New England into the Inner Piedmont, Central New England and Avalon Platform provinces (N.Y. PFC, pp. A-13, A-14), referring primarily to Dr. Hall's testimony under cross-examination. Tr. 3201-07, 3308-11. In this testimony Dr. Hall objected to the use of rock age, type and stratagraphic succession to outline provincial boundaries. The State also pointed to its primary objection that the proposed provinces are based on second and third order geological characteristics. Tr. 1713-14.

We note however that the State omitted reference to much of Dr. Hall's cross examination by the licensees' counsel, and his redirect examination by State's counsel. When asked for his criteria for establishing a tectonic province, Dr. Hall replied that all of New England is characterized by rocks that have undergone intense deformation and metamorphism and that any subdivision should be based on folds and fault bounded areas. Tr. 3205-06. Furthermore, he admitted that folds and faults are not the only type of geological structure (Tr. 3213) and that there are different degrees of metamorphism, different episodes of folding and different periods of sedimentation in New England. Tr. 3210-13.

Dr. Hall also agreed that based on radiometric dating there are no Grenvillian basement rocks east of the boundary between licensees' Inner Piedmont and Central New England provinces. Tr. 3230. He agreed that this boundary line correlates with a line of Avalonian rocks similar to the rocks of the proposed Avalon Platform. Tr. 3237-38. He further stated that, under the plate tectonic theory:

> ...the bed rock geology of the Central New England province is in large part defined as the Merrimac synclinorium and the rocks that occupy that consist of a eugeosynclinal assemblage of rocks that are Ordovician through at least part of the Devonian in age and these rocks have all been subjected to intense deformation and metamorphism that presumably would have occurred at the time of closing or collision of plates. [Tr. 3238.]

Dr. Hall stated that generally these rock formations are correctly outlined in licensees exhibit 20 (Tr. 3244-45) and that one interpretation of these formations is

> ...that they may represent a portion of Africa that has been somehow sutured onto the present continental extent of North America, and the boundary that is drawn on this map that I keep erroneously referring to is the boundary that is commonly suggested as being the boundary between Avalonian type rocks and those west of the Avalonian type rocks. [Tr. 3237.]

This theory, according to Dr. Hall, is enhanced by the fact that the sedimentary rocks over the Avalonian rocks contain a fossil assemblage that is different from the assemblage of fossils that is present in the rocks of the same age in the western part of the New England area. Tr. 3314. Dr. Hall noted that:

> * * * the fossil assemblage in the overlying rocks in the vicinity of Hoppin Hill in Massachusetts and other local fossil localities in eastern Massachusetts near Boston is the assemblage that is known fairly commonly as the assemblage representative of the Atlantic fauna and the Atlantic fauna is the faunal assemblage that is found in eastern Newfoundland and in parts of Great Britain as opposed to the fauna representative of the early Paleozoic in the western part of New England which is known as the Pacific fauna. [Tr. 3314-15.]

NRC staff witnesses Budge and Robbins agreed that the USGS had defined the proposed Avalon Platform as the Southeast Platform province and had stated that "plate tectonic theory suggests that this had been a part of the African continent." Tr. 3633-34. These two witnesses however, while agreeing with the plate tectonic theory, were uncertain in their own minds that there was sufficient evidence specifically to link the Avalon Platform with the African plate. Tr. 3633-37.

Based on the weight of evidence received, we accept the geological differentiations between the three areas (Inner Piedmont, Central New England and Avalon Platform) to be adequate to classify them as three distinct tectonic provinces within the meaning of Appendix A.

e. Conestoga Valley Province and Southern Section of the Inner Piedmont Province

The Inner Piedmont province continues southwest from Long Island Sound but in this region is bordered by the Coastal Plain on the southeast and the proposed Conestoga Valley province on the northwest. In this area, the geology and the licensees' description of the reasons for two provinces become equally complex and confusing. Upon consideration of the licensees testimony (Lic. Exh. 15, pp. 3-9, 3-10) and the cross-examination by the State (Tr. 2950-67), we are inclined to agree with Dr. Werner's statement

> [s]o we have three things going on there at once, and there's no straightforward answer to anything. We have a facies transition, a zone of structural telescoping, and an area in which there has been complex overfaulting. [Tr. 2955.]

We are not convinced that the Conestoga Valley can be classified as a separate province.

While the site is within the licensees' Conestoga Valley province, we do not need to decide whether this is a separate province. The licensees witnesses first had it included as a province with the Inner Piedmont.

P. 25, supra. If we were to conclude it should have remained undivided, there would still be no earthquakes larger than the design SSE within the enlarged province. Similarly, if the Conestoga Valley province were to be a part of the Highlands province to the west, there would be no earthquake larger than the SSE within this composite province.

f. The St. Albans Thrust Belt and Vermont-Quebec Piedmont Provinces

For the purposes of this decision we need not discuss these two proposed provinces, since neither contains an earthquake larger than the SSE we have assumed for the Indian Point facilities.

g. The Cape Ann-New Hampshire Tectonic Province

The area between the White Mountains of New Hampshire and Cape Ann, Massachusetts, and its continuation seaward was extensively discussed by State, staff and licensees witnesses. While this area has been considered as part of the Boston-Ottawa seismic trend, the testimony of State's witnesses Hall and Diment, the staff panel and licensees witness Dorman[37/] tended to separate this seismic

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37/ Hall - Tr. 3262, et seq.; Diment - Tr. 1287-94; Dorman - Lic. Exh. 17, pp. 10, 11; Staff - Tr. 3410-13.

trend into two distinct areas; the southern section trending north-northwest from Cape Ann and the northern section including the Monteregion Hills running approximately east-west from Montreal.

All witnesses agreed that there is a series of igneous intrusives known as the White Mountain magma series which can be spatially correlated with the region of seismic activity in New Hampshire. Dr. Hall stated that these intrusives are somewhat older than those of the Monteregion Hills but considerably younger than the intrusions of northeastern Massachusetts. State Exh. 13, pp. 3-5. Dr. Diment called the White Mountain intrusives post-orogenic (Tr. 1303) and stated that their alignment corresponds roughly with the New England Seamounts. Tr. 1287-88.

Dr. Dorman called this zone of intrusives with the spacially associated seismicity a tectonic province since he believes this combination meets the definition of tectonic province in 10 CFR 100, Appendix A, Section III(h). Lic. Exh. 17, p. 14. The staff on the other hand believes that the series of intrusions can be called a "tectonic structure" (Appendix A, Section III(i)) to which the seismicity is related. Tr. 3410-11.

The State disagreed with both of these views. It claimed that Dr. Dorman's proposed province is inconsistent with some of those delineated by other licensees witnesses and furthermore that the Cape Ann-New Hampshire region is not characterized by "a consistency of geological structural features, as required by the siting appendix, but merely represents areas of high epicenter density". N.Y. PFC, p. A-15; State Exh. 9, pp. C-19, C-21. In the case of the staff proposal, the State insisted that even if "* * * the White Mountain intrusives satisfy the siting appendix definition of a tectonic structure, they have no relevance to the evaluation of seismic risk because no evidence has been found relating them to a causal mechanism for generating earthquakes.." N.Y. PFC, p. A-17. (But see discussion by staff witness Coplan at Tr. 3620-22.)

We also note the State's general observation (which it applies to inter alia this province) that neither the use of "neotectonics" nor of plate tectonic theory "for the purpose of establishing tectonic provinces" is provided for in Appendix A. N.Y. PFC, p. A-12. (However, see the discussion on this point by licensees witnesses at Tr. 3054-56.) It further asserted that the use of plate tectonic

history,"especially the concepts of initial divergence, convergence, translation and final divergence" by Dames and Moore is pure speculation. N.Y. PFC, pp. A-12, A-13. (See also State witnesses' comments at Tr. 1810-11.)

Considering first the State's general objections to "neotectonics" and "the plate tectonic theory" we find that we must reject both of its claims. Neotectonics is defined as "the study of the last structures and structural history of the Earth's crust, after the Miocene and during the late Tertiary and the Quaternary,"[38/] -- i.e., the most recent 25 million years of the earth's history. The State has given no reason for ignoring this period of the earth's history and we know of none.

With regard to plate tectonics we acknowledge that every facet of this theory is not scientifically proven but it is recognized by the large majority of the witnesses in this case (including three of the State's witnesses) as the "state of the art." We find nothing in Appendix A that prohibits us from utilizing the latest accepted geologic developments in making determinations of tectonic provinces.

38/ Glossary of Geology, American Geological Institute; second printing, 1973, at p. 477.

With regard to whether the Cape Ann-New Hampshire area may be considered as containing either a tectonic province or a tectonic structure, in our opinion the answer is yes. The evidence is clear that the intrusives stretching south from Mt. Megantic through New Hampshire and out into Massachusetts Bay are all of similar age, shape and magnetic signature. It must be assumed therefore that they were produced by the same type of mechanism.[39/] We need not here decide what that mechanism was -- e.g., a transform fault or a crustal weakness. What is evident is that we have in the region "a large scale dislocation or distortion within the earth's crust" -- hence a "tectonic structure" as defined in Appendix A. Similarly we have "a region -- characterized by a relative consistency of geologic structural features" or a "tectonic province." While the choice between the two makes no difference in the final result, we favor the designation of the area as the New Hampshire-Cape Ann province[40/] which would then

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39/ We note that we do not include in this series of intrusives the older intrusives of eastern Massachusetts which were formed about 275 million years before the New Hampshire intrusives. (See Hall testimony, State Exh. 13, pp. 3, 4).

40/ We have outlined the boundary of this province, as described by Dr. Dorman, by a dashed line on Fig. 2 (p. 63, infra).

for our purposes cut through the older Central New England and Avalon Platform provinces as a separate entity.

B. Seismic Events to be Considered

We must now decide whether any of the list of intense earthquakes presented by the State of New York could, under 10 CFR 100, Appendix A, be considered as affecting the Indian Point site at a greater than intensity VII level. We will consider each of the earthquakes listed in Table 1 (on page 32, supra) in terms of their relationship to the tectonic provinces and structures that we have accepted in II.A.

1. Charleston, S. C., August 31, 1886.

Both the State and the licensees[41/] agree that this intensity X earthquake is related to a specific structure. State Exh. 9 at C-3; Lic. Exh. 15 at 4-6, 4-7. We agree and, since this structure is more than 200 miles from the site, it need not be considered. 10 CFR 100, Appendix A, Section IV(a)(6).

2. Off Cape Ann, Massachusetts, June 11, 1638.

Neither the State nor the licensees[42/] believe that this earthquake need be seriously considered because

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41/ We have found no comment by the staff on this earthquake.
42/ We have found no comment from the staff on this event.

of both doubtful location[43] and uncertain intensity. We agree with this assessment. Furthermore, it is located in a province separated from Indian Point by two intervening provinces.

3. Newbury, Massachusetts, November 9, 1727.

While there is some disagreement among the parties as to the actual intensity of this earthquake,[44] there is agreement as to its location. The epicenter is within the boundaries of the Cape Ann-New Hampshire province which we have accepted. Since the nearest boundary of this province is nearly 200 miles from the Indian Point

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43/ Location was more probably in the St. Lawrence River Valley. This location change has been proposed by the Dominion Observatory of Canada as a result of recent new studies of this earthquake. Tr. 3530-31.

44/ The earthquake is listed as VIII-IX by the State but witnesses for all parties agreed that it should be no higher than an VIII and perhaps only a VII (State - Tr. 1870-75; Staff - Tr. 3350; Licensee - Lic. Exh. 15, p. 4-4). We agree with the State that a single analysis by the Weston Geophysical (accurate though it may be) lowering this intensity to VII should not be accepted without thorough review. It is evident however that the intensities of many of the older earthquakes are probably overstated and are perhaps more hysterical than historical. It would seem that in this case a review of the Weston analyses by the State geologic group might have sufficed to settle the argument insofar as this proceeding was concerned. We will, for the purposes of this proceeding, consider it an intensity VIII event.

facilities a similar event will not cause an intensity higher than MM VII at that site.

4. East of Cape Ann, Massachusetts, November 18, 1755.

All parties agree that this was probably an intensity VIII event. Since there is some uncertainty as to its exact location, although somewhere in Massachusetts Bay offshore of Cape Ann, the earthquake may have occurred in either the Cape Ann-New Hampshire or the Avalon Platform province. In either case, since the closest point of the boundary of the nearest of these two provinces is over 100 miles from the Indian Point facility, an intensity VIII event would be attenuated to no more than an intensity VII at the site.45/

5. East Haddam, Connecticut, May 18, 1791.

The State originally rated this earthquake as an intensity VIII event on the basis of its rating in the publication "Earthquake History of the United States." However, on the basis of a Weston Geophysical report of 1964 the publication is now revising the intensity rating to a VII. Tr. 1877, 3341-42. Since all parties now agree to the intensity VII rating, the design of the Indian Point facilities will be unaffected by consideration of this earthquake.

45/ See, for example, TID 7024, "Nuclear Reactors and Earthquakes," T. H. Thomas, et al., August 1963, pp. 15-17.

6. Woburn, Massachusetts, October 5, 1817.

Here again we have some dispute over the intensity of this event but all parties agree that intensity VIII is probably too high. Tr. 1931, 2995-96, 3350-51. While this earthquake appears to have occurred within either the Avalon or Cape Ann-New Hampshire Provinces the location data are not precise enough to say this with certainty. To be conservative we therefore consider the event as having been within the Central New England province. In this case Appendix A requires that the event be considered at the nearest point of the Central New England province to the site or a distance of approximately seventy-five miles from Indian Point. It would therefore present no more than an intensity VII at the site location.[46/]

7. Bay of Fundy, October 22, 1869.

This earthquake was originally assigned an intensity VIII by Smith "Earthquakes of Eastern Canada and Adjacent Areas 1534-1927."[47/] Both the staff and the

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46/ New York State has agreed that since it assumes this earthquake to be intensity VII-VIII it does not consider it to be a controlling event for the Indian Point site. Tr. 1931.

47/ Publications of the Dominion Observatory, V. 32, No. 3, Ottawa (1962). (See State Exh. 9, pp. B-1, B-2).

licensees have been informed by the Dominion Observatory that it has reviewed this event and now rates it as intensity VI and considers it to have been located in New Brunswick rather than the Bay of Fundy. Tr. 3345-46.

While the State insists that this has not been reviewed by the "scientific community" we are of the opinion that a revision by a responsible government agency of its own work must be viewed in a different light than a revision proposed by a private company. We accept the revision of intensity value and location and drop the event from further consideration.

8. Giles County, Virginia, May 31, 1897.

All parties agreed that this was an intensity VIII event. The State considered both the earthquake and the Indian Point site to be in its proposed folded Appalachian Province and therefore argued that the nuclear facilities should be designed for an MM VIII intensity level.

The staff, however, presented convincing detailed evidence that the earthquake occurred in its proposed Southern Valley and Ridge province. Tr. 3347, 3447-48, 3520. This evidence supported the general picture of a

distinct separation between the North and South Appalachians presented by the licensee (Lic. Exh. 15, p. 1-5 and Tr. 3-15-17) and State witness Drake (Tr. 2884-88).

We have accepted the Southern Valley and Ridge province (or Southern Fold and Thrust province). Thus under Appendix A an earthquake equivalent to the Giles County event need be considered as being no closer than about 350 miles from the Indian Point site.

9. Attica, N. Y., August 12, 1929.

All parties have agreed that this earthquake was near the western end of Lake Ontario, more than 200 miles from the site, and in a different tectonic province than that in which the Indian Point site is located. Furthermore all agree that the event can be reasonably linked with the Clarendon-Linden structure. Staff Exh. 5, p. 3; State Exh. 9, p. C-3; Lic. Exh. 15, pp. 4-5, 4-6. We find no reason to consider it further.

10. Grenville Province Earthquakes, February 5, 1663; September 16, 1732; October 17, 1860; October 20, 1870 and September 5, 1944.

All parties agree that these earthquakes were located in the Grenville province. All parties are in

agreement on this province (see Figs. 1, 2, 3) and the fact that its nearest point of approach to the Indian Point site is approximately 200 miles.

Under these conditions any of the listed earthquakes in the Grenville province will be attenuated to a level of VII or less at the Indian Point facilities.

Conclusion

For all of the above reasons we must conclude that none of the earthquakes listed by the State requires an assumption of more than an MM VII intensity at the Indian Point site.

III. Additional Remarks

Included in the Findings of Fact of New York State were the following three items:

> 10. Determination of seismic risk in the eastern United States through the analysis of regional geologic structures and the delineation of tectonic provinces is difficult, because of lack of knowledge about causal mechanisms of earthquakes and because the analysis of modern seismicity in relation to geologic structure does not generate a tectonic province map, but rather a seismotectonic map.

> 11. The NRC has not promulgated an official tectonic province map of the eastern United States.
>
> 12. The NRC Staff has accepted differing sets of tectonic provinces for New England in licensing proceedings for other power plant sites.

State PFC at p. A-3 (references omitted).

These statements are correct and focus on some of the major difficulties that this Board faced in reaching its decision on the selection of tectonic provinces. We believe that further discussion is therefore warranted.

