

https://dspace.org/

# Seismotectonic models, earthquake recurrence and maximum possible earthquake magnitudes for South Africa

**Bejaichund, Mayshree**

**2011-03-31**
http://hdl.handle.net/10539/9298

Downloaded from a DSpace repository. https://dspace.org/

# PART 2

# Collection of Isoseismal Maps for South Africa

**Mayshree Bejaichund[1] and Erna Hattingh**

**[1]Council for Geoscience, South Africa**

**Private Bag X112, Pretoria, 0001, South Africa**

**E-mail: mayshree@geoscience.org.za**

Published in Natural Hazards, 2009, Volume 50. Pages 403-408

## Introduction

In this part a collection of isoseismal maps are presented. These maps date as far back as 1932 and capture the damage footprint of the largest earthquakes recorded by our early inhabitants. It is an essential dataset that will be used the characterise the earthquake hazard in subsequent parts of this work.

## Background

Intensity measurements are based on the direct effects of the shock generated by an earthquake on man-made structures and topography. These are often referred to as macroseismic effects. The intensity is greatest within the epicentral area and usually decreases in all directions as distance from the epicentre increases.

Many seismic intensity scales have been developed. One of the most commonly used is the Modified Mercalli (MM) 12-degree intensity scale proposed by Wood and Neumann (1931) and developed further by Richter (1958). This scale provides a detailed description of the earthquake effects on people, buildings and the environment. The European Macroseismic Scale (EMS; Grunthal 1993), most recently updated in 1998, is the basis for evaluation of seismic intensity in European countries. The INQUA scale was

recently proposed (Michetti et al. 2004) with the aim to assess macroseismic intensity on the basis of only seismically induced ground effects.

In order to determine the intensities that prevailed at different places during an earthquake, questionnaires are distributed to the general public and site visits are made to investigate the epicentral region. When all the data on the effects of an earthquake have been accumulated and after these effects are expressed in intensities, the results are usually represented in the form of isoseismal maps with curves delineating areas with different intensities from each other.

## Review of similar collections

The most complete catalogue of earthquake occurrences for South Africa up to 1949 is by Finsen (1950). This catalogue was supplemented with information on early tremors in the vicinity of Cape Town (Theron 1974). Several other works since then dealt with the seismic history of South Africa. A compilation of relevant works was made (Fernandez and Guzman 1976) where a macroseismic catalogue of earthquakes from 1620-1970 was provided. Other work on historical data available includes Fernandez and Guzman (1979), De Klerk and Read (1988) and Brandt *et* al. (2005). Specifically, for this compilation several isoseismal maps were obtained from the compilations of Krige and Maree (1948) and Fernandez and Labuschagne (1977). Since 1977, no such compilation exists. Isoseismal maps were available in isolated publications as listed in Table 1 below.

## Use and potential of the map collection

The isoseismal maps are valuable complements to the instrumental record and are particularly useful in the field of earthquake engineering. South Africa has been identified as being in a stable continental environment. Hence, relatively large earthquakes occur fairly infrequently. With information from this collection one can then quickly identify those regions having experienced large ground motion historically. This ground motion is recorded as a

macroseismic effect and has thus a direct association with infrastructure damage that was experienced at the time of the earthquake. Furthermore the damage footprint is recorded in the isoseismal traces which can be very useful in modelling earthquake propagation in these regions. In addition, these maps can be used to identify targets for future palaeoseismic and neotectonic investigations. Possible improvements that will be made to this collection are the provision of a detailed catalogue of macroseismic observations from the original reports and corresponding seismograms, where available.

## Compilation Procedure

When there was a large tremor, questionnaires were distributed to local towns to assess the severity of the tremor and the damage it caused. These questionnaires were then analysed, after which isoseismal maps were drawn. These isoseismal maps available in historical reports were revisited and digitised for this study. Five isoseismal maps were prepared by the authors for this study based on questionnaires alone. Most isoseismal maps in the historical record use the MM scale. All maps are therefore provided according to this scale.

## Final Maps

Isoseismal maps listed in this collection date as far back as 1932. The most recent event included here is the event of 23 May 2005 that occurred in the mining district of Carletonville.

The characteristics of each event (figure ID, date, location, epicentral intensity and source) are given in Table 1 below. A map showing location of the epicentre of each event is given in Figure 1. Each isoseismal event is then illustrated in the accompanying appendix.

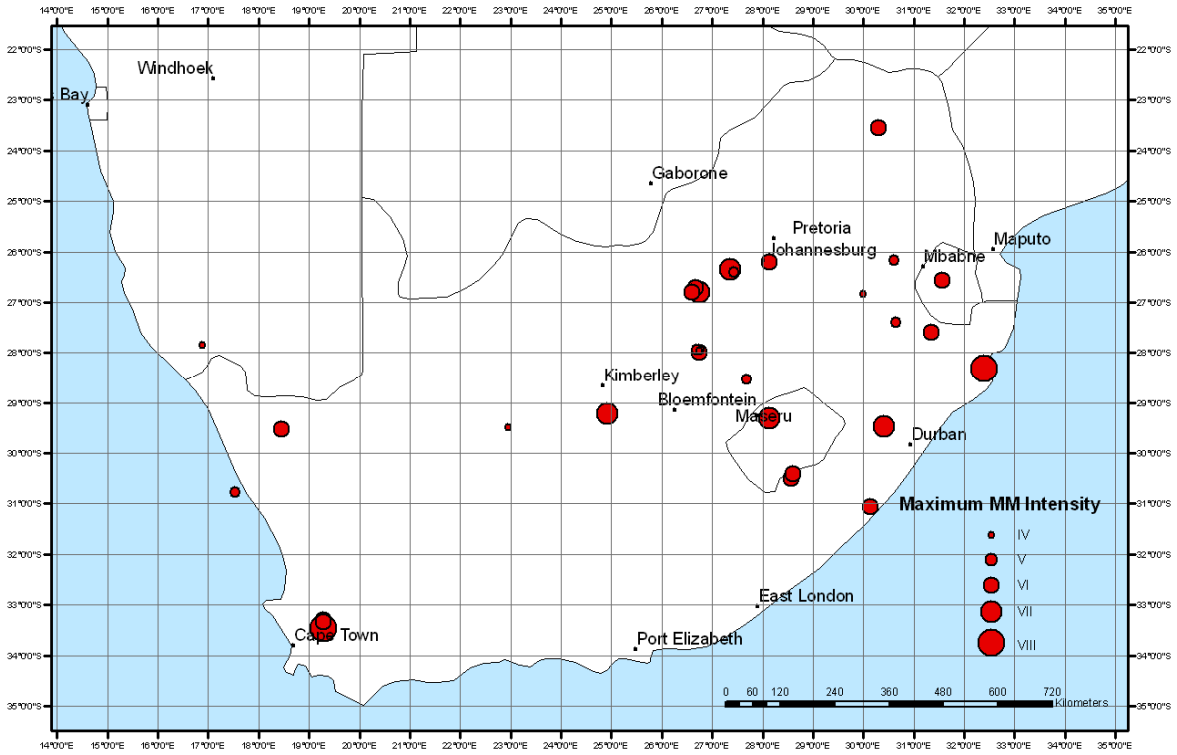



Figure 1 Map of epicentres showing maximum intensities for all events

Table 1 List of characteristics of each isoseismal event included in the collection

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| A1 | 31-Dec-1932 | -28.32 | 32.40 | VIII | Off Cape St. Lucia, RSA | The Zululand Earthquake of 31 December 1932 (Krige and Venter 1933). |
| A2 | 12-Jan-1936 | -26.57 | 31.57 | VI | Mooihoek, Swaziland | The Swaziland and Fauresmith Earthquakes of January 1936 (Krige 1936) |
| A3 | 16-Jan-1936 | -29.32 | 28.13 | VII | Fauresmith, Free State | The Swaziland and Fauresmith Earthquakes of January 1936 (Krige 1936) |
| A4 | 10-Feb-1938 | -27.60 | 31.35 | VI | Zululand | Earthquakes in South Africa (Krige and Maree 1948) |
| A5 | 29-Feb-1940 | -27.83 | 38.60 | V | Harrismith | Earthquakes in South Africa (Krige and Maree 1948) |
| A6 | 19-May-1940 | 32.33 | -24.33 | VI | Mozambique | Earthquakes in South Africa (Krige and Maree, 1948) |
| A7 | 10-Nov-1940 | -23.55 | 30.30 | VI | Tzaneen | An intensity survey following the earthquake of 17 February 1980 in the South-Eastern Transvaal. (Fernandez 1980) |
| A8 | 23-Oct-1941 | -30.78 | 17.53 | V | Namaqualand | Earthquakes in South Africa (Krige and Maree 1948) |
| A9 | 1-Nov-1942 | -31.07 | 30.13 | VI | Port Shepstone | Earthquakes in South Africa (Krige and Maree |

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| | | | | | | 1948 |
| A10 | 24-Nov-1943 | -29.50 | 22.95 | IV | Prieska | Earthquakes in South Africa (Krige and Maree 1948). |
| A11 | 17-Sep-1944 | -27.40 | 30.65 | V | Vryheid | Earthquakes in South Africa (Krige and Maree 1948). |
| A12 | 12-Nov-1944 | -28.53 | 27.68 | V | Ladybrandt | Earthquakes in South Africa (Krige and Maree 1948). |
| A13 | 29-Sep-1969 | -33.47 | 19.28 | VIII | Tulbagh | Some Macroseismic Observations in the Meizoseismal Area of the Boland Earthquake of 29 September 1969 (Keyser 1972) |
| A14 | 1-Jul-1976 | -29.22 | 24.92 | VII | Koffiefontein | Catalogue of Earthquakes in Southern Africa and Surrounding Oceans for 1976 (Fernandez and Labuschagne 1976) |
| A15 | 8-Dec-1976 | -27.93 | 26.75 | V | Welkom gold mines | The Earthquake of the 8th December 1976 at Welkom, Orange Free State (Fernandez and Guzman 1977). |
| A16 | 25-Jan-1977 | -27.85 | 16.88 | IV | Rosh Pinah, Namibia | Catalogue of Earthquakes in Southern Africa and surrounding Oceans for 1977 (Fernandez and Labuschagne 1977) |

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| A17 | 2-Mar-1977 | -33.30 | 19.28 | VI | Ceres | Catalogue of earthquakes in Southern Africa and surrounding oceans for 1977 (Fernandez and Labuschagne 1977) |
| A18 | 6-Jul-1979 | -26.20 | 28.13 | VI | East Rand Gold Mines | An intensity survey following the seismic event of 6 July1979 on the East Rand (Labuschagne and Lopez-Casado 1980). |
| A19 | 17-Feb-1980 | -26.83 | 30.00 | IV | Ermelo | An intensity survey following the earthquake of 17 February 1980 in the South-Eastern Transvaal. (Fernandez 1980). |
| A20 | 5-Oct-1986 | -30.50 | 28.57 | VI | Transkei | The Transkei Earthquake of 5 October 1986 (Graham and Fernandez 1987) |
| A21 | 29-Sep-1989 | -30.42 | 28.60 | VI | Transkei | An Investigation on the Seismic Intensities generated by the Transkei Earthquake of 29 September 1989 (Fernandez et al.1990) |
| A22 | 31-Oct-1991 | -33.33 | 19.28 | VI | Ceres | Isoseismal map compiled for this study |
| A23 | 7-Mar-1992 | -26.35 | 27.35 | VII | Far West Rand Gold Mines | The Carletonville Earth Tremor of 7 March 1992 (Fernandez et al. 1992). |
| A24 | 11-Mar-1993 | -29.53 | 18.45 | VI | Springbok | Isoseismal map compiled for this study |
| A25 | 9-Jan-1994 | -29.48 | 30.42 | VII | Howick | Isoseismal map compiled for this study |

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| A26 | 27-Jun-1994 | -27.93 | 26.68 | V | Welkom | Isoseismal map compiled for this study |
| A27 | 30-Oct-1994 | -28.00 | 26.75 | VI | Free State gold mines | Visit to the Welkom – Virginia area following the occurrence of the earthquakes of 30 October and 1 November 1994 (Saunders et. al.1994). |
| A28 | 1-Nov-1994 | -27.95 | 26.75 | IV | Free State gold mines | Visit to the Welkom – Virginia area following the occurrence of the earthquakes of 30 October and 1 November 1994 (Saunders et. al. 1994). |
| A29 | 7-Feb-2000 | -26.17 | 30.62 | V | Lothair | Isoseismal map compiled for this study |
| A30 | 6-Sep-2004 | -26.80 | 26.60 | VI | Klerksdorp gold mines | The mining event of 6 September 2004, Klerksdorp, South Africa (Hattingh et al. 2005) |
| A31 | 9-Mar-2005 | -26.80 | 26.75 | VII | Klerksdorp gold mines | A preliminary appraisal of the effect of a magnitude $M_L$=5.3 event of 9 March 2005, Klerksdorp, South Africa (Saunders et. al. 2005) |
| A32 | 23-May-2005 | -26.40 | 27.43 | V | Far West Rand Gold Mines | Tremor of magnitude ML=4.0 on 23 May 2005 Carletonville (Saunders and Molea 2005). |

## References


Brandt MBC, Bejaichund M, Kgaswane EM, Hattingh E, Roblin DLR (2005) Seismic History of Southern Africa. Seismological Series of the Council for Geoscience. No 37.

De Klerk WJ, Read J (1988) An account of historical seismicity in Southern Africa with emphasis on the southern and eastern coastal belts in: Investigation for the siting of nuclear power stations: Progress Report No. 9. Atomic Energy Corporation of South Africa Limited. Report AEC-33/89

Fernandez LM (1980) An intensity survey following the earthquake of 17 February 1980 in the South-eastern Transvaal. Geological Survey Report Number 1980-0209.

Fernandez LM, Guzman JA (1976) The seismic history of Southern Africa, Geological Survey Report Number Gh2173.

Fernandez LM, Guzman JA (1977) The Seismic Event of the 8th December 1976 at Welkom, Orange Free State. Geological Survey Report Number Gh2259, 18pp.

Fernandez LM, Guzman JA (1979) Seismic History of Southern Africa, Geological Survey of South Africa, Seismologic Series 9, pp. 1-38.

Fernandez LM, Labuschagne PGA (1976) Catalogue of Earthquakes in Southern Africa and Surrounding Oceans for 1976. Geological Survey Seismological Series 8.

Fernandez LM, Labuschagne PGA (1977) Catalogue of Earthquakes in Southern Africa and Surrounding Oceans for 1977. Geological Survey Seismological Series 11.

Fernandez LM, Craill C, Molea T (1990). An Investigation on the Seismic Intensities generated by the Transkei Earthquake of 29 September 1989. Geological Survey Report Number 1990-0005, 9pp.

Fernandez LM, Graham G, du Plessis A (1992) The Carletonville Earth Tremor of 7 March 1992. Council for Geoscience. Report no: 1992-0134.

Finsen WS (1950), The geological Distribution of some South African Earthquakes" Circular No. 110, Union Observatory, Johannesburg

Graham G, Fernandez LM (1987) The Transkei earthquake of 5 October 1986. Geological Survey Report Number 1987-0163, 20pp.

Grünthal G, (1993) European Macroseismic Scale 1992 (up-dated MSK-scale), Cahiers du Centre Europeén de Géodynamique et de Séismology 7: 1–79.

Hattingh E, Saunders I, Roblin DL, Keyser N, Molea TT, Sutherland BE (2005) The mining event of 6 September 2004, Klerksdorp, South Africa. Council for Geoscience Report Number 2005-0149.

Keyser AW (1979) Some Macroseismic Observations in the Meizoseismal Area of the Boland Earthquake of 29 September 1969 in The Earthquake of 29 September 1969 in the South-western Cape Province, South Africa. 1975. Seismologic Series 4. Geological Survey., 53pp.

Krige LG (1936) The Swaziland and Fauresmith Earthquakes of January 1936. Trans. Geol. Soc. South Africa, 39: 429-440.

Krige LJ, Maree BD (1948) Earthquakes in South Africa. Bull. Geol. Surv. South Africa., 20, 14p.

Krige LJ, Venter FA (1933). The Zululand Earthquake of the 31st December 1932. Trans. Geol. Soc. South Africa, 36: 101-112.