During the course of the hearing on this issue this Board questioned witnesses for all parties on their theories, methodology and criteria for making their decisions on the location and size of tectonic provinces. The State and licensees both presented detailed maps and discussion of their approaches. Only the NRC staff failed to develop its own map of the provinces it was proposing, even though it was requested to do so by the Board. Tr. 3337-40. During cross examination, staff witnesses were able to draw, in rough outline, their proposed provinces on a copy of a Hadley and Devine map supplied by the State.[48/]

48/ This map was entered into evidence as State Exh. 14 (Tr. 3444, 3688). It is presented here as Fig. 3 on p. 64, infra.

In answer to a question by New York State counsel as to why such a map had not been promulgated by the NRC staff, witness Stepp replied:

> I will repeat my answer of earlier today and say that we have given this matter of tectonic provinces endless thought and consideration during the past two and a half to three years and we have discussed it with virtually everyone who has any contact with nuclear power plant siting including our advisors in the USGS who have worked with us on site to site bases and our advisory committee that is formed of the USGS people.
>
> Now we have been advised that it is not now timely on the basis of the data that we have available to us to establish an official tectonic province map that would be used for making -- that would be used in a nondiscretionary way in making decisions about seismic design. We have instead undertaken a very extensive program of obtaining -- to obtain the data that are needed by all of those people who are involved in this program in order to be able to make a decision about such a map.

Tr. 3475-76.

Later Dr. Stepp stated that presently the staff is "simply generally defining the tectonic provinces as defined by King, Rodgers and Hadley and Devine * * * this is the general concept that we would follow, as an illustration". Tr. 3746. However, when being questioned by the Board about the purpose of the Rodgers, et al. maps, the following series of questions and answers took place:

(Q.) And my concern is that Rodgers or Hadley-Devine and King, were those maps really drawn with the knowledge of the distribution of epicenters in mind?

A. Obviously the Rodgers and King maps were not, and were drawn for a completely different reason with no thought whatever of the occurrence of earthquakes.

Q. That becomes a problem, Dr. Stepp, in that okay, here you're saying in the guidelines for applications and so on for seismic that you're basically relying on these two maps, and yet those two maps were not drawn with the purpose in mind that the NRC requires for provinces.

A. That's right. They were not.

Q. So, you know, where does that leave us? Confused or otherwise?

A. Well, I can tell you where it leaves the Staff in trying to make our decisions. It leaves us generally recognizing that the province -- the generalized province concepts that we use are not consistent with what I would interpret to be the intent of Appendix A in defining tectonic provinces.

It leaves us without a set of provinces that I believe might be considered to be consistent with the meaning and intent of Part 100.

Tr. 3749.

We contrast this uncertainty on the part of the staff with the requirement which the same staff places on applicants with regard to what must be shown in the application

for a construction permit. The Standard Review Plan[49/] states, in Section 2.5.2 (entitled Vibratory Ground Motion), subsection 2.5.2.2 (Geologic and Tectonic Characteristics of Site and Region), that:

> The applicant's presentation is accepted when all regional geologic structures and tectonic activity which are significant in determining the earthquake potential of the region are identified. Information presented in Section 2.5.1 of the applicant's safety analysis report (SAR) and information from other literature sources (e.g., Refs. 8, 9, 10, 11, 12) dealing with regional tectonics should be developed into a coherent, well-documented discussion to be used as the basis for determining tectonic provinces and the earthquake-generating potential of the identified geologic structures. * * * In addition, in those areas where there are capable faults, the results of the additional investigative requirements described in 10 CFR Part 100, Appendix A, Section IV(a)(8), must be presented. The discussion should be augmented by a regional-scale map showing the tectonic provinces, earthquake epicenters, locations of geologic structures and other features which characterize the provinces, and the locations of any capable faults.

In view of the staff's uncertainty concerning the definition of tectonic provinces, expressed in the testimony quoted above, we find it difficult to determine the basis on which the staff can evaluate the applicants' response.

49/ NUREG-75/087, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," September, 1975.

It was obvious from the staff panel's comments during this proceeding that the members of this panel could draw their own set of guideline provinces but the NRC advisory committee on geology (composed of USGS employees) has advised against doing so. Dr. Stepp stated that insofar as he knows "the advice that the U.S.G.S. has given this agency has never been modified. I don't think that there is any policy that says the U.S.G.S. is running the show, but in reality their advice has always been followed". Tr. 3752. We are thus faced with the situation where the USGS which had a major role in developing Appendix A (Tr. 3778) nevertheless has expressed the belief "that the Appendix would be extremely difficult to apply and would lead to a lot of confusion in the assigning of tectonic provinces." Tr. 3778-79.

In this situation, we believe that having accepted the USGS concept of tectonic province the NRC staff must now do its "own thing," i.e., decide, on its own, the criteria to be applied and how the regulation is to be enforced. In this proceeding we received little assistance from the staff witnesses in deciding whether the State or the licensees had the correct concept of the tectonic province requirement of Appendix A because they

are apparently required to implement USGS recommendations without question. Thus, while the staff witnesses have the necessary expertise, it seems that management support for utilization of this expertise is lacking. In our opinion it is essential for the NRC to decide whether the tectonic province concept is viable and, if so, it should issue the requisite guidelines for the acceptability of such provinces at the earliest possible moment.

This Board appreciates the effort of New York State in helping to bring this problem to light.

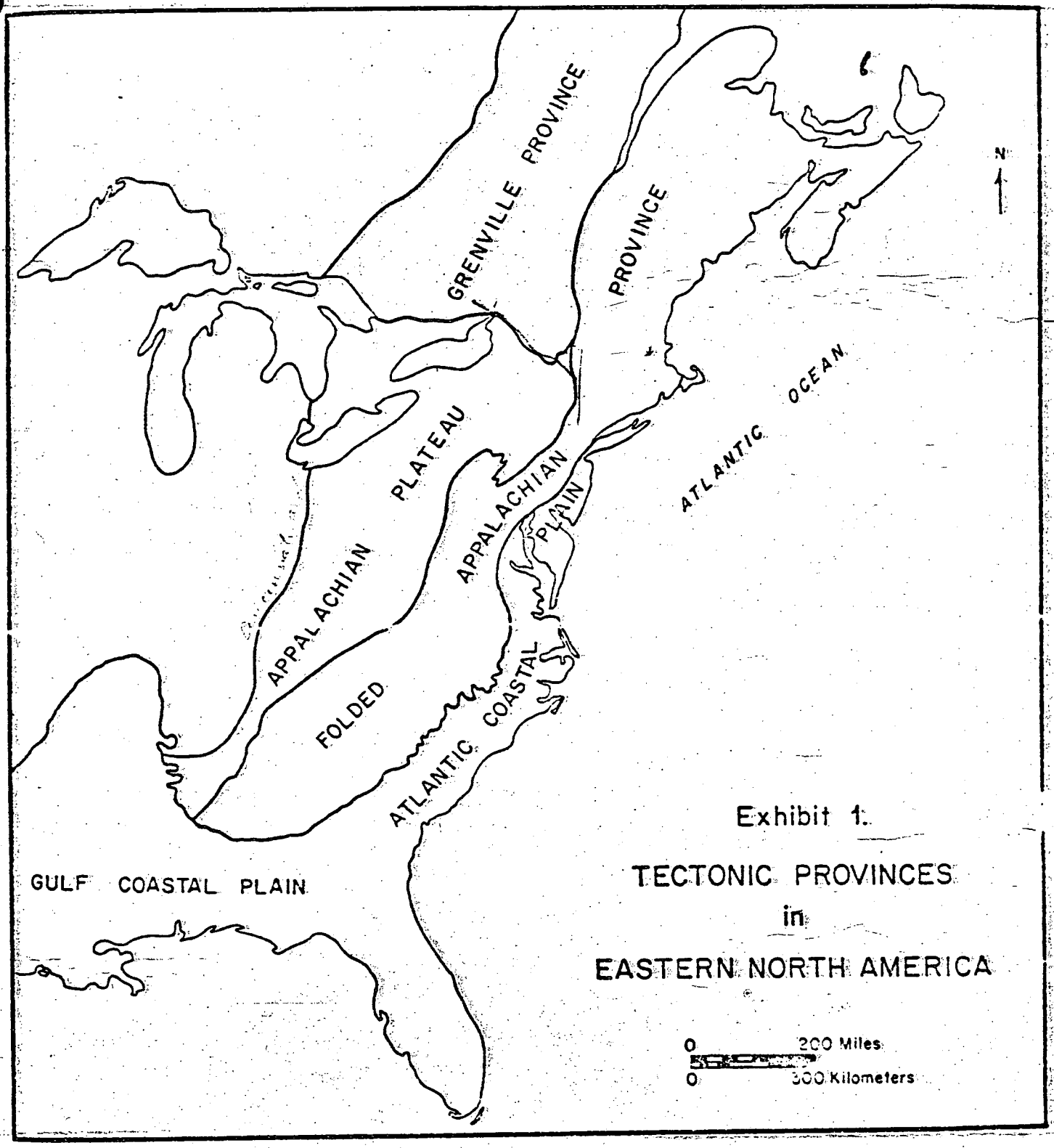

GRENVILLE PROVINCE
PROVINCE
N
ATLANTIC OCEAN
PLATEAU
APPALACHIAN
APPALACHIAN
PLAIN
FOLDED
ATLANTIC COASTAL
GULF COASTAL PLAIN
Exhibit 1.
TECTONIC PROVINCES
in
EASTERN NORTH AMERICA
0 200 Miles
0 300 Kilometers

Fig. 1

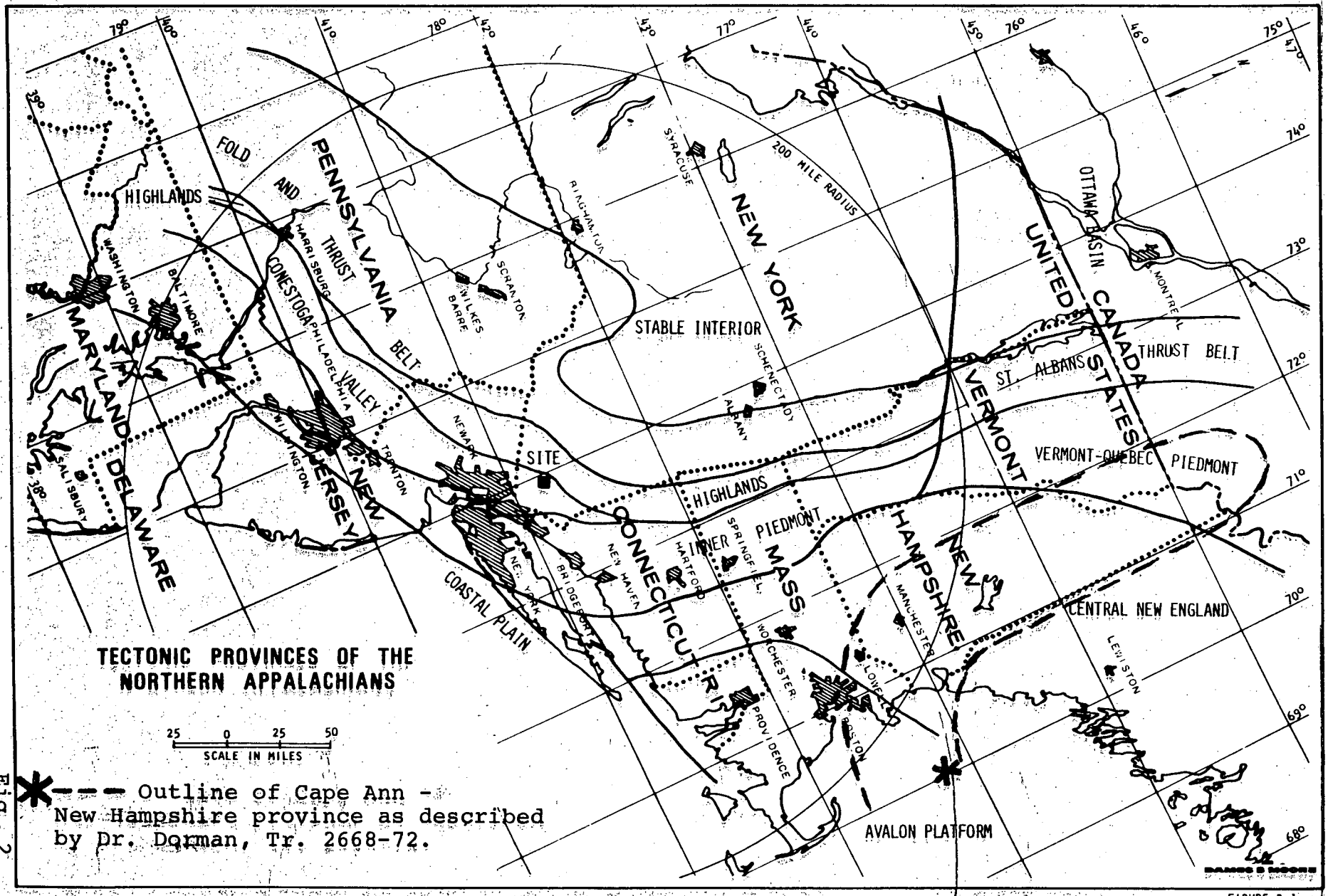
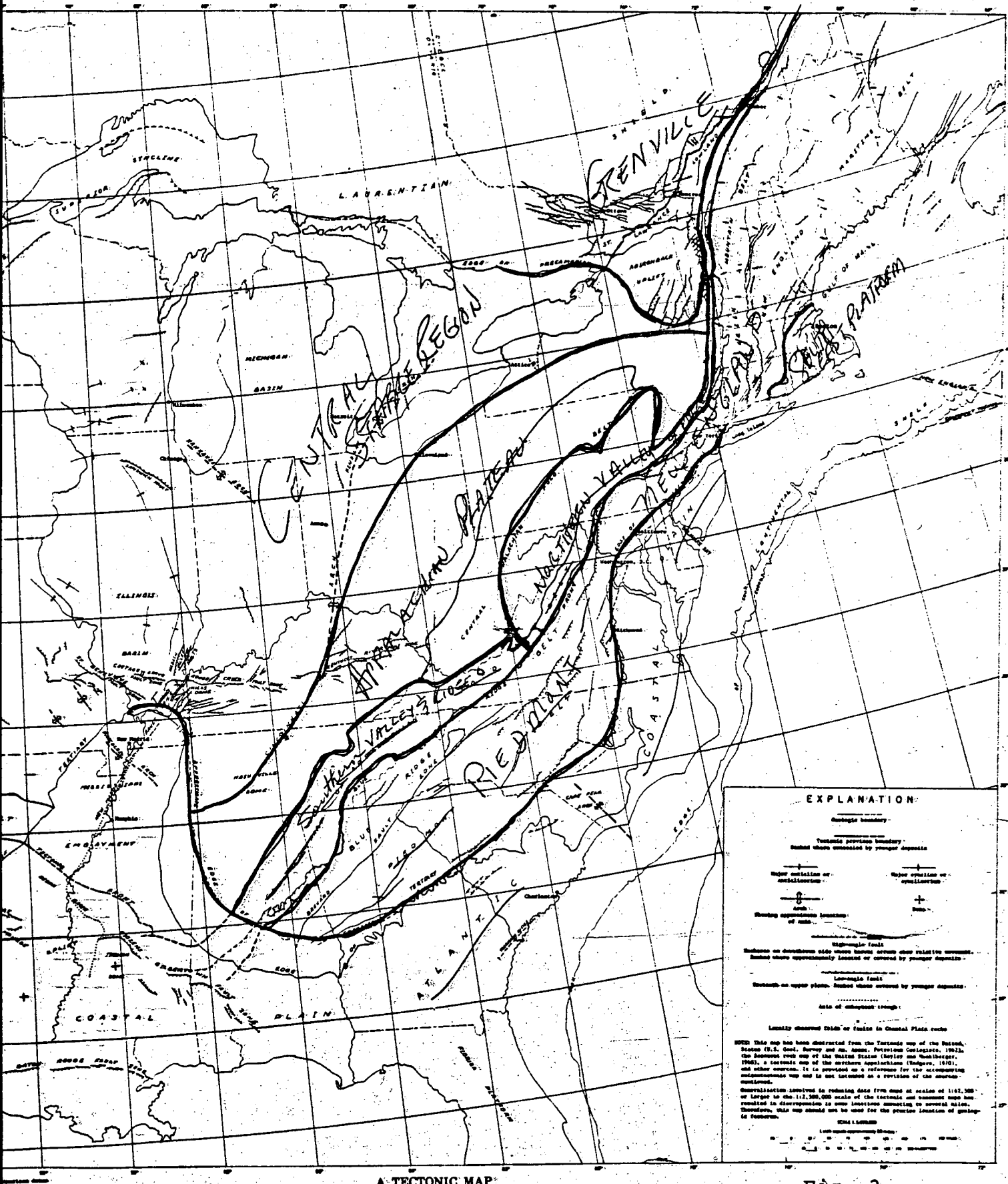

TECTONIC PROVINCES OF THE NORTHERN APPALACHIANS
FOLD AND THRUST BELT
PENNSYLVANIA
MARYLAND
DELAWARE
NEW JERSEY
HIGHLANDS
VALLEY AND RIDGE
COASTAL PLAIN
STABLE INTERIOR
NEW YORK
CONNECTICUT
MASS
VERMONT
NEW HAMPSHIRE
UNITED STATES
CANADA
OTTAWA BASIN
ST. ALBANS
THRUST BELT
VERMONT-QUEBEC PIEDMONT
INNER PIEDMONT
CENTRAL NEW ENGLAND
AVALON PLATFORM
200 MILE RADIUS
SITE
SYRACUSE
SCRANTON
WILKES BARRE
HARRISBURG
PHILADELPHIA
BALTIMORE
WASHINGTON
TRENTON
NEWARK
ALBANY
SCHENECTADY
MONTREAL
SPRINGFIELD
HARTFORD
NEW HAVEN
BRIDGEPORT
NEW YORK
WORCHESTER
PROVIDENCE
BOSTON
MANCHESTER
LOWELL
LEWISTON
SALISBURY
WILMINGTON
25 0 25 50
SCALE IN MILES
Outline of Cape Ann - New Hampshire province as described by Dr. Dorman, Tr. 2668-72.
DAMES & MOORE
FIGURE 3-1

Fig. 2

PREPARED IN COOPERATION WITH
THE U.S. ATOMIC ENERGY COMMISSION

MISCELLANEOUS FIELD STUDIES
MAP MF-620
(SHEET 1 OF 3)



A, TECTONIC MAP

Fig. 3

SEISMOTECTONIC MAP OF THE EASTERN UNITED STATES

By

Jarvis B. Hadley and James F. Devine

1974

ISSUE 2.

Should the ground acceleration value used for the design of Indian Point Unit 1, 2, or 3 be increased?

In the Safety Evaluation Report for Indian Point Nuclear Generating Station Unit 3 the staff concluded (at pp. 3-5, 3-6) that the licensees' decision to use a horizontal ground acceleration of 0.15g for the safe shutdown earthquake was acceptable. This conclusion was based on a maximum probable earthquake intensity of MM VII at the site. Intervenor CCPE objects to this determination and insists that a horizontal acceleration value of 0.20g be used for intensity VII and 0.40g for intensity VIII. Six full days of hearings (April 21-23 and 26-28, 1976) were used to cover this issue. Since we have found in Issue 1 that an intensity VII is the maximum intensity to be considered for the Indian Point site we will limit our discussion to that level.

It is recognized that the ground acceleration at a given site as the result of an earthquake depends, inter alia, upon the intensity of the shock at that particular location. However, as the State of New York noted in its testimony:[50/]

50/ State Exh. 1, "Testimony of Dr. James F. Davis, Dr. Paul W. Pomeroy, and Dr. Robert H. Fakundiny (Panel) on Behalf of the New York State Atomic Energy Council on Issue II".

> Intensity of ground motion as reported at a given distance from the earthquake source, is a highly subjective quantity and any relationship between intensity and acceleration must be considered to have significant uncertainty associated with it. Furthermore, intensities of historic earthquakes (such as the Cape Ann earthquake of 1755) have been assigned relatively recently based on historical accounts. Thus a second order of subjectivity is present in the intensity values for most historic earthquakes.
>
> Only well documented relationships between intensity and acceleration should be used to determine the assymptotic acceleration value for a design response spectrum.

State Exh. 1, p. 1.

In their testimony[51] the licensees utilized the intensity-acceleration relationship developed by Coulter, Waldron and Devine of the United States Geological Survey.[52] The other parties (the State, CCPE, the NRC staff) all used the relationship developed by Trifunac and Brady.[53] While

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51/ Lic. Exh. 2., Dames and Moore Report: "Evaluation of Ground Acceleration for the Indian Point Site," March 15, 1976.

52/ H. W. Coulter, H. H. Waldron and J. F. Devine, "Seismic and Geologic Siting Considerations for Nuclear Facilities," Fifth World Conference on Earthquake Engineering; Rome, Italy, 1973. (Lic. Exh. 2, pp. 4-6).

53/ Presented in a series of papers included in testimony of CCPE witness Dr. Mihailo Trifunac, Assistant Professor of Applied Science, California Institute of Technology. (See CCPE Exh. 1 and 2, "Testimony of Dr. Mihailo D. Trifunac -- Estimating Peak Accelerations in Terms of the Modified Mercalli Intensity Scale" and Staff Exh. 5, "NRC Staff Testimony on Issue No. 1 and No. 2".)

there was considerable discussion during the hearings about the value of each of these sets of relationships, their ultimate conclusions are very similar.

We will first briefly outline the differences in the correlation between intensity and acceleration as developed by Coulter, Waldron and Devine and that of Trifunac and Brady. We will then discuss the application of such relationships to the Indian Point units 2 and 3, followed by a brief review of the requirements for unit 1.

1. The principal difference between the Coulter, Waldron, Devine (Coulter) and the Trifunac and Brady (Trifunac) correlations is that the raw data for much of the Coulter material is not publicly available and thus has not been subjected to the normal peer review process, while the Trifunac material has been published. The Coulter correlation data were presented at the Fifth World Conference on Earthquake Engineering, but the backup material was not nor has it been made generally available. Witness Pomeroy for the State had been unable to obtain the information from the authors (Tr. 651) but licensees witness Fischer had seen enough of the data in private meetings to convince him of the reliability of the conclusions. Tr. 773.

If there were, in fact, large differences in the conclusions to be drawn from the two sets of data we might be constrained to investigate the matter further. However, all parties agree that the two correlations are the most up-to-date and are better than any other available information. With this in mind, since the Trifunac and Brady data appear to be the most fully documented, we will for our purposes consider only their relationship between intensity and acceleration.54/

2. The major difference between CCPE and the other parties is on the conservatism that should be used in the application of Trifunac and Brady data to the Indian Point reactors. If these data are used, the licensees, NRC staff and the State all agree that the acceleration at the site for an intensity VII earthquake should be the mean of all the acceleration peaks measured by Trifunac and Brady for such intensity earthquakes.55/ All three of these parties consider this to be suitably conservative because the peaks utilized include the high frequencies representative of near field conditions. As witness Fischer explained,

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54/ This of course does not imply that the Trifunac-Brady correlation is technically superior to that of Coulter, Waldron and Devine.

55/ Staff Exh. 5, p. 5; State Exh. 1, p. 1; Lic. Exh. 2, pp. 8-9.

these peaks have little significance in establishing the level of response spectra, yet they produce a much higher mean amplitude. He pointed out that even a building as poorly constructed as an adobe hut would not be affected by the high frequency, because "[t]he high frequency spike carries so little energy and is over so fast * * *". Tr. 800. As an example, Mr. Fischer noted

> ...there's a barn out in California that housed a seismograph where the acceleration peak reached -- I think it was roughly 60 percent g and the barn is still there and the instrument is still there and the barn could in no way be considered an earthquake resistant design structure. [Tr. 800.]

However, Dr. Mihailo D. Trifunac, a witness for CCPE, contended that use of the mean of the peak accelerations may not be conservative enough. He pointed out that his correlation is based primarily on West Coast data and there is evidence to show that "the attenuation of high frequency waves in the East [of the United States] is considerably smaller than that in the West."[56/] CCPE Exh. 1, p. 7.

56/ It would appear that such a lower attenuation of the high frequencies would result only in a slightly larger distance at which the near field high frequencies would be important.

On this basis, he recommended that the correlation between intensity and acceleration be made on the basis of the average of the peak accelerations "plus one standard deviation of all the peak amplitudes". Id. at pp. 4-5. For an intensity VII earthquake this would result in designing the facilities at Indian Point to withstand a 0.20g acceleration instead of the 0.13g calculated on the basis of the mean of the acceleration peaks only.

In his testimony, Dr. Trifunac asserted that soil condition may be a factor in the degree of damage to be expected (Tr. 321) and that:

> Contrary to the frequently stated opinion that alluvium layers amplify strong-motion acceleration at certain "predominant" frequencies, the data studied in this paper show that on the average peaks recorded on hard rock may be higher, but not significantly, than the peaks recorded on alluvium. This is in accord with our previous study (17) where we demonstrated that for a given Modified Mercalli intensity level peak accelerations reached on a hard rock site are on the average higher than the same recorded on alluvium. [CCPE Exh. 2, App. C, p. 51.]

But he appeared to agree with Mr. Fischer on the significance of high frequency peaks when he stated:

> Finally, it should be pointed out here that, from the practical earthquake engineering point of view, high acceleration amplitudes should not necessarily be associated with a proportionally

> higher destructive potential. An extended duration (19) of strong ground motion and high acceleration amplitudes characterize destructive earthquake shaking, while one or several high-frequency high-acceleration peaks may, in fact, constitute only minor excitation because of the short duration involved and may lead to only moderate or small impulses when applied to a structural system. [Ibid.]

Dr. Trifunac admitted that he had no personal knowledge of the Indian Point site or the design of the Indian Point reactors and that his testimony was concerned with a generic estimate of peak accelerations in terms of the Modified Mercalli scale without reference to Indian Point. Tr. 332.

On the basis of all of the testimony discussed above, we must conclude that the approach taken by Dr. Trifunac is unnecessarily conservative for the Indian Point site. It is our opinion that, given the current state-of-the-art in this area, use of the correlation of the mean of the peak accelerations with the Modified Mercalli intensity scale as suggested by the licensees, the staff and the State is a reasonable method of applying the data. This requires that the Indian Point reactors be designed to withstand a horizontal acceleration of 0.13g. In actuality the Indian Point units 2 and 3 are designed to withstand a 0.15g so that there is more than adequate assurance that

the health and safety of the public will be protected insofar as the Indian Point nuclear reactors are concerned.

However, we do not mean to imply that further study of this question is not desirable. The opinion we have expressed is based upon our understanding of the seismic design procedure used by the staff in this connection. This procedure includes conservatisms at various stages of the process as pointed out by staff witnesses Stepp and Coplan (Tr. 1159-61) and licensees witness Fischer. Tr. 1011-14. One part of this process is the selection of the appropriate value of acceleration to be used as the "anchor" point (zero period limit) for the design response spectrum. For this purpose the staff obtains the average peak value for a given intensity by using the maximum peak acceleration from each of the individual accelerograms resulting from events of that intensity. Tr. 1166-68. Dr. Trifunac appeared to indicate during cross-examination that the procedure he used in his studies was the same as that used by the staff. Tr. 290. However, questions were raised regarding what is believed to be unnecessary conservatism in this approach.

Licensees witness Fischer suggested that use of other parameters might produce better correlations of intensity

with earthquake damage. Tr. 1008-17. Specifically, Mr. Fischer stated:

> [w]hat I have tried to indicate is that there are other, and I believe better ways of attempting to correlate damage than merely peak accelerations. Peak accelerations have little to no significance in building design.
>
> What would be better correlation is perhaps velocity or something that would be considered a sustained level of acceleration.

Tr. 1008-09.

Mr. Fischer had earlier suggested that a more appropriate parameter for correlation with intensities might be the "sustained" or "effective" acceleration of a given record as suggested, e.g., by Ploessel and Slossen in a note entitled "Repeatable High Ground Accelerations". Tr. 828-29; see also Tr. 584-94. Such a correlation (based on "sustained" acceleration) would appear, on its face, to be less conservative than the procedure currently used by the staff and licensees. It would, nonetheless, be desirable for the staff to provide a more quantitative assessment of its current methods. This perhaps should include an evaluation of the frequency spectrum associated with the individual peak acceleration associated with each record using, for example, a Fourier type analysis. (This should indicate the level of the damaging accelerations involved.) However,

a complete quantitative assessment can be properly carried out only through parallel consideration of all of the factors involved in selecting and applying acceleration values. These factors would include safety margins related to the structural engineering evaluations. Dr. Trifunac agreed that, in choosing the design acceleration value selected for a nuclear plant one must "consider numerous factors". Tr. 600-02.

3. We face a different situation with respect to Indian Point unit 1. This plant was built prior to any specific requirement for earthquake protection and is not designed to withstand a 0.15g acceleration. At present the plant is inoperative. If it is to be operated again, changes will have to be made so that it can withstand an intensity VII earthquake.

Indian Point unit 1, however, does have a fuel storage pool containing fuel and intervenor CCPE questioned whether the pool and stored fuel support structure would withstand such an earthquake. Licensees presented William Cahill, a vice president of Consolidated Edison, as a witness on this matter. Under cross-examination by CCPE counsel, the witness demonstrated convincingly that the pool and accessories as designed and built have adequate engineering

safety factors to withstand an acceleration of 0.15g. (See Tr. 697, et seq.).

Under these circumstances we find that there is reasonable assurance that the fuel storage pool of Indian Point unit 1 is adequately designed and built to protect the public health and safety if subjected to an Intensity VII earthquake.

ISSUE 3

Is the Ramapo fault a capable fault within the meaning of Appendix A, 10 CFR 100?

Appendix A to Part 100, "Seismic and Geologic Siting Criteria for Nuclear Power Plants," in section III, "Definitions," defines a capable fault as follows:

> (g) A "capable fault" is a fault which has exhibited one or more of the following characteristics:
>
> (1) Movement at or near the ground surface at least once within the past 35,000 years or movement of a recurring nature within the past 500,000 years.
>
> (2) Macroseismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault.
>
> (3) A structural relationship to a capable fault according to characteristics (1) or (2) of this paragraph such that movement on one could be reasonably expected to be accompanied by movement on the other.
>
> In some cases, the geologic evidence of past activity at or near the ground surface along a particular fault may be obscured at a particular site. This might occur, for example, at a site having a deep overburden. For these cases, evidence may exist elsewhere along the fault from which an evaluation of its characteristics in the vicinity of the site can be reasonably based. Such evidence shall be used in determining whether the fault is a capable fault within this definition.

Notwithstanding the foregoing paragraphs III(g)(1), (2) and (3), structural association of a fault with geologic structural features which are geologically old (at least pre-Quaternary) such as any of those found in the Eastern region of the United States shall, in the absence of conflicting evidence, demonstrate that the fault is not a capable fault within this definition.

A. Age of the most Recent Movement on the Ramapo System

1. The licensees have sponsored extensive studies of the site and surrounding region by Dr. Nicholas M. Ratcliffe, Department of Earth and Planetary Sciences, City College of C.U.N.Y., and by the consulting firm of Dames and Moore. While Dr. Ratcliffe's report was not presented for the record by any of the parties, it was used as a basis for cross examination of both D & M and staff witnesses.

On the basis of its study of the entire Ramapo fault system, D & M includes in the system the primary Ramapo fault extending from northern New Jersey to northeast of Ladentown.[57/] At that point the fault branches into a wide

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57/ See Lic. Exh. 26, "Testimony of Dames & Moore (Panel) on Behalf of Licensees on Issue no. 3", p. 2-1 and plate A1-1. Ladentown appears to be some 8 miles southwest of Indian Point.

zone of less well-defined faults. These include, in addition to the Ramapo, the Thiells fault, the Letchworth fault, the Cedar Flats fault, the Mott Farm Road fault and the Timp Pass fault. Lic. Exh. 26 at 2-1, Plate A1-1. The Mott Farm Road fault trends towards Indian Point but neither Ratcliffe nor D & M show it crossing the Hudson River.

The licensees presented a panel of D & M scientists and engineers as witnesses[58/] to sponsor testimony concerning the Ramapo fault system. They testified, under cross-examination, that while they had not shown a connection between certain faults on the east side of the river and those of the Ramapo system on the west side, they were suspicious that some of them might be part of the Ramapo fault system.

The State of New York witness panel[59/] generally agreed with the D & M geographical description on the west

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58/ Lic. Exh. 26, "Testimony of Dames and Moore (Panel) on Behalf of Licensees on Issue no. 3", Joseph A. Fischer, Samir G. Khoury, Bernard Archer, Jerzy Szymanski, Todd M. Gates, Umesh Chandra. Tr. 4364-66.

59/ Drs. James F. Davis, Robert H. Fakundiny, Leo M. Hall and Klaus H. Jacob, who replaced Dr. Paul W. Pomeroy of the earlier panel. Tr. 4302. This panel sponsored State Exh. 18, "Testimony of Dr. James F. Davis, Dr. Paul W. Pomeroy, and Dr. Robert H. Fakundiny, and Dr. Leo M. Hall (Panel) on Behalf of the New York State Atomic Energy Council on Issue III". Tr. 4301-08.

side of the river, but contended the northeast trending faults on the east side should be included. N. Y. Exh. 18 at D-1, D-2.

The staff panel[60/] was also in general agreement with the D & M definition of the system. However, staff witnesses stated that there were some conflicts between D & M and Ratcliffe and, until the staff completes its evaluation, all the faults shown by both Ratcliffe and D & M have to be considered as part of the Ramapo system. The staff panel expressed the view that the question of the faults on the east side is "still a little up in the air." Tr. 5304.

The evidence on a possible relationship of the east and west side faults is enough for us to consider it likely that they are connected. However, as developed in our further findings on the capability of the Ramapo fault, infra, we do not need to decide this question.

2. There was no significant conflict between the staff and licensees witnesses on the dating of the latest

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60/ Staff Exh. 17, "Direct Testimony on Issue III by J. Carl Stepp, Seth M. Coplan, David R. Budge, Richard B. McMullen". Tr. 5115.

movement on the fault system. While intervenors State and CCPE disagreed, they presented no evidence of their own on this point.