Labuschagne PGA, Lopez-Casado C (1980) An intensity survey following the seismic event of 6 July 1979 on the East Rand. Geological Survey Report Number 1980-0069.

Michetti AM, Esposito E, Gürpinar A, Mohammadioun B, Porfido S, Rogozhin E, Serva L, Tatevossian R, Vittori E, Audemard F, Comerci V, Marco S, McCalpin J, Mörner NA (2004) The INQUA scale. In: Vittori, E., Comerci, V., (Eds.), An innovative approach for assessing earthquake intensities based on seismically induced ground effects in natural environment. Special paper APAT, Mem. Descr. Carta geol. d'Italia, LXVII.

Richter CF (1958) Elementary Seismology, Freeman W.H., San Francisco 768pp

Saunders I, Molea TT (2005) Tremor of magnitude ML=4.0 on 23 May 2005 Carletonville, South Africa. Council for Geoscience Report Number 2005-0168.

Saunders I, Brandt MBC, Kgawsane E, Molea TT (2005) A preliminary appraisal of the effect of a magnitude $M_L$=5.3 event of 9 March 2005, Klerksdorp, South Africa. Council for Geoscience Report Number 2005-0066.

Saunders I, Brandt MBC, Nel W M (1994) Visit to the Welkom – Virginia area following the occurrence of the earthquakes of 30 October and 1 November 1994. Council for Geoscience Report Number 1994-0188.

Theron JN (1974) "Die Seismiese Geskiedenis van die Suid-westelike Kaapprovinsie". Die Aardbewing van 29 September 1969 in die Suidwestelike Kaapprovinsie, Suid Afrika. Seismologiese Reeks 4 Geological Survey, Pretoria.

Wood HO, Neumann F (1931) Modified Mercalli intensity scale of 1931, Bulletin, Seismological Society of America 21: 277–283.

# APPENDIX

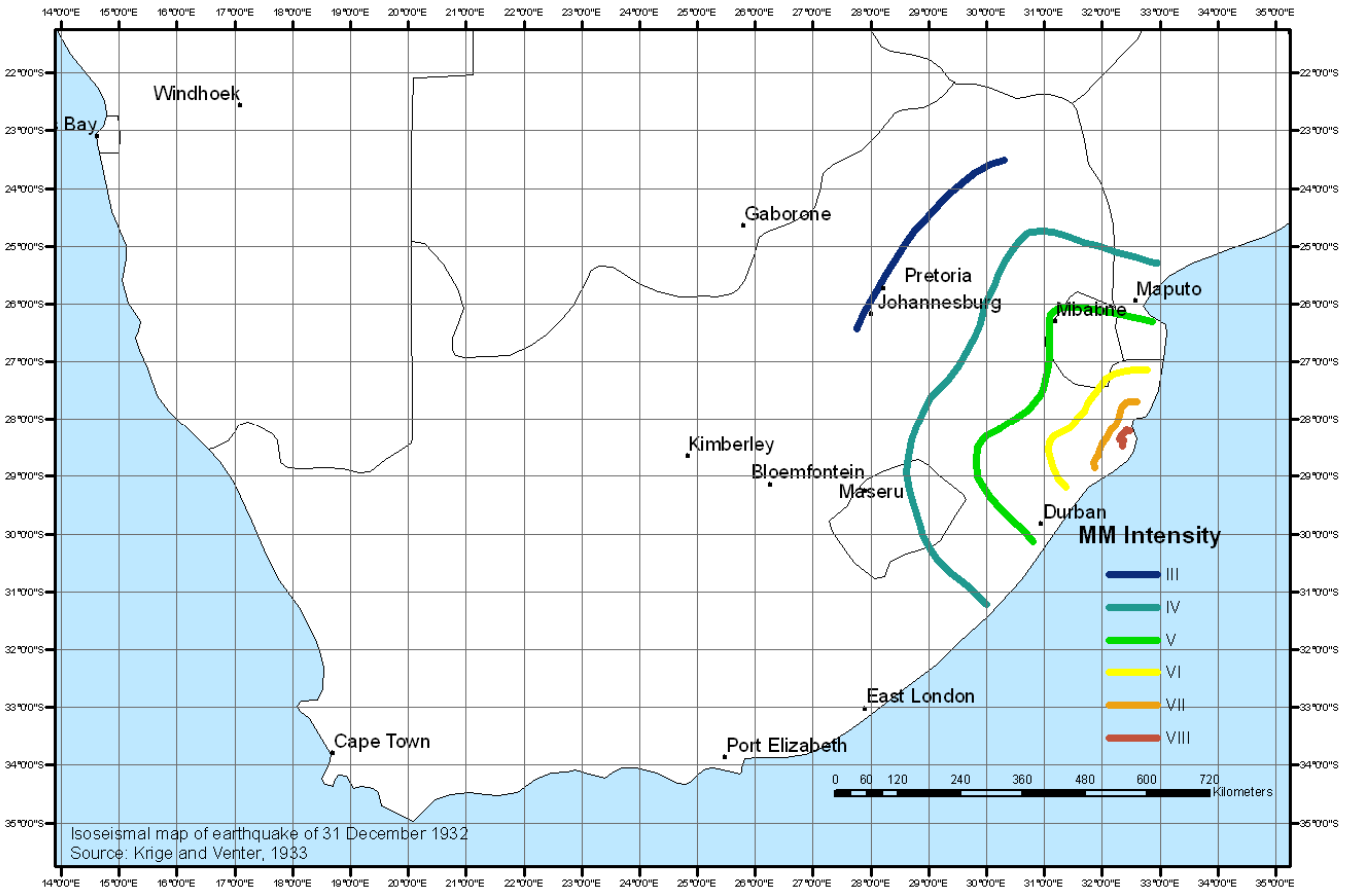



Figure A1 Isoseismal map of earthquake of 31-Dec-1932

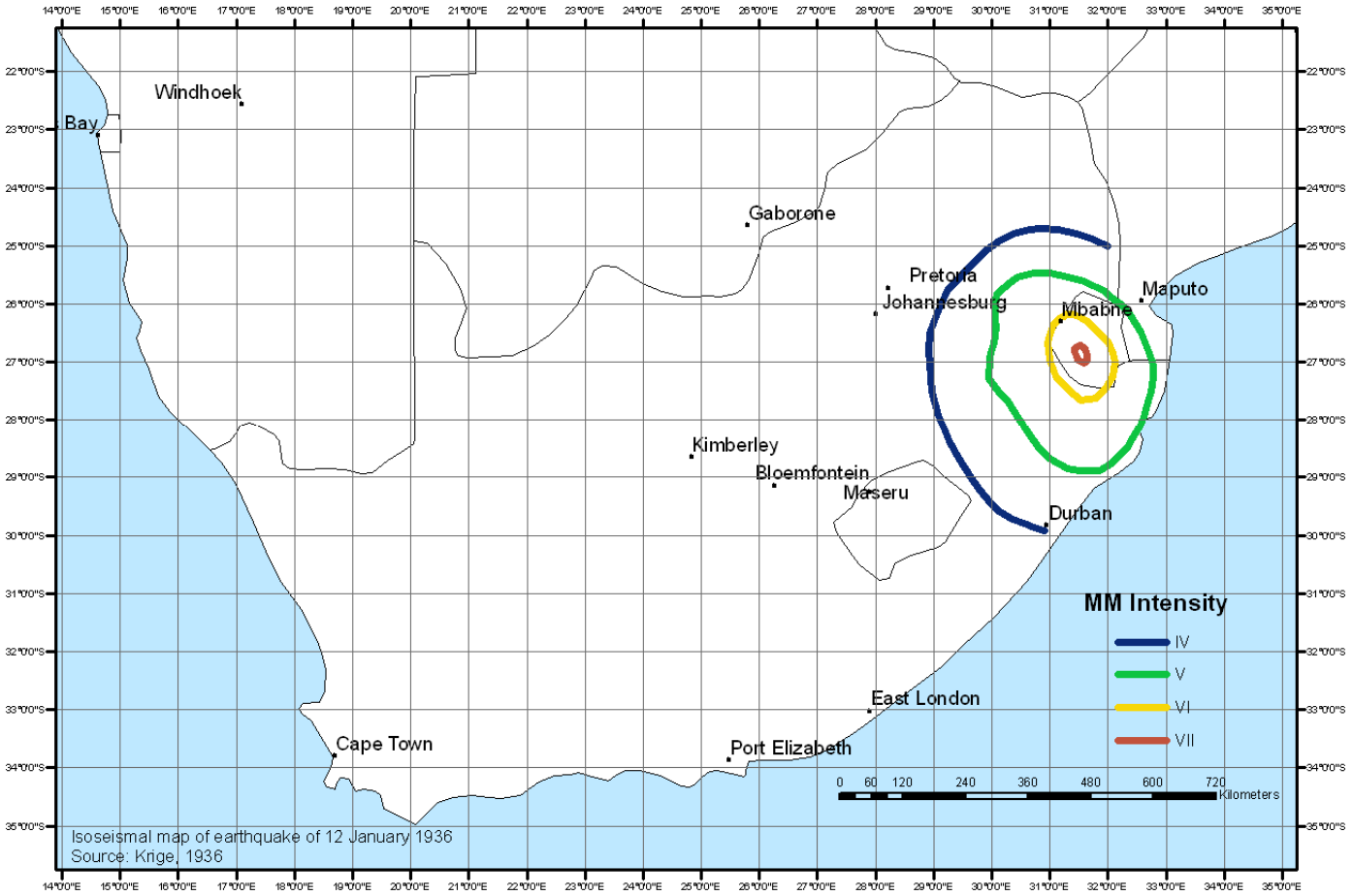



Figure A2 Isoseismal map of earthquake of 12-Jan-1936

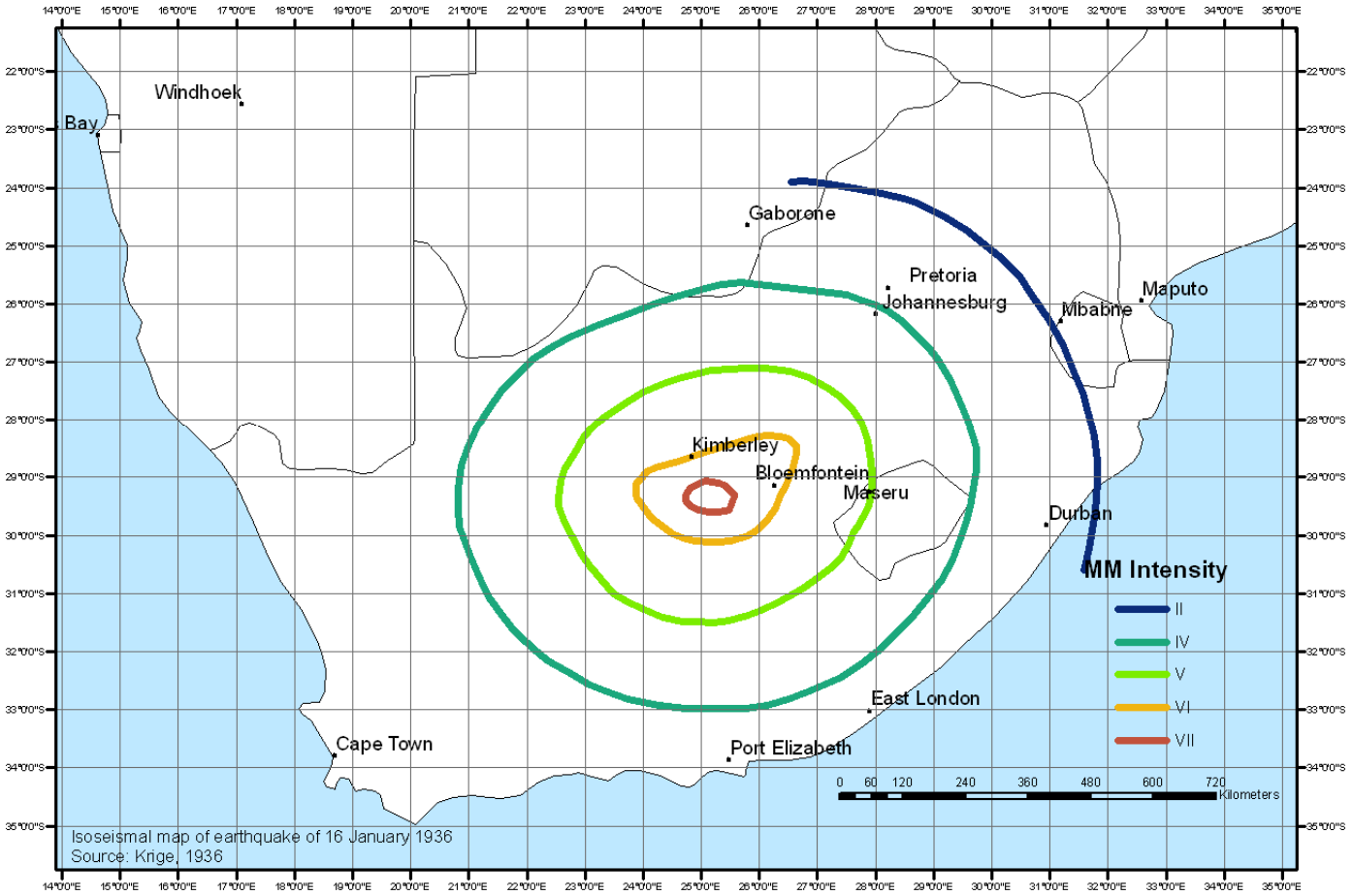