The D & M testimony traced the geological history of the region and concluded that the most recent movement was 73 ± 5 m.y. ago. Based on this analysis, the D & M witnesses believe tectonic displacement along the Ramapo has not occurred since the opening of the northern North Atlantic Ocean (late Mesozoic). Lic. Exh. 26 at 2-6. Undeformed zeolite crystals growing on top of undeformed calcite crystals have been K-Ar dated and give a minimum age since last movement of 73 ± 5 m.y. Id. at 2-5. This compares well with opening of the northern North Atlantic Ocean about 80 m.y. ago. Ibid. The faults on the east side of the river show no movement more recent than 73 ± 5 m.y. Tr. 4975-76.

The staff testified that the determination of the minimum age of unbrecciated calcite crystals from faults in the vicinity of the site give an upper limit for the age of the last movement of several hundred thousand years. Furthermore, it believes the relative uniformity of homogenization temperatures of all fluid inclusions in calcite crystals reviewed to date suggests a regional hydrothermal

event for which conditions have probably not existed in the area of the site since Mesozoic or early Tertiary time (37 to 65 million years ago). Staff Exh. 17 at 17. This opinion is supported by the conclusions of a special review panel set up to assess the results of the D & M investigation.[61] This panel's report, signed by Drs. Price and Coates, states that "* * * the last movements on the faults occurred many millions of years ago * * *." Ibid.

The New York State witnesses stated that they do not believe "the minimum age of fault movement has been conclusively determined by fluid intrusion studies of calcite crystals found within the fault planes." State Exh. 18 at B-3. They do not agree with the D & M thesis that movement after formation of the crystal will deform the crystal. Ibid. However, they did not present any evidence in support of their views on this point. On cross-examination by the licensees, the state witnesses said they had found no information that the Ramapo fault has exhibited evidence of physical offset at or near the surface within the past 500,000 years. Tr. 4309.

61/ This panel was assembled by the licensees, at the staff's suggestion, and consisted of Dr. R. Price of Queens University, Kingston, Ontario, Dr. D. Coates from State University of New York at Binghamton and Dr. N. M. Ratcliffe, City College, the City University of New York. Id. at 18.

3. Two other points on the age question brought forth different opinions among the parties. In his investigation of the region, Dr. Ratcliffe had found an exposed polished surface with a small offset at Call Hollow. He said this could be a glacially polished surface. Ratcliffe, June 1976, pp. 76 and 133.62/ (See also Tr. 4462 and 5322.) Since the most recent glaciation in this region was more recent than 35,000 years, if the surface is glacially polished the offset is more recent than 35,000 years. The D & M panel, in response to questions by the State, expressed its belief that the surface was not glacial, and that the small offset was due to quarry and construction activities nearby. Tr. 4463-64. The staff panel was also questioned on this point and witness Stepp stated it is geologically unreasonable to expect such a localized offset on a major feature and no evidence of it otherwise. Tr. 5322-23. We find this offset surface is not evidence of recent tectonic activity.

The second point is related to the indication of river bottom anomalies found by a D & M bathymetric survey

62/ This refers to a report by Dr. Ratcliffe, a consultant to the licensees, which was utilized in the hearing by New York State for cross examination of licensees witnesses. See Tr. 4462, et seq. Also see Tr. 5322. This report was not entered into evidence.

in 1975. Tr. 4470, et seq. One of these anomalies was later identified as a pipeline crossing. Tr. 4476. In an effort to identify the others a diver was sent down to explore the river bottom but he was unable to find any special feature. Tr. 4499. Another bathymetric survey of the area was run in 1976, but no indications of the suspected anomalies were found. Tr. 4473. Furthermore, there was no corresponding feature on shore. Tr. 4484-85, 5037-39. These facts led D & M to conclude that the anomalies had no tectonic significance. Lic. Exh. 26 at 2-8.

The staff panel testified and were cross-examined on this matter, stating that the features appear to be irregularities at the water-sediment interface attributable to erosion and debris. When questioned, Dr. Stepp said an offset of the magnitude indicated (3-4 feet) would, if tectonically generated, require an earthquake of magnitude six or seven. Thus it would be geologically unreasonable to expect such an offset not to be identified onshore. Tr. 5327; Staff Exh. 17 at 16.

We find that the evidence shows the latest movement at or near the surface on the Ramapo system occurred at least 73 ± 5 m.y. ago. Hence the fault is not capable in terms of 10 CFR 100, Appendix A, section III(g)(1).

B. Magnitude and Location of Earthquakes

1. Before determining the capability of the Ramapo fault under the criterion of Appendix A, section III(g)(2) (p. 76, supra), it is necessary to arrive at a definition of "macroseismicity." This term is not defined in Appendix A, nor is it much in use among seismologists. Tr. 4648, 4981, 5268. Each party in this proceeding had its own definition.

In North Anna Environmental Coalition v. U. S. Nuclear Regulatory Commission, ___ F.2d ___ (D.C. Cir. 1976), the court gave a definition of macroseismicity which it based on a book authored by Dr. Charles F. Richter.[63/] However, in his testimony[64/] Dr. Richter stated that the definition relied upon by the court related to macroseismic effects, not macroseismicity. He also said that Dr. Sykes misapplied the same quotation from the book in using it to characterize the December 1962 and March 1976 earthquakes as macroearthquakes. Lic. Exh. 29 at 2-3.

63/ Dr. Charles F. Richter, Professor Emeritus, California Institute of Technology; member Lindvall, Richter & Associates, Consultants in Earthquake Sciences.

64/ Lic. Exh. 29, "Testimony of Charles F. Richter". Tr. 4625.

Dr. Richter gave his definition as follows:

> * * * I understand "macro-seismicity" to refer to large and significant seismic activity like that observed in California, such as is generally associated with fault movement at the surface. [Lic. Exh. 29 at 4.]

During cross examination he added that one earthquake of magnitude 6 would not constitute macroseismicity, but "[i]f you had a region in which earthquakes of that magnitude were frequent, then I would consider that as possibly categorized as macro-seismicity." Tr. 4659.

The members of the D & M panel gave their own definitions, which were probably best summed up by Dr. Chandra:

> A micro-earthquake is observable merely by the aid of instruments. A macro-earthquake produces geological effects such as ground rupture, sand boils, landslides, etc. Its effect is observable without the aid of instruments or the presence of nearby population centers. [Tr. 4982.]

Dr. Davis, a New York witness, defined a macroseismic event as one "which has an Intensity greater than III * * * and a magnitude * * * somewhere between 2 and 2.5." Tr. 4322. Later he said there should be more than one such event to constitute macroseismicity. Tr. 4336.

Dr. Sykes, a witness for CCPE, believes the intensity for qualifying as a macroearthquake will vary with locality,

but for southeastern New York he thinks intensity III is the lower limit for a macroearthquake. Tr. 4060. He stated that the most significant consideration is to determine whether there exists a tectonic pattern identified with a constant driving mechanism and a potential for damaging earthquakes. Tr. 4059. Again he said "macroseismicity would be earthquakes of a sufficient size, sufficient intensity, that they will be tectonically significant in terms of ascertaining the potential for damage from an earthquake". Tr. 4255.

Staff witness Coplan stated:

> My understanding of the term macroearthquake is that it is the complement of that [micro], * * * in other words, earthquakes of magnitude greater than 3. [Tr. 5381.]

He also agreed with others that there can be a macroearthquake without macroseismicity. Tr. 5382.

The staff panel introduced a "working definition" as Staff Exhibit 18:[65/]

> The staff considers the term, macro-seismicity, as used in Section III(g)(2) of Appendix A to 10 CFR Part 100, to mean seismicity of a level that implies significant, coherent, sustained tectonic activity. With respect to individual

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65/ Staff Exh. 18 "Staff Panel's Working Definition of Macroseismicity", Tr. 5122, 28.

> faults or fault zones, we interpret macroseismicity to be seismicity of a level that implies a significant and constant tectonic driving mechanism.
>
> We consider the term to refer to the seismicity of larger earthquakes. In our view such seismicity might have different aspects in different areas. Therefore, decisions as to what seismicity is "macroseismicity" must be made after consideration of the seismicity of a region.

Thus, while there are differences in these definitions, the parties are generally agreed that earthquakes below Modified Mercali intensity III or magnitude 2 are not macroearthquakes. Hence, we need examine only those earthquakes above intensity III or magnitude 2. Furthermore, the weight of the evidence is that macroseismicity involves more than one macroearthquake.

2. Before proceeding to a consideration of the earthquakes which may be of interest in connection with a determination under section III(g)(2) of Appendix A, a brief summary of how earthquakes are located will be useful in understanding further discussion of the issue.

When an earthquake occurs several types of elastic waves emanate from the source, traveling outward in all azimuths at velocities characteristic of each particular wave type. Distant seismographs respond to these passing

waves by recording the ground motions at their respective locations as functions of time on plots called seismograms. The waves of particular interest for use in determining the location of the earthquake are a shear wave, S, and a compressional wave, P. The P wave travels faster than the S wave, so in computing the location from the seismogram the seismologist may utilize any of the three phase (wave) arrival times -- P arrival, S arrival or S-P arrival time interval. An error is introduced in such a calculation using the P or S arrival if the clock of the seismograph station is in error, so clock accuracy must be verified by checking against time signals from the National Bureau of Standards. As expressed by the staff, "[t]he basic problem then is simply one of determining a location and origin time that is consistent with the phase arrival times, given the velocities with which the different types of waves travel through the earth." Staff Exh. 17 at 26.

The waves travel through different parts of the earth at somewhat different velocities so a specification of the spatial distribution of velocities within the earth, called a velocity model, is used in calculating the location of the source. Models can best be determined by

observing the travel times of waves from known sources such as quarry blasts or test explosions. The usual velocity models assume lateral homogeneity of the earth, yet in real life this may not be true and hence significant errors in the calculated location of the earthquake may result.

By using phase arrival times from seismograms of several recording stations and assuming velocity models, the seismologist obtains several "locations" which can be statistically combined to determine a "best" hypocenter.66/

It may be noted that numerous solutions for the location of a given earthquake were obtained by different witnesses, or even by the same witness, using differing velocity models. Factors which affect the accuracy of the final determination of a hypocenter include: accuracy of the velocity model, coordinates of the seismograph station, clock corrections, readings of arrival times from the seismograms and weight given the result of any one station in the statistical combining of results. Dr. Sykes testified that in parts of California, where there are many stations offering good azimuthal distribution and where there are good velocity models, a precision of something better than

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66/ The hypocenter is the location, including depth, of the initiating rupture causing the earthquake.

a kilometer may be obtained. He further stated that the accuracy in the New York-New Jersey region has improved considerably over the last few years with a better distribution of stations until now "it's possible to talk about a precision at the few-kilometer level or better." Tr. 4085.

3. Earthquakes which the various parties have claimed should be considered in resolving the question of the capability of the Ramapo fault are presented in Table 2 (pp. 92-93, infra).

New York claims that events 5, 7 and 10 of Table 2 (and possibly 9, 11, 12, 14, 16 and 18) may indicate that the Ramapo system experiences a "significant and constant tectonic driving mechanism" (N.Y. PFC at I-4) which would qualify it as an area of macroseismicity under the staff's "working definition" (p. 86, supra). However, the State believes that the uncertainty of location and lack of sufficient focal plane solutions[67/] do not permit a conclusion

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67/ To obtain a focal plane solution, an arbitrary unit sphere is drawn with its center at the focus (hypocenter) of the earthquake and first motion observations from each station are plotted on this sphere. The motion for a given station is plotted by determining where the vector from the source to the
(FOOTNOTE CONTINUED ON NEXT PAGE)

that the Ramapo system is capable or that it is not. N.Y. PFC at I-4; State Exh. 18 at E-1.

From Table 2 and the listed references to each seismic event it is evident that items 1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 14, 18, 19 were not instrumentally located or, in some cases, not felt. We must therefore eliminate these from consideration. Similarly items 6, 13, 15, 17 and 21 are eliminated as being too far from the Ramapo fault to be of concern.

We are therefore left with the earthquakes of December 20, 1962 and March 11, 1976 (Numbers 10 and 16 in Table 2) for further consideration.

67/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE) particular seismograph penetrates the unit sphere. The first motions (compressions or rarefactions) are obtained by reading the seismogram and are indicated on the plot by appropriate symbols. The resultant drawing is a circle with compression and rarefaction points grouped. Two orthogonal nodal planes can be drawn through the center of the arbitrary sphere separating these two groupings so compression points are in two quadrants and rarefaction points in the other two. One of these planes is the fault plane, the other is called the auxiliary plane. By comparing these planes with known fault planes of the region any correlation of the fault planes with the results of the focal plane solution aids in determining the association of the earthquake with the known fault. Lic. Exh. 26 at C-10, 11; Tr. 3945-49.

Table 2

	Date	Intensity (MM)	Remarks	Reference
1.	11/30/1783	VI	Not instrumentally located.	CCPE Exh. 4, Table 1; Lic. Exh. 26, Table C1.
2.	9/1/1895	VI	" "	Tr. 3897
3.	1943	V	Doubtful. Not listed in usual tables. Recollection of one individual 30 years later. Felt location.	Tr. 3864-70.
4.	4/1/1947	III		Tr. 3876; CCPE Exh. 4 at 9.
5.	1948		Perhaps a typo. Not listed in tables in this record.	N.Y. PFC at I-4.
6.	9/3/1951	V	Located too far from Ramapo (10-15 Km.)	Tr. 3813, 3951, 3975-9; 3806-7; 4982. Lic Exh. 26, Tables C-1, C-2, C-3.
7.	9/15/1951*/	V	Apparently a typo.	N.Y. PFC at G10.
8.	3/23/1957	VI	Not instrumentally located.	Tr. 3891.
9.	10/13/62	(M:1)	No felt reports	State Exh. 18, Table C-1; CCPE Exh. 4 at 9.
10.	12/20/62	IV		Tr. 4982; State Exh. 18 at C-1.

*/ Apparently a typo in the State's proposed findings and conclusions of law. Perhaps it should be event No. 6 above. (See State Exh. 18 at C-5.)

Table 2 (continued)

	Date	Intensity (MM)	Remarks	Reference
11.	11/30/64	M:1	Not felt	State Exh. 18 at C-1; Tr. 4329.
12.	5/21/66	M:1-1.5	Not felt	State Exh. 18 at C-1; Tr. 4329.
13.	1969	M<1.5	Too far away (≈20 km NW of Ramapo).	CCPE Exh. 4 at 13; NRC Exh. 17 at 20.
14.	5/11/72	--		N.Y. PFC at I-4.
15.	7/19/75	M:2.3	Located E. of river, near Fahnstock State Park.	State Exh. 18 at C-3; Lic. Exh. 26 at Table C-1; Tr. 4330.
16.	3/11/76	IV	Pompton Lakes	CCPE Exh. 4 at 10; Tr. 4982, 4330.
17.	4/13/76	M:3.0	Too far away, 30 km Sykes, 20 km staff.	CCPE Exh. 4 at Fig. 2; NRC Exh. 17 at 22.
18.	9/22/76	--	Not in evidentiary record.	N.Y. PFC at I-4.

Note: In Table III-C-2 of State Exh. 18 the State listed eleven earthquakes located in 1975-76 by the Con Ed network. Only three of these were felt (Tr. 4330) as follows:

a.	6/15/75	--	Quarry action, not macro.	State Exh. 18 at C-3.
b.	3/11/76	IV	Pompton Lakes	State Exh. 18 at C-3; Tr. 4330.
c.	4/13/76	IV	Sykes places 20 km SE of Ramapo.	CCPE Exh. 4, Table 1, Fig 2; NRC Exh. 17 at 22.

Note: Table III-C-3 of State Exh. 18 lists nine probable earthquakes but a state witness said none were evidence of macroseismicity. Tr. 4330.

C. The December 20, 1962 and March 11, 1976 Earthquakes

1. There were widely different views on the December 20, 1962 event depending on the witness' definition of macro-earthquake. Dr. Chandra said that although it had an intensity of IV it produced no observable geological effects and hence was not a macroearthquake. Tr. 4982-83. On the other hand, Dr. Sykes stated in his testimony that it was a macroearthquake, and cited Richter's definition of macro-effects to support his view.[68/] He apparently confused the definition of macro-effect with that for macroearthquake. Lic. Exh. 29 at 3. He considers the 1962 earthquake to be macroseismicity under his definition of the term -- "* * * earthquakes of sufficient size, sufficient intensity, that they will be tectonically significant * * *." Tr. 4255, 4264. The New York panel's written testimony stated that the event (with the March 11, 1976 one) fits "at least one definition of 'macro' seismicity." State Exh. 18 at C-5. On cross-examination Dr. Davis of the New York panel said this "one definition" referred to Dr. Sykes' definition. Tr. 4320.

68/ CCPE Exh. 4, "Testimony of Dr. Lynn Sykes -- The Capability of the Ramapo Fault", p. 10. See also p. 84, supra.

According to Dr. Sykes, some investigators (Isacks and Oliver, 1964) used records from seven stations to locate the December 20, 1962 event a few kilometers from the main trace of the Ramapo fault. Tr. 3850, 3856. Dr. Sykes himself assumed the December and the October 31, 1962 earthquakes had a common focus, and, using S-P data for the two events combined, he obtained a location "along the Ramapo fault". CCPE Exh. 4 at 9. Later he obtained new clock corrections for the stations and used these with the data from the December event alone to calculate a new location, still along the Ramapo fault and within a kilometer of his previous one. Tr. 3844-45. A third solution using corrected coordinates for one of the recording stations (Ogdenburg) changed the result about 300 meters in a direction parallel to the fault. Tr. 4251-52.

Dr. Chandra also used the combined data for the October and December earthquakes to calculate a location of the events. He conceded that there is no evidence that this assumption of a common focus is valid, but, due to the poor quality of the data, it was necessary. Tr. 4374; Lic. Exh. 26 at C-6 and C-7. Later, however, clock correction data for the three stations used were found in Lamont-Doherty files so the location of the December earthquake

was recomputed using the P and S data for it alone. Tr. 4374-75; Lic. Exh. 26 at C-24. This solution is about one kilometer from the surface trace of the Ramapo fault. Lic. Exh. 26 at plate C-3; Tr. 4546.

The final solutions by both parties are very close to one another, and, as Dr. Chandra said, the epicenter location could be coincident with the Ramapo fault. Tr. 4546. However, both the staff and the State panel testified that the location of one event, without additional evidence, does not establish the "direct relationship" required by Section III(g)(2) and (3) of Appendix A. Tr. 4334, 5225-27.

Staff panel member Coplan amplified this by saying that, rather than how close a single earthquake is to a fault, the important consideration is "* * * what the other earthquakes in the area are doing". Tr. 5227. Dr. Davis, of the New York panel, said they "* * * would want to see several events well located of that kind * * * exceeding our conception of the threshold of macroseismicity." Tr. 4336. Dr. Richter stated, "[t]he occurrence of a small number of earthquake events which are suspected of being related to a given fault is also not very conclusive evidence" of a direct relationship with a given fault. Tr. 4814.

The parties generally agreed that an obvious lineation of earthquakes would be cause to consider a possible relationship with a fault. However, no one presented evidence of such a lineation here. The State panel claimed to show an alignment of epicenters with the Ramapo fault, but when presented with an epicenter map of the region without faults or geographical boundaries[69/] shown they were unable to detect a lineation marking the Ramapo fault. Lic. Exh. 22; Tr. 4312-16. The staff panel's testimony states that the map entitled "Exhibit 2" of the State's testimony (State Exh. 18, p. E-4) shows no "* * * concentration that aligns with the Ramapo fault." Staff Exh. 17 at 19. Dr. Richter was cross-examined on the question of lineation and he stated that the 1951, 1962 and 1976 locations do not comport with his testimony concerning the significance of earthquakes found to line up and repeat along a known fault. Tr. 4774-77. Furthermore, when presented with a copy of plate C-2 (from Lic. Exh. 26) with the 1974, 1976 (2 events) and 1975 earthquake epicenters marked in yellow, Dr. Richter said such alignment as there

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69/ Lic. Exh. 22, a map bearing the legend "Seismicity of Northeastern United States." Tr. 4313.

might be does not agree with the trend of the surface trace of any of the faults shown on the map. Tr. 4784, 4787-88; Lic. Exh. 26, plate C-2.

Fault plane solutions of the 1962 earthquake were not introduced since there are insufficient data to find a solution for that event by itself. Dr. Sykes prepared a composite solution of the 1951, 1962 and 1976 earthquakes. CCPE Exh. 4 at 14a; Tr. 3940-44. We do not find such a composite solution persuasive as it involves assumptions of a common source at different times. Such widely separated occurrences do not necessarily have consistent causal mechanisms. Lic. Exh. 26 at C-14, C-15.

We find that the mere location of the earthquake near the Ramapo fault cannot establish a direct relationship, and there is no other valid evidence in the record to support such a direct relationship.

2. The solutions obtained by the parties for the March 11, 1976 earthquake differ more widely. Dr. Sykes gives the location as about 0.75 km from the main trace of the Ramapo fault. This value was obtained using his preferred velocity model which is supported by data from quarry blasts. CCPE Exh. 4 at pp. 6-7, and Figure 1.

The licensees witnesses did a more elaborate calculation, using 12 velocity models with two different data sets for each, thereby producing a total of 24 solutions. Lic. Exh. 26, Table C-7. They agreed that Dr. Sykes' preferred velocity model (his model 6) was the preferable one, and using it (their solutions 23 and 24) they got locations of 4 and 6 km respectively from the surface trace of the fault. Tr. 4561, 4615, 4618, 4874; Lic. Exh. 26 at C-10, Plate C-3.

The difference between the solutions of the two parties is significant and we are faced with the need to find which is preferable. For the reasons set forth below we find the location of the epicenter of the March 11, 1976 earthquake to be some 4-6 km from the main trace of the Ramapo fault.

Both parties used the S wave arrival time at OGD,[70/] but their readings differed appreciably. Dr. Sykes read this as 27.6 and characterized Dr. Chandra's reading of 27.02 as a gross error. Tr. 4104. The actual OGD seismogram was presented to the Board and Dr. Chandra demonstrated to the Board how he determined the arrival point

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70/ The seismograph stations are identified by letters for the name of the location, e.g. OGD is Ogdenburg.

for the S wave. Tr. 4550, et seq. Also, Dr. Willis, another witness[71] for the licensees, made an independent determination on each of three records and read 26.9 and 27.0 seconds. Tr. 5073. Mr. Coplan of the staff panel looked at all three components and gave 27.1 as his selection. Tr. 5410. We find the D & M value to be the preferable one.

Station PNJ, used by both parties, is an amateur station. While the operator of the station furnished clock corrections, there was no way to verify their accuracy. Tr. 4233-34. Because of this, licensees witness Dr. Chandra chose to use the S-P time, so the absolute arrival time (and hence clock correction) were not involved. (See our discussion at pp. 87-88, supra.) Dr. Sykes used the P wave arrival. Tr. 4378, 3880-81.

Dr. Sykes also used a velocity correction for station PNJ because, he said, the wave path traverses a low velocity material of the Triassic Basin. Tr. 4035-36. However, he did not make a velocity correction for station PAL

71/ Dr. Willis is Professor of Geophysics and Chairman of the Department of Geological Sciences at the University of Wisconsin. He was serving as a consultant on the location of the 1951 and 1962 events but was asked by the licensees to read the OGD record here.

which also is across the Triassic Basin from the hypocenter. The staff panel agreed that a correction would be proper if the Triassic velocities were definitely known. Tr. 5444. The D & M panel said that station corrections are determined from (1) the average of the residuals at that particular station from a large number of earthquakes, or (2) accurate geological information like the thickness of the Triassic Basin. Tr. 4894-95. Dr. Sykes presented no evidence that he determined his PNJ correction from either, so his correction appears to us to be somewhat arbitrary.

The licensees presented, as Exhibits 32 and 33, the residuals[72/] provided by D & M for each station used in

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72/ The residual for a given station and wave type is equal to the observed arrival time minus the calculated arrival time, where the calculated time is that computed as the time of travel to the station from the epicenter after this location has been determined using a particular velocity model. The significance of this is that a small residual gives one confidence about the reading of phases. Conversely, a large residual indicates (1) the phase arrival reading is incorrect or (2) the velocity model used to obtain the location is incorrect. Tr. 5001.

Lic. Exh. 32 and Lic. Exh. 33 are copies of Table C-5 from p. C-25 of Lic. Exh. 26 upon which residuals for each of the stations have been inserted by its witnesses. Lic. Exh. 32 was marked with a "23" in the upper right hand corner indicating it applied to solution number 23, and Lic. Exh. 33 was marked with a number "24" indicating it applied to solution number 24. Tr. 5066-67.

its solutions for Models 23 and 24. It is worthy of note that the D & M residual for station PNJ S-P model 24 solution is -0.02, one of the lowest found, thus indicating high degrees of correctness in the phase reading and the velocity model. Tr. 5003. The residual for OGD, the station for which the phase reading by licensees witnesses was questioned by Dr. Sykes (p. 99, supra), is -0.01, the lowest of all residuals for model 24. Ibid. The record is silent on the matter of the residuals for Dr. Sykes' solutions for stations OGD and PNJ, but his residual for PAL is 0.14 for the P wave. Tr. 4235. The D & M residual for the P wave for station PAL is -0.12. Lic. Exh. 33. These low residuals give confidence in the models used for PAL and raise a question concerning the correctness of applying a different model for PNJ as was done by Dr. Sykes.

All parties agreed that fault plane solutions are significant and relevant to the question of a "direct relationship." Dr. Sykes and the D & M panel submitted such solutions for the March 11, 1976 event.

Dr. Sykes prepared his focal plane analysis by using a composite of the data for the 1951, 1962 and 1976 earthquakes. He testified that the fact that a composite

solution fits the data from three events suggests a similar mechanism for all three and is also suggestive of a regional pattern of stress. CCPE Exh. 4 at 14a; Fig. 4. Under cross examination he said his Fig. 4 was actually constructed using the data from the March 11, 1976 earthquake and its aftershock, and the information from the 1951 and 1962 events were then added. Tr. 3940-44.

We do not find such a composite solution persuasive. Events widely separated in time do not necessarily have the same causal mechanism. Even the main event and its aftershocks may have different mechanisms. Licensees witnesses testified that McKenzie (1972) said "A curious feature of several of the large shocks [in the Mediterranean region] for which fault plane solutions could be obtained for the main shock and one major aftershock was that the two often had different mechanisms." They also quoted Strelitz (1975), "the September 5, 1970 Sea of Okhotsk earthquake consisted of two possibly causally related but dissimilar events." Additionally, "the fault planes and principal stress axes of the two events are significantly different; furthermore, the second event does not lie on either of the nodal planes of the first event." Lic. Exh. 26 at C-14, C-15.

Examination of the resultant Sykes solution (CCPE Exh. 4, Fig. 4) indicates the result is not clean-cut.

Dr. Sykes characterizes his composite solution for the 1976 event as unique.[73] CCPE Exh. 4 at 15. We cannot agree with this characterization. The D & M panel obtained two fault plane solutions for the same event based on their solution 24. Lic. Exh. 26 at C-11, C-12, plate C-4. CCPE questioned the D & M solutions, claiming the polarity of the instruments at stations GSC and DBM were reversed and hence D & M plotted the points for these stations incorrectly. The record reflects only that CCPE's own witness said these polarities were in question. CCPE Exh. 4 at 15; Tr. 4950-54. The licensees introduced two exhibits, 30-A and 30-B,[74] showing the identification of the stations for their focal plane solutions given in figures a and b on Plate C-4 of Lic. Exh. 26. An examination of these two exhibits shows the points for the two stations in question to be in the center of a cluster of

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73/ "Unique" means only one set of normal planes can correctly separate the data points.

74/ Lic. Exh. 30-A and 30-B are copies of figures a and b, respectively, on Plate C-4 in Lic. Exh. 26. These figures show the focal plane solutions for the March 11, 1976 earthquake. Tr. 4960.

points of similar polarity. Hence, if these two are changed, the result would not appear to change the location of the planes but merely to give two anomalous points. In cross-examining the D & M panel, CCPE attempted to show that stations near the nodal plane could be determined from the shape of the first P wave arrival. The panel did not agree with this hypothesis or that it is a "common method of picking up nodal arrivals or [determining] the nodal planes." Tr. 4948. CCPE also criticized the D & M solutions because they did not allow for refraction of the wave. Tr. 4963-66. However, the record does not show that refraction of a wave in the region in question actually occurs.

The solutions of Dr. Sykes and that given in Lic. Exh. 30-A are quite similar and one plane, striking N52°E, has approximately the strike of the Ramapo fault (N40°E-N45°E). Lic. Exh. 26 at C-11; Tr. 4946. The other plane would indicate the strike as N74°W and, while there is no known fault in this area with this strike, there is a possibility of such a fault sub-surface. Lic. Exh. 26 at C-12.

The second D & M solution (Lic. Exh. 30-B) shows E-W striking planes. There is no surface rupture to aid in

determining which solution is correct. The staff said "* * * there's not really any reason in the data to choose one over the other," since neither exhibits consistency with other relatively nearby focal mechanism solutions. Tr. 5446.

On the basis of the above findings we conclude that the March 11, 1976 event does not "demonstrate a direct relationship with the fault." We prefer the D & M location and accept the staff's statement that the Ramapo fault dips approximately 70° to southeast (away from the D & M location). Tr. 5464. Thus the hypocenter is even more than 4-6 km from the fault. The two D & M fault plane solutions, while we find them equally valid, do not offer the necessary demonstration of a "direct relationship" of this event with the Ramapo fault.

D. Structural Relationship between the Ramapo Fault and any known Capable Faults

The record does not contain any evidence to indicate a structural relationship between the Ramapo fault and other faults known to be capable. The New York panel testified that it had found no evidence indicating such a relationship. Hence we conclude the Ramapo fault does

not meet the condition for a capable fault set forth in section III(g)(3) of Appendix A. See p. 76, supra.

For the above reasons we find that, in accordance with the definitions in 10 CFR 100, Appendix A, section III(g), the Ramapo fault is not a capable fault.

ISSUE 4

Is the operating license condition for Indian Point 3, requiring an expanded microseismic monitoring network along the Ramapo fault warranted?

This issue arose following the evidentiary hearings on the previous three issues as the result of the licensees' motion to us requesting that we "issue an order modifying the time limits within which [they] must comply" with a particular condition of the Indian Point 3 reactor operating license. Licensees' Motion to Modify License Condition, dated August 27, 1976, p. 6.

The condition in question was part of Amendment 2(C) issued by the NRC staff on April 5, 1976. Amendment 2(C)(4) ordered the licensee to "conduct a program of geological and seismological investigations."[75/] As part of the seismological investigations the licensees state that they "were directed to expand the existing microseismic monitoring network southwestward to include Pompton Lakes, New Jersey, and northeastward to include Fahnestock, New York." Id. at p. 2.

75/ See pp. 3-4, supra, for summary statement of Amendment 2(C)(4).

Following our review of the record concerning this matter we issued a memorandum and order[76/] deferring our decision pending an evidentiary hearing by us on the matter. This hearing was conducted for six days between March 8 and March 16, 1977. Written testimony was supplied by the licensees, the State of New York and by the NRC staff. CCPE submitted no testimony but participated in cross-examination.

For the reasons given below we have decided that the enlarged monitoring network would not contribute to the assurance of health and safety of the public and is therefore unnecessary.

We were first made aware of the imposition of the license condition on July 26, 1976 -- the last day of our evidentiary hearing on Issue 3. The matter arose during cross-examination of staff witnesses by the licensees and was followed up by Board questions to the staff. In the course of the questioning by the Board on the reasons for requiring the expanded monitoring system, staff witness Stepp responded to a question:

76/ ALAB-357, 4 NRC 542 (1976). Our reasons for calling an evidentiary hearing are fully explained in that order and are not repeated in this decision.

Question: Let me ask this: Are you suggesting this program of micro-seismicity stations to prove or disprove activity on the Ramapo fault, or are you looking at it as a pure research project?

Answer: There are elements of both here. So far as my understanding of the problem goes, the principal benefit that we might expect from the microearthquake monitoring is one of attempting to define the tectonic environment, I will characterize it, the way the stresses are behaving, the kinds of focal mechanisms that are occurring in the area, and so on.

It is in part a research project. While a number of important people, very prominent people, Page, Isacks, and Oliver, among them, Dr. Sykes, who have considerable knowledge in the Eastern United States have postulated that microearthquakes or small earthquakes are occurring along the Ramapo, it is not clear so far as I know in anyone's mind what these small earthquakes may mean so far as the potential for larger earthquakes in this region.

That is really the problem we are trying to address here. I would extend this in the context of this being in some aspects of a research project to the general statement that we do not know what the significance of microearthquakes may be so far as being able to estimate what they mean -- to determine what they mean for the potential for defining where future larger earthquakes may occur in the Eastern United States.

Tr. 5530-31.

As the result of further Board questioning witness Coplan added:

> There may be, as Dr. Sykes has claimed on the basis of his data, a stress condition, in that region that is conducive to some movement on the Ramapo Fault. But we don't know how much or how often.
>
> We know that it is very much less than what we would see on faults in California that would normally be considered to be active.
>
> While we think that given in fact we are quite confident that, given the data that we have available to us, the situation is not one that causes a hazard for the Indian Point site, or creates any great degree of risk, there are just some things that we are a little bit uncertain about and we would like to know more about.
>
> And that is what we have directed this program toward.

Tr. 5537-38.

At that time the Board questioned (1) the usefulness of the monitoring network on only one section of the tectonic province, (2) whether such a limited network would present a biased picture of the seismicity along the fault, and (3) whether it would supply any useful information with regard to the safety of the Indian Point site.

When the decision to call for an evidentiary hearing was made[77/] we requested that all parties presenting written evidence address the following questions:

1. Is an enlarged microseismic monitoring network warranted for reasonable assurance of the public health and safety in connection with the Indian Point nuclear facility?

2. If not:

   a. On what other basis can the licensees be made responsible for the cost of the expanded network?

   b. Is the problem concerning the significance of microearthquakes on the east coast of the United States of sufficient importance to be of concern to State and Federal governments because of general danger to east coast residents?

3. In answering the following questions, consideration should be given to the Dames & Moore testimony on the possible location of shallow tensional stress fields surrounding the northern end of the Ramapo Fault:

   a. If an expanded seismic monitoring network is found to be warranted, is the presently suggested expansion the best one?

   b. If such a stress field exists, should the expanded network be concentrated around it rather than the Ramapo Fault?