Figure A3 Isoseismal map of earthquake of 16-Jan-1936

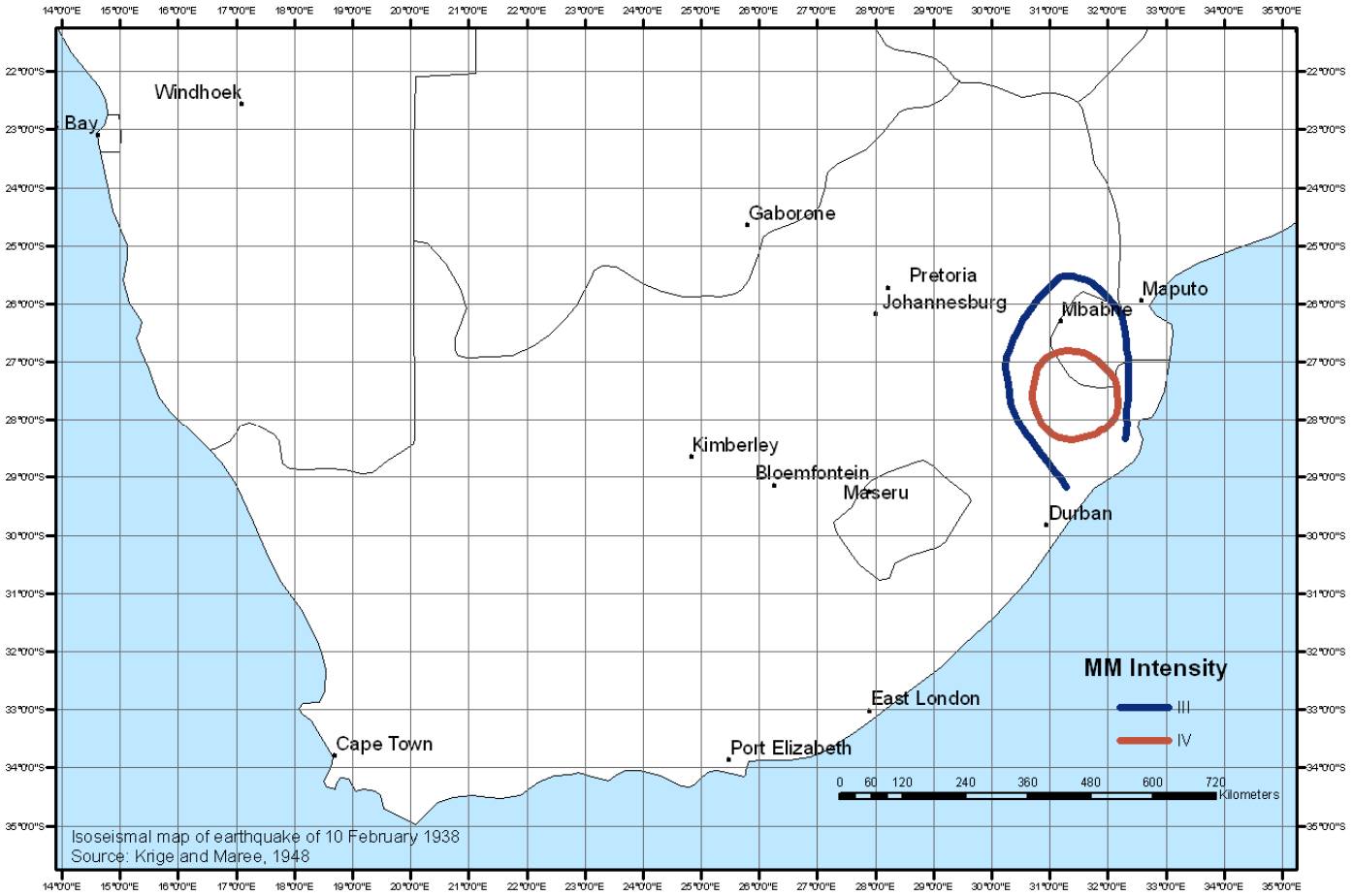



Figure A4 Isoseismal map of earthquake of 10-Feb-1938

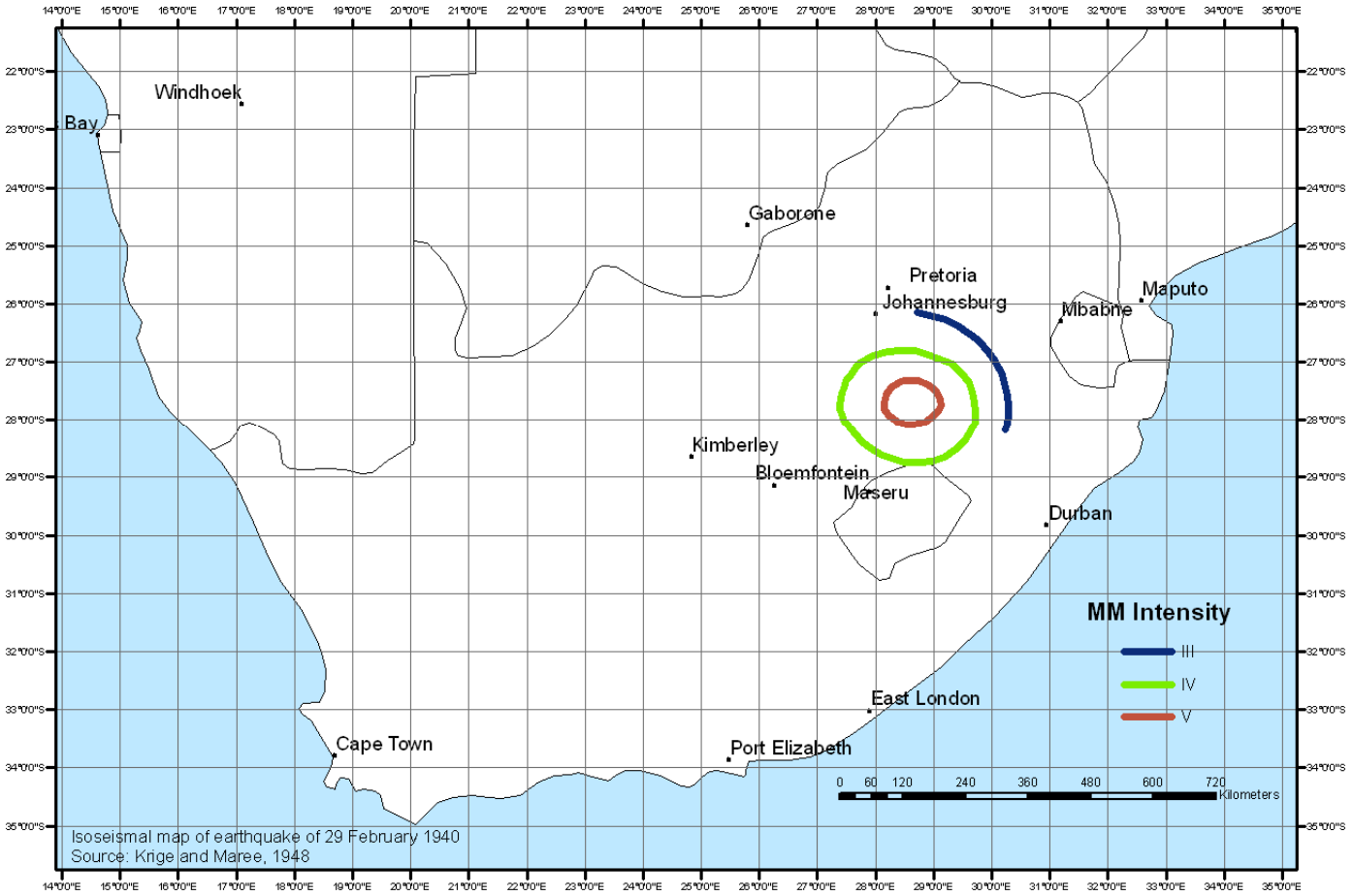



Figure A5 Isoseismal map of earthquake of 29-Feb-1940