77/ Mr. Farrar dissented from this decision. See 4 NRC at 552-57.

c. If the stress field is a more likely source of microseismicity in the area, should not the research work on the stress field be completed before consideration of an expanded seismic network?

ALAB-357, supra, 4 NRC at 551.

We will first outline the testimony of the licensees, NRC staff and New York State relevant to these questions, and then discuss the entire record.

I. Testimony of the Parties

A. Licensees Testimony

Licensees testimony was presented in three sections: (1) a discussion of the questions asked by this Board (Witnesses Fischer, Werner and McWhorter), (2) a detailed discussion of the relationship between microseismicity and the occurrence of larger earthquakes (Witness Willis), and (3) the projected cost of installing and operating the expanded microseismic monitoring network (Witness Gonnella).

We shall discuss these seriatim.

1. Fischer, Werner and McWhorter Testimony

a. This section of the licensees testimony[78] is basically summarized in their response to question 1, as follows:

> First, it is our opinion that the contribution to the reasonable assurance of public health and safety, that would be provided by the enlarged microseismic monitoring network would be next to nil. To date we are aware of no reasoned and logical analysis by which the risk of an earthquake in excess of the SSE can be determined from only microseismicity.
>
> Second, the assurance of the public health and safety in connection with the Indian Point facility is provided in performing a series of geologic and seismologic investigations done in accord with Appendix A to 10 CFR, Part 100. The enlarged network would not make a meaningful contribution to the level of assurance provided by the above investigations. As consulting earth scientists we are obliged to point out aspects in investigative programs that would not reasonably be expected to indicate whether or not the Ramapo Fault System is capable within the meaning of Appendix A to 10 CFR, Part 100.

Lic. Exh. 35, p. 5.

78/ Lic. Exh. 35. "Testimony of Dames and Moore (Panel) on Behalf of Licensees on the Expansion of the Microseismic Monitoring Network," James G. McWhorter, Matthew L. Werner, III and Joseph A. Fischer. Tr. 5631-47. As we have noted in section 1, supra, all those witnesses are employees of Dames and Moore (D & M), consultants to the licensees.

The witnesses further noted that the staff (at pp. 2-6 of Supplement No. 3 to the Indian Point Unit No. 3 SER) had stated:

> We consider the lack of evidence of geologically young movement and the absence of any obvious clustering of historic earthquake activity along the Ramapo Fault System to support the conclusion that the fault is not capable within the meaning of Appendix A to 10 CFR Part 100. We, therefore, consider our original position, that the design of the units for the largest historic earthquake to have occurred randomly within the site's tectonic province, provides reasonable assurance that the plant will not be subjected to ground motion greater than that for which it was designed.
>
> Nevertheless, because of the recent location of the two earthquakes near the fault, we consider a confirmatory program directed toward more definitive determination of the age of most recent movement and a determination of the potential for earthquake activity on the fault system to be necessary.

Lic. Exh. 35, pp. 7-8.

In other words the additional monitoring network was to be required for confirmatory information over and above the stated requirements of Appendix A.

In their testimony the licensees witnesses pointed out that the State's initial rationale for recommending the expanded microseismic monitoring network included the demand for an "[a]nalysis of microseismic patterns to ascertain whether

such patterns might be used to forecast larger earthquakes". Lic. Exh. 35, p. 7. The State had gone on, however, to admit that these "* * * tests are new to the science of seismology and are in and of themselves inconclusive * * *." Ibid.

The licensees witnesses discussed the question of a relationship between the occurrence of small earthquakes and the potential for larger earthquakes. They stated that: "in order to describe this relationship: (1) one must be aware of all of the variables in the system; and (2) at least the most important variables must be observed". Lic. Exh. 35, p. 10. They pointed out that, in establishing simply a monitoring network, most of the other variables in the system are ignored. Id. at p. 11. Reducing the system to only the comparison between small and larger earthquakes immediately increases the amount of data and time required to identify the relationship, if any, that may be involved. Id. at pp. 11-12.

The witnesses noted that only two intensity IV and two intensity V earthquakes[79/] have occurred within the

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79/ Indian Point 2 and 3 reactors are designed to withstand ground motions resulting from an intensity VII earthquake at the site (see pp. 6, 71, supra).

area of the proposed network in the last 278 years, therefore the chances of obtaining sufficient data in the next two years on both micro- and macroearthquakes to determine a relationship between the two is extremely remote. Id. at p. 12.

Licensees therefore concluded that the addition of the monitoring network would not add to the assurance of public health and safety insofar as the operation of the nuclear reactors at Indian Point is concerned.

b. Question 2

The licensees' witnesses did not attempt to answer Board question 2.a. on the basis that it called for a strictly legal conclusion. As far as question 2.b. is concerned, a yes or no answer was not given but the witnesses discussed the difference between the overall geologic approach of Appendix A and the use of microearthquake measurements to obtain a determination of reasonable assurance of public health and safety. They pointed out that prediction of earthquakes by any means is in its infancy and, where predictions over a limited range have been somewhat successful, they have been made by the use of several variables (e.g., magnetic field, tilting of surface,

strain measurements) and not on microseismicity alone. Even in these cases, the estimates of earthquake intensities by the Appendix A method have always been the most conservative. Id. at pp. 18-19.

The witnesses further noted that, while low intensity earthquakes may be of major concern to the public in general (Tr. 5734), the design of the Indian Point nuclear plants is such as to give reasonable assurance of public health and safety up to and including intensity VII. Thus, according to them, for microseismic measurements to add to the assurance of public health and safety a relationship must be found between microseismicity and earthquakes of intensity VIII or greater. Id. at pp. 19-20.

The witnesses did agree that a long range research program to study microseismicity in areas of high seismicity should be established for general public interest but they emphasized that "[w]e cannot accept that two years of microseismic monitoring in a very small area is going to even marginally increase our understanding". Id. at p. 22. See also pp. 27-28.

c. Question 3

Licensees witnesses answered Board Question 3 in two ways -- depending on the purpose for which the monitoring network is established. Licensees see two such possible purposes: (1) in their view the staff considers the monitoring network to be largely for research and development directed at determination of the relationship between microearthquakes and larger earthquakes; (2) they believe this Board by its question 1 had raised the possibility that the monitoring network has a "purpose in connection with the assurance of public health and safety". Lic. Exh. 35 at p. 27. (See also Tr. 5713-14).

The witnesses expressed the belief that such an R&D program will not be capable of achieving the sought objective until much larger data bases (i.e., recorded events) are obtained in areas of high seismicity. Lic. Exh. 35 at pp. 27-28. In addition, they noted that their own shallow stress measurements had been completed but were inconclusive as to the location of any uniform shallow stress field. Id. at 29.

With regard to the assurance of public health and safety it is the licensees' view that this has been reasonably assured by the other geological and seismological

investigations required by the license conditions and Appendix A to 10 CFR Part 100. They indicated that the installation of the monitoring network might add a false sense of security. Id. at 30.

2. Willis Testimony

Dr. Willis' testimony[80/] concerning the relationship between microseismicity and larger earthquakes was primarily a discussion of the empirical equation $\log N = A + bM$ developed by Richter.[81/] Lic. Exh. 35 at p. 5. As Dr. Willis pointed out, if b is constant the equation "implies that within a range of magnitudes governed by the linear log N versus M law seismic activity is simply described by the constant A". Id. at p. 6.

Recent work has shown, however, that b, which is considered to be related to the physical characteristics and distribution of stress in a region, varies between values of 0.5 and 1.5. Id. at pp. 5-16. The value of b

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80/ Lic. Exh. 37, "Testimony of Dr. David E. Willis on Behalf of Licensees on the Expansion of the Microseismic Monitoring Network." Tr. 5918-21. See also fn. 71, p. 100, supra.

81/ M = magnitude
N = number of earthquakes of magnitude M or larger per unit of time.
A and b are empirical constants.

may vary between geographical regions, with depth or, in some cases, with time and between fore shocks and after shocks. Id. at pp. 15-16, 24.

On the basis of his data Dr. Willis stated that even in areas of high seismicity with a broad data base, b values obtained "are shown not to be valid to project the occurrence of earthquakes with magnitudes above 3.5". Id. at p. 23. Because of this Dr. Willis concluded that "it is uncertain whether data from a microseismic monitoring network can be utilized in the above equation to accurately predict large earthquakes". Id. at p. 24.

3. Gonnella Testimony

The licensees presented Victor C. Gonnella as a witness to provide data[82/] on the projected cost of installing and operating the expanded microseismic monitoring network. These data were based on the bid prices received from the successful bidder, and were presented here in four sections. Phase I dealt with relocating the present

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82/ Lic. Exh. 39, "Testimony of Victor C. Gonnella on Behalf of Licensees on the Costs Associated with Expansion of the Consolidated Edison Microseismic Monitoring Network". Tr. 6038-45.

recording station and operation of the present network during the transition period. The cost of Phase I was estimated as $104,500. Phase II covered the detailed design and site selection for the expanded network and was estimated to cost $47,000. Phase III was the cost of equipment and installation of the network. The cost for this latter phase was $358,500. The final phase concerned operation of the expanded network for 24 months, at a cost of $561,000, thus making a total of $1,071,000. Lic. Exh. 39, pp. 3-5.

This Board believes that cost is not a factor if a proposed action is important for the public health and safety. However, cost is a factor if health and safety are not involved, and is also a factor in selecting among options where more than one is available.

B. Staff Testimony

1. The NRC staff testimony[83/] was presented by a panel of four witnesses, J. Carl Stepp, Richard B. McMullen, John Kelleher, and David Budge. This testimony, while answering generally the three questions posed

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83/ Staff Exh. 25, "Testimony of J. Carl Stepp, Richard B. McMullen and John Kelleher". Tr. 6186-90.

by the Board, was basically aimed at explaining the staff rationale for imposing the monitoring condition. The thrust of the staff testimony was that, while geologic evidence permitted the conclusion that the Ramapo fault is not capable, "* * * [w]e were not able to conclude conservatively that this structure does not play a possible role in localizing earthquake activity". Staff Exh. 25, p. 1. Because of this, the staff stated it would "* * * continue to press for expansion of the microearthquake network, so that a more accurate determination of what the relationships are between earthquakes and geologic structures in the region". Id. at 2.

According to the staff, this relationship "is an important means of assessing the likelihood of future movement of faults and, when this relationship is known, an accurate assessment of the seismic hazard at the site can usually be made." Ibid.

2. Prior to the amendment[84/] of the license by condition 2(C), the NRC staff had licensed Indian Point Unit 2 for operation and Indian Point Unit 3 for fuel loading and subcritical testing on the basis that the Ramapo fault was not capable and that the maximum historic earthquake

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84/ Amendment 2 was dated April 5, 1976. (See p. 108, supra.)

occurring in the tectonic province had resulted in a Modified Mercalli intensity VII.[85/] The authorization for Indian Point 3 to engage in subcritical testing was issued on December 12, 1975.

By that time the licensees, following discussions with the State of New York, had agreed to set up a network of 12 microseismic stations (later expanded to 13) in the vicinity of the Indian Point Station but aimed at the northern end of the Ramapo fault. Tr. 6317. This network began partial operation June 1, 1975 and full operation in September, 1975.

The staff witnesses testified that they had taken and still do take the position that the Ramapo fault is not capable within the meaning of Appendix A to 10 CFR Part 100. Staff Exh. 25, p. 12. However, they have not been able to conclude that the Ramapo fault "plays no role in localizing earthquake activity". Ibid. The witnesses indicated that

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85/ See "Supplement No. 1 to the Safety Evaluation Report (SER) -- of the Indian Point Nuclear Generating Station Unit No. 3", (January 16, 1977) at pp. 1-5. This decision was confirmed in Supplement No. 2 to the SER (December 12, 1975) at pp. 2-1 through 2-3 and p. 22-1.

the staff's concern about the "localization" of earthquakes began with the occurrence of a magnitude 2.5 earthquake near Pompton Lakes, New Jersey[86] on March 11, 1976 which followed a 1951 earthquake in Rockland County, New Jersey. Id. at 1-2.[87]

Initially, condition 2(C)(4) called only for a southwestern expansion of the monitoring system but, following discussions with New York State, the system was later expanded to include stations to the northeast.[88] The entire condition 2(C) was then issued at the time of the issuance of the SER Supplement 3 for the Indian Point 3 station without prior discussion with the applicants.[89]

3. Throughout the hearing the staff insisted that the data collected by the expanded microseismic network neither would nor could be used to predict the advent of

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86/ The earthquake epicenter was located about 50 km from Indian Point but close to the surface trace of the Ramapo fault.

87/ The March 11, 1976 earthquake (which was a magnitude 2.5 event) was at that time thought to have occurred adjacent to the Ramapo fault about 20 km from the Indian Point site. A later review of the data placed the epicenter about 9 km from the Ramapo (approximately 30 km from Indian Point). Tr. 6193, 6493; also Lic. Exh. 26 plates C2 and C3.

88/ Tr. 6317-18.

89/ Tr. 6318. The supplement was issued on April 5, 1976 shortly prior to the time that the licensees expected to receive their full operating license.

large earthquakes either in the short term or long term.[90/] It did insist that the expanded network would enable it to detect and obtain accurate focal plane solutions for any microseismic events that might occur along the entire length of the Ramapo fault. It pointed out that the expanded network including the segment north of Indian Point would cover 4 to 5 times the area of the present network.

According to witness Stepp, the data would supply the following:

> The data themselves would not necessarily -- the microearthquake data themselves would not necessarily lead you to a determination of the potential of movement on the fault. That alone would not. But considerations -- this would be a two step process.
>
> We're considering the first step in it now, whether or not there is any reason to be unduly concerned about localization of earthquakes along this structure, and the microearthquake can lead us directly to that -- can directly lead to a conclusion about that.
>
> Now if in fact it should be determined that earthquakes of small magnitude are localized along this fault zone then the question arises of what the maximum earthquake along that fault zone should be and that determination would involve other considerations than simply the microearthquakes, and considerations of the extent of the fault, the fault geometry,

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90/ Statement by Staff Counsel. Tr. 5591. Statement by staff witnesses Stepp and Kelleher. Tr. 6226-27.

> possibly the sense of movement, possibly the levels of stress in the area, stress conditions in the area, and the depth extent of the fault.
>
> In short, it would consider -- it would be based upon considerations of the, I guess the fault dynamics, if we could use a very generalized term, and its geometry and dimensions.

Tr. 6231.

Later, when pressed for a course of action if the data showed the worst possibility, Dr. Stepp stated:

> Well, let's suppose that the data -- for a moment suppose the data caused us to conclude that earthquakes are being localized along -- preferentially along the Ramapo Fault system; that is, that it has a greater risk of having -- a greater probability of having earthquakes, if they should occur in the region, localized along it than would be the case assuming scattered activity throughout the region.
>
> Then the course of action we would take is to assess what the maximum earthquake activity would be on it.
>
> There are several outcomes from that, it seems to me.
>
> (Q. All right, Now on what basis do you do that?)
>
> The assessment would be made, based upon the nature of the activity along the fault zone. Maybe it clusters only at Pompton Lakes and there's not another earthquake along the fault zone anywhere. Maybe those focal mechanisms are eventually shown to be incompatible with the geometry of the Ramapo Fault system. Maybe they are compatible but it clusters only there. Then that would pose one situation.

> Maybe the earthquake activity is rather uniform along the extent of the fault. That would pose another situation.
>
> One outcome could be that -- and it would seem to me the most likely one, in the event we concluded that earthquake activity was being localized along this fault zone at all, one outcome could be that we would accept the maximum earthquake as being represented by the maximum regional earthquake just as we've done now, and we would say something like an Intensity VII might be produced by this fault zone, or a magnitude 5-plus.
>
> But the difference would be that if we concluded that this fault is in fact localizing earthquakes is that -- we would have to consider that that particular earthquake has a greater likelihood of being localized near the plant than we now have considered.
>
> And our recommendation most likely would be that the design response spectrum be reevaluated to determine whether or not it embraces an earthquake of that magnitude that close to the plant site.

Tr. 6350-52.

The staff admitted that "[w]hile many [microseismic] studies have been reported in the literature, a general relationship between microearthquake activity and the occurrence of larger earthquakes significant to engineering design has not yet been established." Staff Exh. 25, p. 5. It nevertheless claimed that "because microearthquakes reflect current tectonic activity more directly than any other measurable geophysical data, they are

powerful data for evaluating the geologic causes of earthquakes." Ibid.

The staff provided no data as to the probability of finding that microearthquakes were focusing on the Ramapo, apparently basing their concern in this matter entirely on the March 11, 1976 earthquake.

4. In summary, the staff stated (id. at p. 7) three reasons for requiring the expanded network:

> 1. If the tectonism is uniform in the area a larger network will get more data in less time.
>
> 2. A greater potential will be provided for gathering data for more focal mechanism solutions and from there to assess whether there is the potential for movement along a particular fault.
>
> 3. The network should show whether or not earthquakes are concentrated along the Ramapo fault.

C. State Testimony

The testimony[91/] for the State of New York was presented by its witness, Dr. Aggarwal, and it discussed Board questions 1 and 3.

91/ State Exh. 19, "Testimony of Dr. Yash Pal Aggarwal on Behalf of the State of New York". Tr. 6379-91. Certain parts of this testimony were stricken following a motion by the licensees (March 8, 1977). See also Tr. 5969-92, 5995-6017, 6161-73, 6177-81, 6303-05, 6379-95.