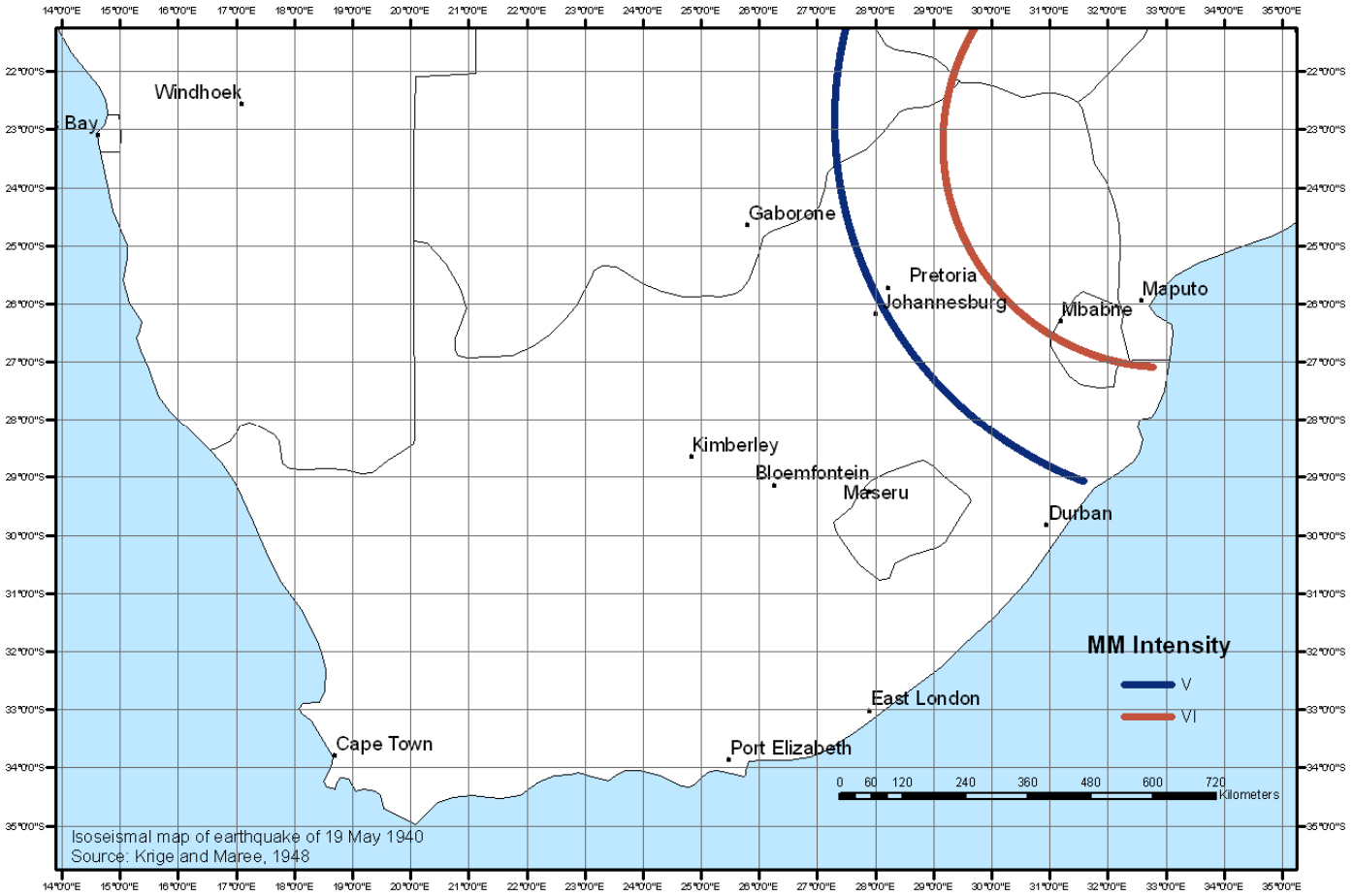



Figure A6 Isoseismal map of earthquake of 19-May-1940

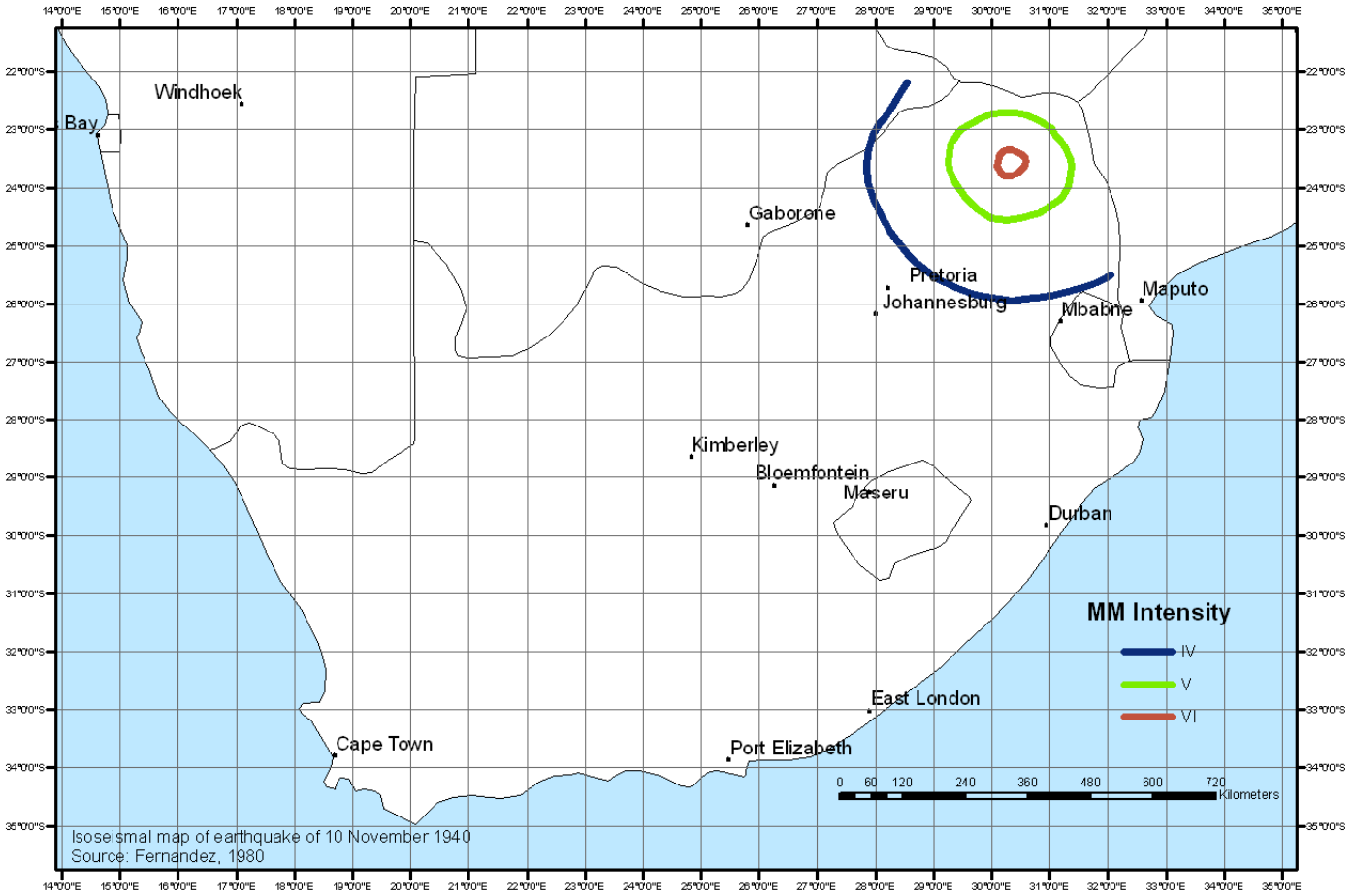



Figure A7 Isoseismal map of earthquake of 10-Nov-1940

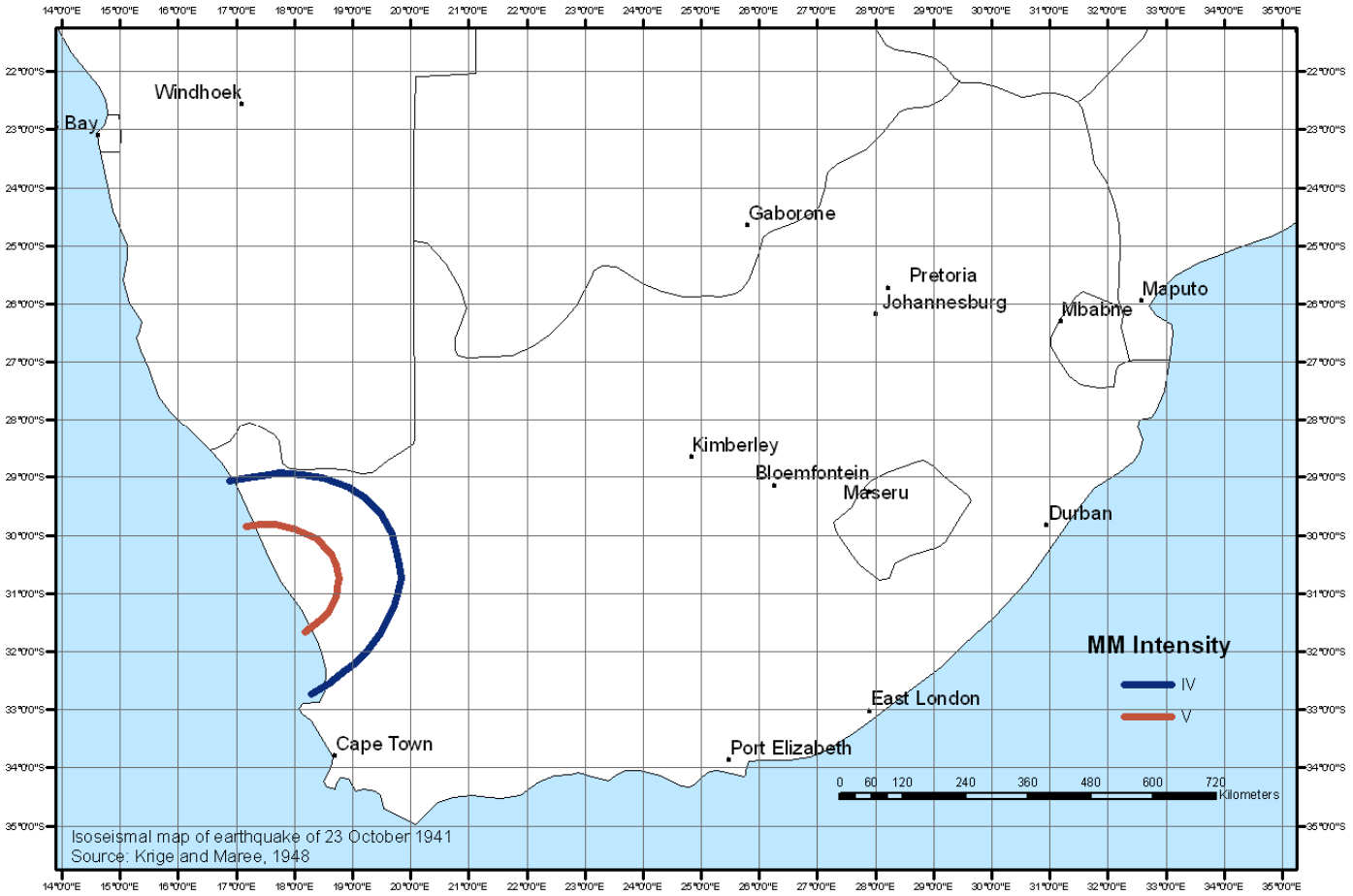



Figure A8 Isoseismal map of earthquake of 23-Oct-1941

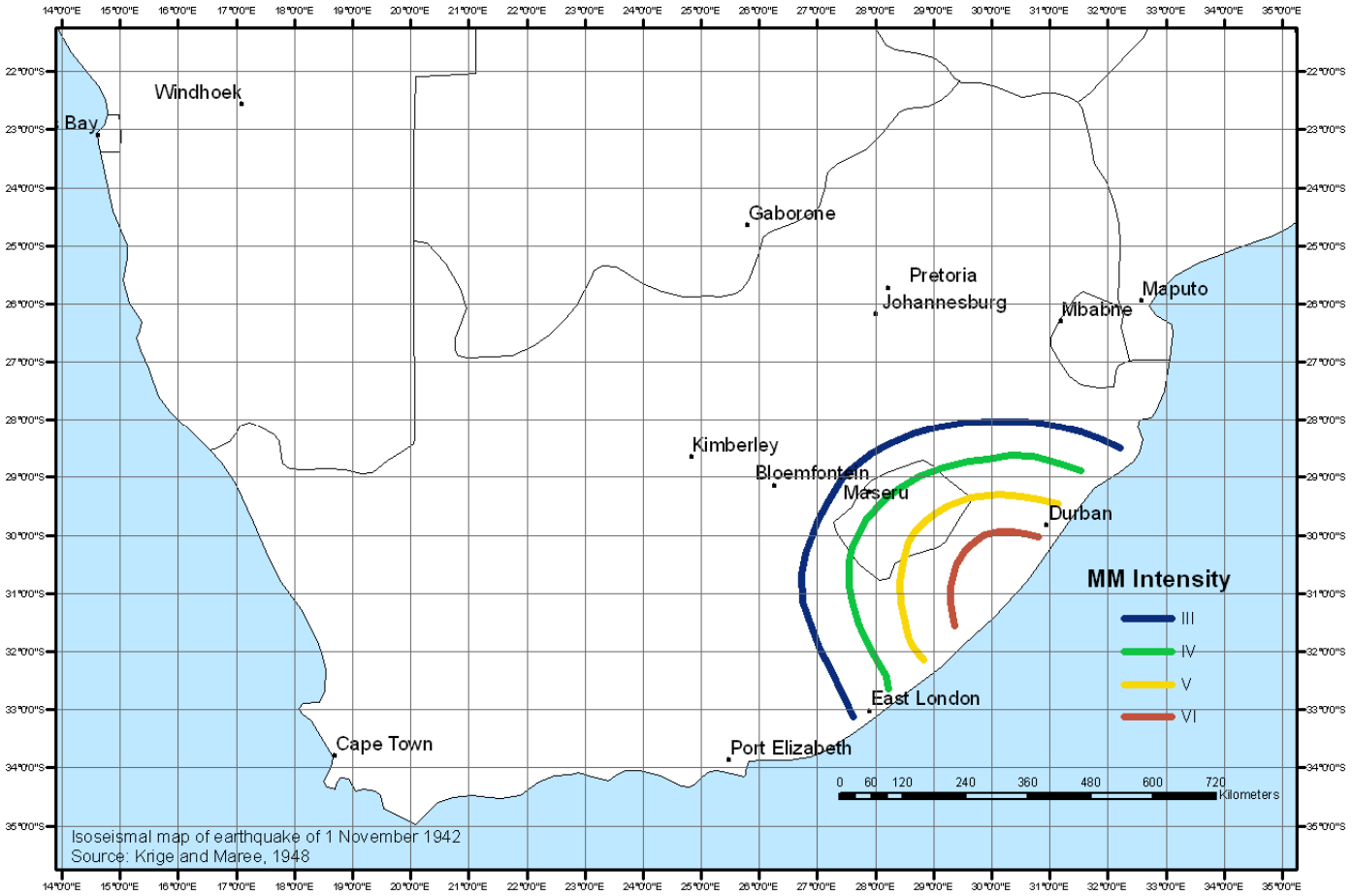



Figure A9 Isoseismal map of earthquake of 1-Nov-1942

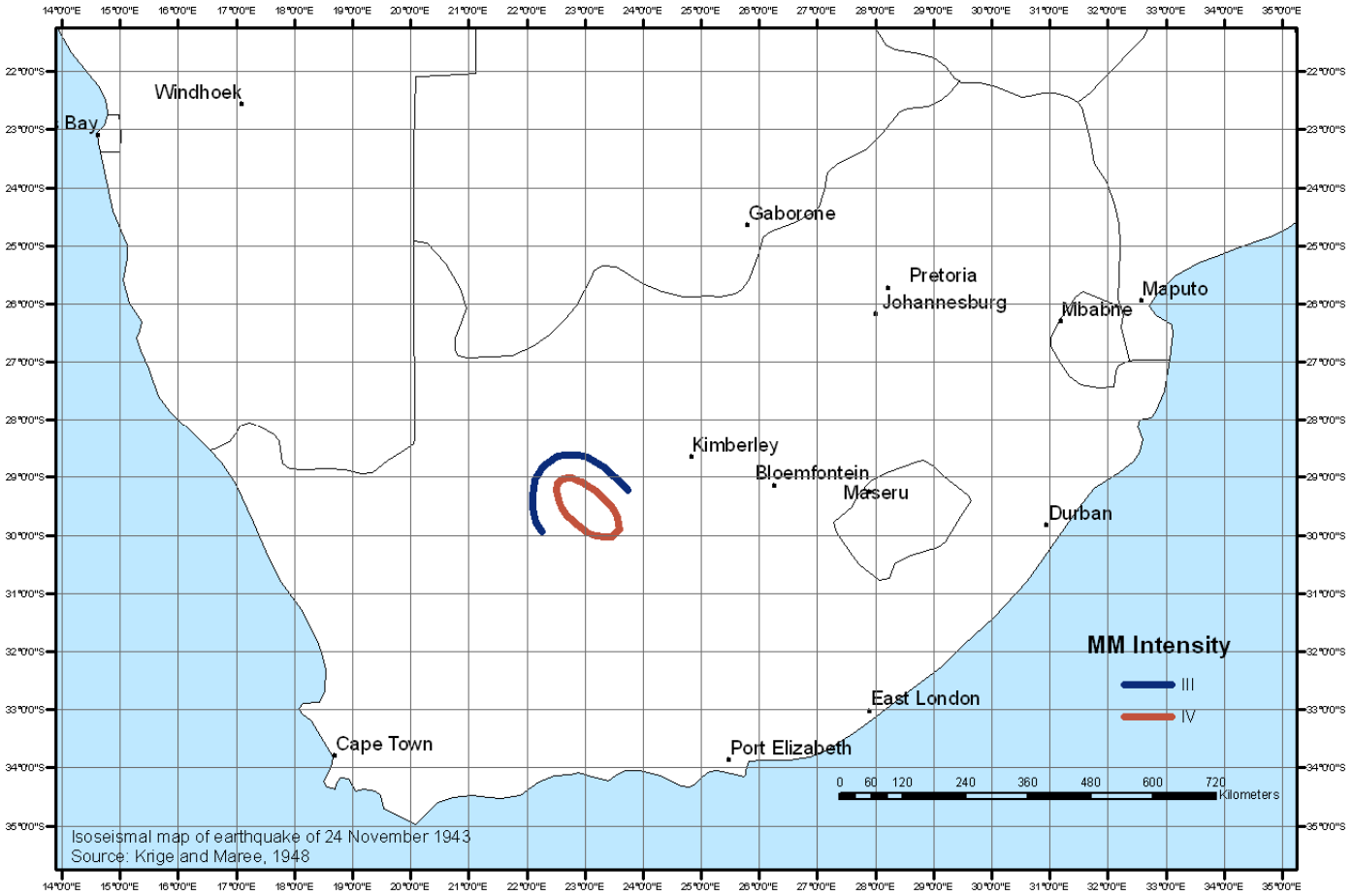