State Exh. 20, "Supplementary Testimony of Dr. Yash Pal Aggarwal on Behalf of the State of New York". Tr. 6396-6403.

1. The major portion of the written testimony concerned question 1 and the State's position on the need for an expanded microseismic network. The State maintained that "[i]n order to evaluate risk to public health and safety from the Indian Point nuclear facility, it is necessary to evaluate the seismic potential of the Ramapo Fault System." State Exh. 19, p. 6. To do this the State urged that one must (a) understand the "earthquake problem" in the eastern United States, (b) critically evaluate the historical record of earthquakes in the area of interest, and (c) consider the seismotectonics of southeastern New York and northern New Jersey in light of the most recent instrumental data. Ibid. On the basis of such requirements, the State concluded that an enlarged microseismic network is necessary.

To support its conclusion, the State's testimony discussed the relatively brief historic record of seismicity in eastern United States compared to the longer record in China. Since historical events of intensity VI and VII have occurred in southeastern New York and northern New Jersey, the State observed that "* * * [i]ntensity VII or greater events may occur in this region in the future". Id. at 8.

Finally, the State maintained that, since it is futile to attempt to associate historic events "with faults in this area" (id. at 9),

> the alternative is to examine the more recent instrumental data for seismic events in the area and to ascertain whether these more accurately located events show any relationship to local faults. If such is the case, then we can conclude with reasonable certainty that the historical events were also associated with faults in the area.

Ibid.

The State asserted that the necessary instrumental data can only be supplied by an expanded microseismic network because this will be able to detect microearthquakes along the Ramapo fault with enough precision to allow calculations of focal mechanism solutions. In the State's opinion only such precise information can link a particular fault with a given earthquake. Id. at 18-19.

The State asserted that the present microseismic network is inadequate since, of eighteen earthquakes reported in the general area in the last three years, focal mechanism solutions were obtainable on only eight.92/ It claimed that, had the expanded network been in operation, more focal plane solutions might have been obtained and uncertainties in one of the present solutions eliminated.

92/ State Exh. 20, p. 1.

State Exh. 19 at p. 19. The State thus implies that a decision could be reached as to whether the Ramapo fault is localizing current seismicity.

2. The State's answer to our question 3 asserted in essence that the focal plane solutions are the only way to determine stress orientation at the depth of the hypocenter and that shallow direct stress measurements may or may not indicate the same stress orientation. The placement of an expanded network therefore does not depend on completion of shallow stress measurements. State Exh. 20, p. 3.

II. Discussion of the Testimony

A. Question 1

As above noted the first question posed by the Board was:

> Is an enlarged microseismic monitoring network warranted for reasonable assurance of public health and safety in connection with the Indian Point nuclear facility?

ALAB-357, supra, 4 NRC at 551.

We will discuss the testimony received in response to this question in the light of 10 CFR 100, Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants". If we find the answer to this question to be negative the remaining questions need not be considered.

In Appendix A which was adopted in November 1973[93/] (just 1-1/2 years before the staff condition was imposed) the Commission set forth:

> * * * the principal seismic and geologic considerations which guide the Commission in its evaluation of the suitability of proposed sites for nuclear power plants and the suitability of plant design bases established in consideration of the seismic and geologic characteristics of the proposed sites.

10 CFR 100, Appendix A, Section I.

These criteria are primarily based on the geology and seismicity of the geographic region around the site with particular regard to the geologic and seismic history of the area. Particular emphasis is placed on faulting near the site and determinations of whether such faults are "capable."

The definition of a "capable" fault given in Appendix A, Section III(g) is of particular importance but since this definition has already been quoted in full under issue 3 (see p. 76, supra), we will not repeat it here. Further, in imposing condition 2C the staff placed reliance on paragraph IV(a)(7) which reads:

93/ See 38 Fed. Reg. 31281 (Nov. 13, 1973), as amended at 38 Fed. Reg. 32575 (Nov. 27, 1973).

> For faults, any part of which is within 200 miles of the site and which may be of significance in establishing the Safe Shutdown Earthquake, determination of whether these faults are to be considered as capable faults. This determination is required in order to permit appropriate consideration of the geologic history of such faults in establishing the Safe Shutdown Earthquake. For guidance in determining which faults may be of significance in determining the Safe Shutdown Earthquake, Table 1 of this appendix presents the minimum length of fault to be considered versus distance from site. Capable faults of lesser length than those indicated in Table 1 and faults which are not capable faults need not be considered in determining the Safe Shutdown Earthquake, except where unusual circumstances indicate such consideration is appropriate.

Since we have determined in Issue 3 that the Ramapo fault is not capable, we must now decide (1) whether, in accordance with section IV(a)(7), there are unusual circumstances here that require special investigations; and (2) whether the installation and operation of an expanded microseismic network is a required part of these investigations.

When asked for a statement of what was considered to be the special circumstances which required further investigation of the Ramapo fault, staff witness Stepp replied:

> The unusual circumstance here is founded both in the geologic history of this particular fault zone and in the seismicity of the area,

> in my view. The geologic history of the fault is such that it has been a locus of movement dating from pre-Cambrian time, at least into the Mesozoic time, a period of several hundred million years, and spanning many different orogenic phases, several different orogenic phases, I should say.

Tr. 6336.

In further questioning, Dr. Stepp asserted that there is "a higher level of seismicity in this general region." Tr. 6337. He later admitted that seismicity around Indian Point, while higher than seismicity to the west, is not higher than the activity to east of the site or for that matter not more than the rest of New England in its entirety. Ibid.

Despite this lack of unusual seismicity compared to the rest of New England, we agree with Dr. Stepp that the historical circumstances of the Ramapo fault structure are somewhat unique in that it is a fault system which, though not capable now, has had a history of movement through the geologic ages and does have splays which are close to the site of a nuclear facility. It is therefore appropriate to be sure of the most recent age of movement and of the location of the fault.

In Supplement No. 3 to the SER for the Indian Point Nuclear Generating Station, the staff briefly stated the

special program of investigations required by license amendment 2C as follows:

(1) Geological mapping in sufficient scope and detail to accomplish the following:

(a) Definition of the main trace of the Ramapo Fault and associated faults of the Ramapo Fault System.

(b) Structural and tectonic relationship of the Ramapo Fault System with faults at the Indian Point site.

(c) Identification of crosscutting features and faults which might be used to determine the age of most recent movement on faults of the Ramapo system.

(d) Age dates of the fault along those sectors near the epicenters of the 1951 Rockland County, New York, earthquake and the 1976 Pompton Lakes, New Jersey, earthquake.

(2) Determination of the age of most recent movement on the Ramapo Fault and the Ramapo Fault System by appropriate age dating techniques and relationship to crosscutting features.

(3) Determination of the relationship of current and historic earthquake activity to the Ramapo Fault and Ramapo Fault System. The existing earthquake monitoring network is to be extended southward to include the Pompton Lakes, New Jersey epicenter area and northward to include the Fahnstock region. The density of the network should be sufficient to obtain precise locations and focal mechanism solutions. Velocity studies needed to obtain reliable earthquake locations and mechanism solutions should be conducted. This network is to be operated at least two full years following complete installation of all stations. These studies should be supplemented by stress measurements to define the current tectonic environment of the area.

> (4) Additional geochronological age dates of most recent movements shall be obtained on those faults observed in the immediate vicinity of the plant, including each of the different fault sets. Fluid inclusion dates are to be confirmed by dating other mineral assemblages and/or by using other dating techniques.

Staff Exh. 24, p. 2-7.

Only the part of item 3 of this list covering the proposed installation and operation of an additional microseismic monitoring network is being questioned in this proceeding. In other words, because of the special circumstances that we have discussed (see p. 131, supra) on the relationship of the Ramapo fault to the Indian Point nuclear facility, major projects of mapping, age dating and stress measurements are being accomplished in a large area surrounding the Indian Point site. What we must now decide is whether, in addition to the programs already completed or underway, data from an enlarged microseismic network would be of any real significance in assuring the health and safety of the public insofar as the nuclear facilities at Indian Point are concerned.

As we have seen, the State of New York and the NRC staff insist that the condition is necessary to make the decision for reasonable assurance of health and safety. The licensees insist it is worthless in this respect.

1. We will first consider the license condition for the microseismic network in the general terms of whether the condition is a proper one under Appendix A. After consideration of the record before us, it is our opinion for the reasons given below that it is not.

a. We note first of all that mention of instrumentally determined earthquakes in the definition of a capable fault concerns only those earthquakes which produce macroseismicity. On cross-examination the staff was asked to explain, if microearthquakes are one of the better (if not the best) source of information, why microseismic evaluations were not specifically included in Appendix A. Staff witness Stepp gave the following answer:

> The answer is that I don't really know. I could speculate and I think it would be somewhat informed speculation because it's a question that I've asked a number of times myself.
>
> If I understand the reasoning that went into it, it could be specified as that related to the state of the art of the use of microearthquake data and a cost-benefit you might say reason with regard to the state of the art when Appendix A was being formed. Microearthquake studies was even in more infancy than it now is in. And the people who were forming Appendix A, some of them at least, held the strong view that such information would create more confusion than not and eventually the use of microearthquake data was not included in the Appendix.

> Part of the reason, I believe, for it not being included in there is that we do not have these data available to us. The Appendix was written around data that are available to us in ordinary circumstances. Microearthquake information, microearthquake data are generally not available to us because the level of the netowrk capability that we have is simply not sufficient to provide those data.
>
> Moreover, and this, as I understand it, was a very large factor in the consideration to include or not include the data, one could not place great reliance on the locations for as you go down in magnitude fewer stations record the events. The scatter in the data become greater and reliance on the epicenters becomes weakened.
>
> So for all of those reasons a requirement to consider microearthquake data was not included in Appendix A.

Tr. 6277-79.

Dr. Stepp agreed that Appendix A is a recent regulation having become effective in December 1973 and he gave no indication that any great advance in microseismic techniques had taken place in the 18-month interval between December 1973 and April 1975 when the condition was imposed.

b. Witnesses for all of the parties agreed that the focal plane mechanism can provide data concerning the direction of the stress field at the hypocenter but can give no indication of the magnitude of the stress. Licensees, Tr. 5934; State, State Exh. 19, p. 13 and Tr. 6507;

Staff, Tr. 6270. However, it was noted by staff witnesses (Tr. 6269-72) and agreed to by Dr. Aggarwal (Tr. 6511-12) that, if the earthquake occurs near a pre-existing fault, the uncertainty of the direction of the principal stress is at least ±20° and may therefore present an erroneous picture of the stress orientation near the fault.

c. In various discussions during the hearing several ways in which microseismic monitoring systems had been used were mentioned. Primarily such systems have been used in areas of high activity for monitoring the seismicity of faults known to be active. In these cases the number of micro-occurrences was large -- perhaps several per day. In one or two instances a decrease in the frequency of microseismic events has been shown to have preceded by some hours or days the occurrence of a larger quake. Tr. 5826-27.94/

In low seismicity areas, however, microseismic networks had previously been required by NRC to meet special situations in two instances, e.g., in one case to monitor the change

94/ Several references were cited here by licensees' witness Dr. Werner to papers by Dr. Sykes, State witness on issue 1, and Dr. Kelleher, now a member of the NRC staff and a witness in this proceeding.

in microseismicity during and following the filling of a large reservoir. No usage has previously been made of microseismicity by itself in either low or high seismic areas to establish a relationship between microseismic events and the potential of a fault for larger movement. Tr. 6360. This is demonstrated by the following staff testimony:

> Q. Gentlemen of the panel, let me ask if you will direct your attention to page 2 of your testimony, the first full paragraph which starts there in the middle of the page and there it's your testimony, is it not, that an expansion of the network is required:
>
> "... so that a more accurate determination of what the relationships are between earthquakes and geologic structures in the region...."
>
> That correctly states your testimony, is that correct?
>
> A. (Witness Stepp) Yes, that's correct.
>
> Q. Do you expect to be able through the use of this microearthquake data to define any type of relationship between these earthquakes and structure that would allow you to assess the potential of an event in excess of the SSE?
>
> A. I would like to answer no and then explain why.
>
> We do not expect these microearthquake -- any microearthquakes that may be located by this network to lead directly to an assessment of a larger than SSE earthquake. In fact we had not even considered that at this point and we think that such an earthquake would be

> extremely remote based upon regional considerations and that's why we accept the level of SSE that we have accepted. We think that's consistent with the level of conservatism that is embodied in Appendix A.
>
> The measure to which that might be drawn upon for such a determination is really not clear to me at this time. I would not wish to state one way or the other whether one could extrapolate from a set of small earthquakes to predict larger earthquakes.

Tr. 6226-27.

Given these considerations we do not believe that a research project with such tenuous usefulness is one which should be required of an applicant or licensee under Appendix A.

d. Finally, we observe that the staff has apparently ignored the third paragraph of Appendix A, section III(g)(3) (see p. 76-77, supra) which appears to fit the situation at the Indian Point site. This paragraph states:

> Notwithstanding the foregoing paragraphs III(g)(1), (2) and (3), structural association of a fault with geologic structural features which are geologically old (at least pre-Quaternary) such as many of those found in the Eastern region of the United States shall, in the absence of conflicting evidence, demonstrate that the fault is not a capable fault within this definition.

As we have seen in section 3 of this decision (pp. 79-81, supra), the licensees and staff agree that the latest movement along either the Ramapo fault system

or the faults on the east side of the Hudson appears to have occurred at least several million years ago. The State claims that the faults sampled have not been proven to be the youngest but they admit that there is no physical evidence at or near the surface of movement in at least the last 500,000 years. See p. 81, supra.

We find that the weight of the evidence strongly indicates that there has been no movement in the faults around Indian Point since the end of the Mesozoic period. On this basis there is no need for the "additional investigations" suggested by Section II of Appendix A[95/] beyond mapping and age dating.

2. We will now assume arguendo that we have erred in our decision in subsection 1 above and examine the actual seismic situation that we find around Indian Point. A microseismic network of 13 stations around Indian Point has been in use for over 18 months.[96/] The system began

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95/ Appendix A, Section II, "Scope," third paragraph.

96/ The network stations are located over an area of approximately 300 km^2 (25 km northeast-southwest, 12 km east-west). One station is 20 km west of the main group. State Exh. 19, p. 2 and Fig. 2. Within the area surrounded by the stations the network is capable of detecting an earthquake down to magnitude zero or a little less. Tr. 5667.

operating in June 1975 and became fully operational in September of 1975. Since that time licensees' quarterly reports to the NRC indicate that some 839 tremors have been recorded.[97] Of these only 18 appear to be natural events, the remainder being disturbances caused by quarry and construction blasting.

The State's testimony indicates that since April 8, 1974 the Indian Point network together with the Lamont-Doherty and Connecticut seismic networks have recorded a total of 18 events of possible interest to the Indian Point facility.[98] Of these the four events at Wappinger Falls, which may have been quarry blasts, are agreed by all parties to have no relationship to the Ramapo Fault. Similarly, the earthquakes at Schooley Mountain were over 75 km from Indian Point and apparently not connected with the main Ramapo Fault.[99] We are thus reduced to a consideration of 12 events during the last two years. These 12 events taken in chronological order and numbered as in the State's Table 1 (see fn. 98, below) are shown in the following table:

97/ See Quarterly Reports for the Seismic Monitoring Program for Indian Point dated Oct. 22, 1975, Jan 5, 1976, April 12, 1976, Aug. 10, 1976, Nov. 8, 1976 and Feb. 14, 1977.

98/ State Exh. 19, Table 1, appended thereto.

99/ State Exh. 19, Table 1 and State Exh. 20, Fig. 1.

Table 3

No.	Magnitude	Location*/	Date
5	2.1	7 km S.SW of I.P. close to splay of Ramapo **/	4/8/74 (prior to operation of I.P. network)
9	2.3	20 km N.E. of I.P.	7/19/75
10	2.3	15 km S. of I.P. ~12 km S.W. of Ramapo	8/22/75
12	1.5	40 km S.W. of I.P. 5 km from Ramapo	11/10/75
13	1.0	17 km S.E. of I.P. 17 km from Ramapo and east of Hudson River	3/6/76
14	2.5)	50 km S.E. of I.P.	3/11/76
15	1.8)	Close to Ramapo	3/12/76
16	3	50 km S. of I.P.	4/13/76
17	2.5	27 km S.E. of I.P. 25 km from Ramapo; east of Hudson River	8/20/76
18	1.8	About 2 km N. of I.P. in the Hudson River	9/22/76
19	1.0	60 km S.E. of I.P. may be near extension of Ramapo	10/28/76
20	1.9	30 km S. of I.P. 20 km from Ramapo east side of Hudson River.	11/22/76

*/ All distances given in the table are scaled from Fig. 1 of State's Supplemental testimony. State Exh. 20.

**/ Distance from fault is stated along a line perpendicular to fault trace to epicenter.

From this table we see that only two events (5 & 18) occurred within the Indian Point network, i.e., within 13 km of the site. Of the rest, only 12, 14, 15 and 19 can conceivably be directly connected with the Ramapo fault.

We believe that it is important to note that the two earthquakes (5, 18) nearest to the Indian Point facility appear to be near splays of the Ramapo. Staff witness Kelleher emphasized the importance of this with the following remarks:

> If there's a complicated fault system and if there's -- In general, the more heterogeneous it is, the more splays, the more broken up, the more transfer structures, in general the smaller will be the earthquakes associated with that.
>
> So if you have a very complex, complicated fault system with a lot of splays on it, and you're getting a number of different events on these, small events, microearthquakes on various parts of the system, I would not necessarily feel that there was potential for a much larger earthquake.

Tr. 6286.

In the case of earthquake 18 (the September 22, 1976 event) which occurred just to the north of Indian Point, State witness Aggarwal was of the opinion that this earthquake was most probably associated with the Timp Pass fault, a member of the Ramapo fault system. Tr. 6479. Dr. Aggarwal pointed out that his focal plane solution of

earthquake 18 showed a fault dip of approximately 62° and hypocenter depth of 8 km. He stated that this dip extending from the hypocenter to the surface would come close to the surface trace of the Timp Pass fault. Tr. 6479-85.

In rebuttal testimony, however, the licensees witnesses Werner and McWhorter presented a strong argument that the actual measured dip of the Timp Pass fault is 81°. Tr. 6562, et seq. Since this fault is a strike-slip fault, Dr. Werner explained that the dip measured near the surface will be maintained at depth:

> Q. (Mr. Curley) * * * What we're talking about is a dip at the surface. Must that angle continue to depth?
>
> A. (Dr. Werner) I would say yes it is a law established on several levels, the one being the rock mechanics level where observations are that, you know, in response to a given stress system you're going to have a planar break develop, a flat planar break and that's what the fault represents.
>
> Additionally there are field observation studies -- I can't give you exact citations right now because I don't have the material with me, but I would reference the work of Handon relative to rock mechanics.
>
> There are field studies which indicate that strike-slip faults as a class are planar. They maintain their dip at depth and in that I would cite the works of Moody and John Wilcox.

Tr. 6571-72.

Under these circumstances the Timp Pass fault could not extend eastward to the hypocenter of earthquake 18.

It should be noted that events 12, 14, 15 and 19, at least three of which were detected by the Indian Point network and a focal plane solution obtained on one, are at the extreme southern end of the proposed expanded network. In addition, Figure 1 of State Exh. 20 indicates that five (10, 13, 16, 17, 20) of the earthquakes in their Table 1 are located east of the Ramapo fault, three of them east of the Hudson River. In answer to a Board question (Tr. 5536) as to the significance of a hypothetical scatter of earthquakes either close to or at some distance from a fault, staff witness Stepp gave the following comment:

> So that to answer your question, Mr. Farrar, directly, the fact that micro-earthquakes may be scattered rather randomly throughout a broad region here, occurring on many faults, even though the overall stress system may be consistent with movement on the Ramapo, the distribution of the earthquakes in a more random fashion would suggest that at the very worst, if we speak of worst in terms of hazard of movement of faults, all of the faults in the area of some kind of equal participation in the deformation that is going on, so that if one then distributes the level of seismicity among all of these faults, it gets pretty much diluted so far as the significance that it has for movement on any one of the faults.

Tr. 5540.

In summary, it is apparent to us that the picture presented by the data from the existing Indian Point, Lamont-Doherty and Connecticut monitoring networks is of a very few microearthquakes in a large region about the Indian Point facility. Only three of these earthquakes were within 12 km of the Indian Point site and at worst these may have been connected with splays of the Ramapo fault. Five of the earthquakes were 40 km or more southeast of the site near the southern extension of the Ramapo fault. The remainder of the events were well east of this fault. This picture would be in accordance with the historic data shown by applicants plate C2.[100/] This plate shows a trend line of historic earthquakes in the area running north-south some 30 km east of Indian Point. The activity appears to increase as one goes east from the area of the Ramapo and decreases to the west of the fault.

The preponderance of the evidence indicates that an expanded network will not produce data to enhance assurance of public health and safety. The data already at hand from the existing networks do not provide any basis for requiring an additional network. Thus we find no

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100/ Attached to licensees testimony (Lic. Exh. 26) on issue 3 of this proceeding.

justification for requiring the installation by the licensees of the expanded monitoring network.

Findings

For the reasons given in this opinion, we have made the following findings:

1. No historic event requires the assumption, in accordance with 10 CFR, Part 100, Appendix A, of a Safe Shutdown Earthquake greater than Modified Mercalli intensity VII for the Indian Point facilities.

2. The horizontal ground acceleration design value should remain at 0.15g for the Indian Point site based on a maximum probable earthquake of intensity MM VII.

3. The Ramapo fault is not a capable fault.

4. That section of Amendment 2 to the Indian Point Unit 3 operating license numbered 2(C)(4)(c), which contains the requirement for an enlarged microseismic monitoring network will not add to the assurance of public health and safety and is unnecessary.

5. Determination of the seismic risk in the eastern United States through delineation of tectonic provinces is difficult. Because of advice from its geologic advisory

committee the staff has not promulgated an official tectonic map of eastern United States, nor has it issued guidelines to the industry to aid it in developing such provinces. It now appears that the U. S. Geological Service which had a major role in developing Appendix A has expressed the opinion "that the Appendix would be extremely difficult to apply and would lead to a lot of confusion in the assigning of tectonic provinces." Tr. 3778-79.

6. In this proceeding the licensees presented the most reasoned scientific approach to the selection of tectonic provinces and the staff offered no opposition to those provinces. We have accepted most but not all of them.

7. If the tectonic province approach is to remain viable, guidelines must be issued so that the industry and public alike can be aware of the ground rules. In other words the staff must know, and tell others, what rules it is trying to enforce.

As the result of these findings, we conclude that the operating licenses for Indian Point units 2 and 3 should not be modified except with respect to amendment 2 to

the Indian Point unit 3 license. That amendment is to be modified by the deletion of that portion of section 2(C)(4)(c) which relates to installation of an expanded microseismic monitoring network.

The licensees should be allowed to continue operation of the unit 1 fuel storage pool, but before operation of that reactor may be resumed necessary modifications must be made to ensure the public health and safety in the event of an intensity VII earthquake.

It is so ORDERED.

FOR THE ATOMIC SAFETY AND LICENSING
APPEAL BOARD

Margaret E. Du Flo

Margaret E. Du Flo
Secretary to the
Appeal Board

The opinion of Mr. Farrar, dissenting in part, follows.
See pp. 153-60, infra.

Opinion of Mr. Farrar, dissenting in part:

I disagree with my colleagues on a number of counts, and thus cannot join in the opinion which they have prepared. It will be some time, however, before I can complete the writing of a full response to what they have said, and they are anxious to issue their opinion. 1/ Considering all the circumstances, we have agreed that the best course to follow in this case is to release their opinion now, accompanied by only an outline of the main points on which my views differ from theirs. I will supply a complete opinion as soon as possible, and in it set forth a detailed analysis supporting my conclusions.

1. A number of earthquakes greater than Intensity VII (the level taken into account in designing the second and third units of this plant) have occurred in and around the Eastern seaboard in the past 200 years. Under the Commission's regulations, we must assume that earthquakes of this size

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1/ Although the majority decision does not call for any change in the status quo of the facility, its authors believe that some of their holdings will be important in other cases, and that licensing boards should therefore have the guidance of their opinion now. Particularly important, in their judgment, is the need for senior NRC staff management to focus on the ambiguities concerning the meaning and application of the tectonic province concept embodied in the present regulations (see pp. 55-61, supra).

will recur; the question is -- where? In that connection, we are told by the regulations to assume that, unless a prior earthquake can be associated with a particular structure, it can happen again anywhere in the same "tectonic province". Such a province is defined as "a region of the North American continent" having "a relative consistency of * * * geologic structural features * * *."[2/]

In deciding which of the widely varying versions of proposed tectonic provinces to accept, we must be conscious of the context of our inquiry. In searching for "relative consistency", we should be paying particular attention to those features which are similar or dissimilar in terms of what they signify in terms of earthquake potential. In other words, structural differences which have no discernible bearing on the present likelihood of earthquakes should not, as I read the regulations, form the basis for drawing province boundaries.[3/]

2/ 10 CFR Part 100, Appendix A, §III(h).

3/ In light of this principle, and the fact that the definition of a province is couched in terms of a "region" of the "continent", I find perplexing the majority's unbuttressed statement (pp. 33-34, supra) that it is "inconceivable" that the drafters of the regulation could have intended that only so-called "first-order" characteristics be employed, resulting in provinces of the size proposed by the State. The suggestion that any such intent would have been stated "explicitly" ignores the imprecise wording of the regulation, which was deliberately drawn with vague contours. Indeed, one of

(FOOTNOTE CONTINUED ON NEXT PAGE).

I am not convinced that in all instances the majority opinion adheres to this principle. Yet my colleagues should not necessarily be faulted on this score, for the lengthy hearing revealed a paucity of knowledge about earthquake mechanism. In the face of this inexactitude, our task is difficult but our course is plainly marked. As I have stressed before, "in recognition of the gaps in our understanding of earthquake occurrence and mechanism, the Commission's regulations insist that in this area, more so than in others, conservatism be the watchword".[4/]

Without going into detail at this time, I can say that my conservative application of what I believe to be the controlling principle leaves me at odds with my colleagues on some of the province boundaries they adopt. But, in light of the imprecise state of the art, I would be exceptionally careful to avoid deciding matters not absolutely necessary to the disposition of this case. In

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3/ (FOOTNOTE CONTINUED FROM PREVIOUS PAGE).

the reasons the dispute on this issue was so sharp, and the evidence so voluminous, was precisely because the deceptively simple definition of tectonic province leaves so much room for differing interpretations.

4/ Public Service Co. of New Hampshire (Seabrook Units 1 and 2), ALAB-422, 6 NRC ___, ___ (July 26, 1977) (dissenting opinion) (slip opinion, pp. 172-73).

this connection, it can be seen from the majority's opinion that the disputes which are crucial to a decision involve relatively few earthquakes and province boundaries. Thus, my opinion will deal with this issue on as narrow a basis as possible. I cannot now, before my own analysis is complete, say with certainty whether I will be able to endorse the majority's ultimate conclusion on the first issue, i.e., that it was acceptable to use only an Intensity VII earthquake as the starting point for plant design.

2. The Commission's regulations go on to require that, once a forecast is made of the highest intensity earthquake likely to be felt at the site of a nuclear power plant, the plant be designed to take account of the "maximum" acceleration which might result from such an earthquake.[5/] 10 CFR Part 100, Appendix A, §VI(a). We have indicated elsewhere that this requirement was not intended to be applied literally; it is to be understood as referring

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5/ In effect, then, the regulations require that the somewhat subjective intensity ranking (see p. 8, fn. 6, supra) be converted into a specific, objective measurement of the force which the earthquake in question might bring to bear on the nuclear power plant.

only to a lesser quantity, i.e., maximum effective acceleration.[6] But even at that, the majority's decision on how to determine the effective acceleration level to be associated with a particular intensity suffers from the same deficiencies which I outlined when the identical question came up in Seabrook.[7] In both instances, the board majorities settled upon a figure which has not in my judgment been shown to correspond in any significant way to the maximum effective acceleration for the intensity in question.

In a nutshell, the problem is this. The basic data relied upon, about which there is no dispute, have been taken from a large number of earthquake records. Tracings -- called seismograms -- recording the acceleration measured by an instrument at a particular location during a particular earthquake have been grouped according to the intensity believed to have been felt near the location of the seismograph

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6/ Seabrook, ALAB-422, supra, 6 NRC at ___, ___ (majority opinion, p. 60; dissenting opinion, p. 176); see also p. 158, infra.

7/ ALAB-422, supra, 6 NRC at ___ (dissenting opinion, pp. 175-76).

during that same earthquake. The seismograms in each intensity group were then analyzed to ascertain the highest amplitude, or peak, acceleration recorded on each of them. The dispute before us involves the validity of conclusions drawn from an analysis of the several peak acceleration figures found in each intensity group.

All parties agree that it is not necessary to use the highest peak associated with a particular intensity level to represent the maximum acceleration expected for that intensity. This is because the highest peaks generally have a large component of high frequency waves which will have no discernible impact upon the facility. In other words, the maximum effective acceleration lies at some level below the highest peak.

While it is thus permissible not to insist on the use of the highest peak, there is not, in my judgment, an adequate explanation in the record or in my colleagues' opinion for countenancing use of the mean, or average, of the peaks to represent the maximum effective acceleration. This approach might have obvious merit if the several peak acceleration figures, taken from the seismograms for all earthquakes of a particular intensity, fell within a narrow

range. But their scatter is large -- the record reveals that the highest and lowest peaks associated with each of the relevant intensities differ from each other by an order of magnitude, i.e., by a factor of ten. 8/

Consequently, the mean of the peaks taken from all seismograms associated with a particular intensity might fall considerably below the level of effective or sustained acceleration found, for example, on one of the seismograms reflecting generally high levels of acceleration. And it is that quantity -- the maximum effective acceleration -- which the regulation requires be employed to represent an earthquake of the intensity under scrutiny. I cannot perceive any justification in this record for stating that the mean of the widely scattered peaks found in a number of records is inherently representative of the maximum effective acceleration latent in one. And I fail to see in the majority's decision to accept the use of the mean of the peaks any other legitimate support for doing so. I believe that an effort should be made to ascertain the maximum effective acceleration in some other, rational, manner. 9/

8/ Trifunac testimony (CCPE Exh. 1), pp. 3-4; Tr. 312-15 (the reference at Tr. 314 to the figures found in Appendix "C" of the written testimony should be to Appendix "E").

9/ The views I have been espousing may at last be gaining some degree of acceptance. See the majority's additional remarks, pp. 72-74, supra.

3. I do not take issue with my colleagues' resolution of the third issue, i.e., the capability of the Ramapo Fault. Although I would not express the reasons for my own conclusion in quite the same way they do, we all agree that the evidence thus far accumulated and presented to us does not demonstrate that any of the criteria which determine capability have been met.

Nonetheless, the staff has made what to me is a convincing presentation supporting its claim that the fault might "play a possible role in localizing earthquake activity" and that the expanded microseismic monitoring network is warranted. Thus, on the fourth issue, I must agree with the staff, the State, and the Citizens' Committee that the monitoring condition which the staff attached to the Unit 3 operating license should be upheld. I dissent, then, from the majority's opinion on that score. As previously indicated, I will explain the reasons for this conclusion, and the other views I have expressed, in a subsequent opinion.[10/]

10/ In Seabrook (ALAB-422, supra), I made a similar commitment in connection with my dissent on the seismic questions presented in that case. The Commission has extended its time to decide whether to review those questions until it receives and analyzes my opinion. (See its Seabrook order of September 15, 1977, CLI-77-22, 6 NRC __, __). As noted above (pp. 156-157, supra), one of the questions here is the same as one of those in Seabrook. Moreover, the so-called "Boston-Ottawa seismic trend" or "Cape Ann-New Hampshire tectonic province" plays a significant role in both proceedings. Consequently, I intend to release my supplemental opinion in both cases at the same time.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.	)	Docket No.(s) 50-3 50-247 50-286
	)	
(Indian Point Nuclear Generating Station, Units 1, 2 and 3)	)	
	)	
	)	

CERTIFICATE OF SERVICE

I hereby certify that I have this day served the foregoing document(s) upon each person designated on the official service list compiled by the Office of the Secretary of the Commission in this proceeding in accordance with the requirements of Section 2.712 of 10 CFR Part 2 - Rules of Practice, of the Nuclear Regulatory Commission's Rules and Regulations.

Dated at Washington, D.C. this
30th day of Oct 1977.

Office of the Secretary of the Commission

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	
CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.	)	Docket Nos. 50-3 50-247 50-286
	)	
(Indiana Point Nuclear Generating Units 1, 2, and 3)	)	(Seismic 2.206)

SERVICE LIST

Michael C. Farrar, Esq., Chairman
Atomic Safety and Licensing Appeal Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dr. John H. Buck
Atomic Safety and Licensing Appeal Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dr. Lawrence R. Quarles
Atomic Safety and Licensing Appeal Board
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Office of the Executive Legal Director
Counsel for NRC Staff
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Michael Curley, Esq.
New York State Energy Office
Swan Street Building
Empire State Plaza
Albany, New York 12223

Arvin E. Upton, Esq.
LeBoeuf, Lamb, Leiby and MacRae
1757 "N" Street, N.W.
Washington, D.C. 20036

Anthony Z. Roisman, Esq.
Roisman, Kessler and Cashdan
1025 - 15th Street, N.W.
Washington, D.C. 20036

Sarah Chasis, Esq.
Natural Resources Defense Council
15 West 44th Street
New York, New York 10036

Nicholas A. Robinson, Esq.
Marshall, Bratter, Greene, Allison and Tucker
430 Park Avenue
New York, New York 10022

Honorable Louis J. Lefkowitz
Attorney General
State of New York
2 World Trade Center
New York, New York 10047

Edward J. Sack, Esq.
Joyce P. Davis, Esq.
Consolidated Edison Company of New York, Inc.
4 Irving Place
New York, New York 10003

William H. Cuddy, Esq.
Gerald Garfield, Esq.
Dayberry and Howard
One Constitution Plaza
Hartford, Connecticut 06103

Hendrick Hudson Free Library
31 Albany Post Road
Montrose, New York 10548