Figure A10 Isoseismal map of earthquake of 24-Nov-1943

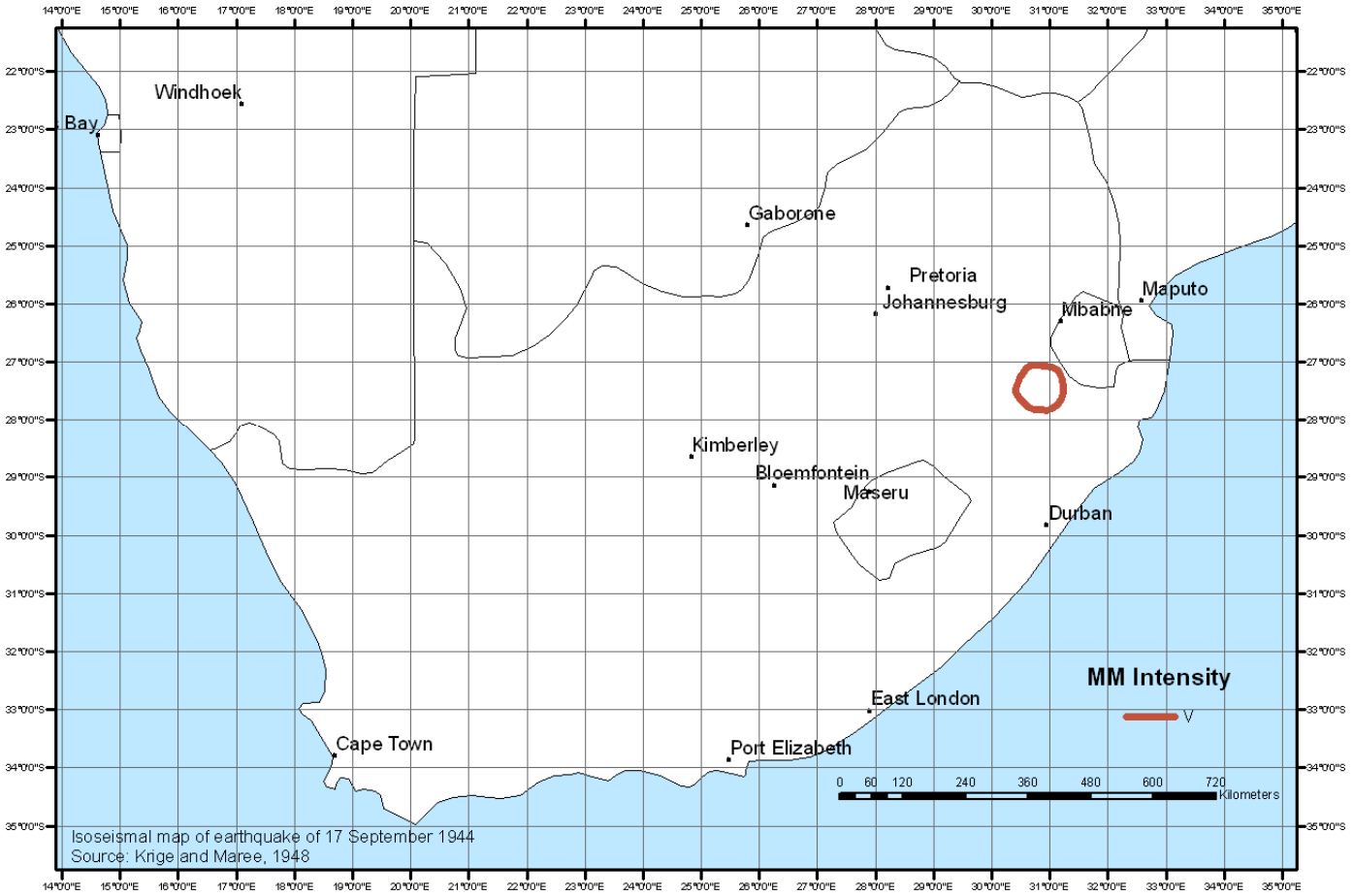



Figure A11 Isoseismal map of earthquake of 17-Sep-1944

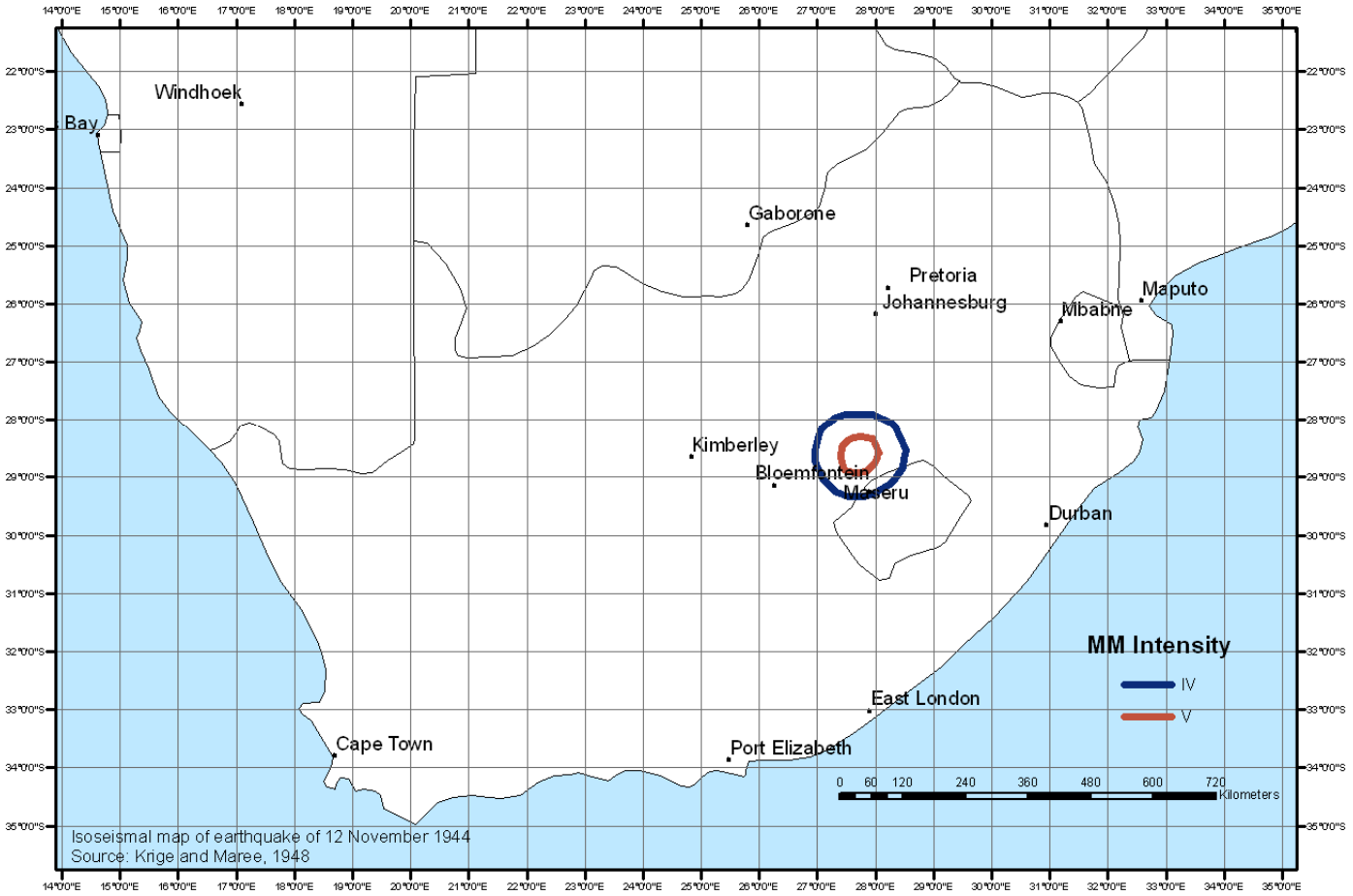



Figure A12 Isoseismal map of earthquake of 12-Nov-1944

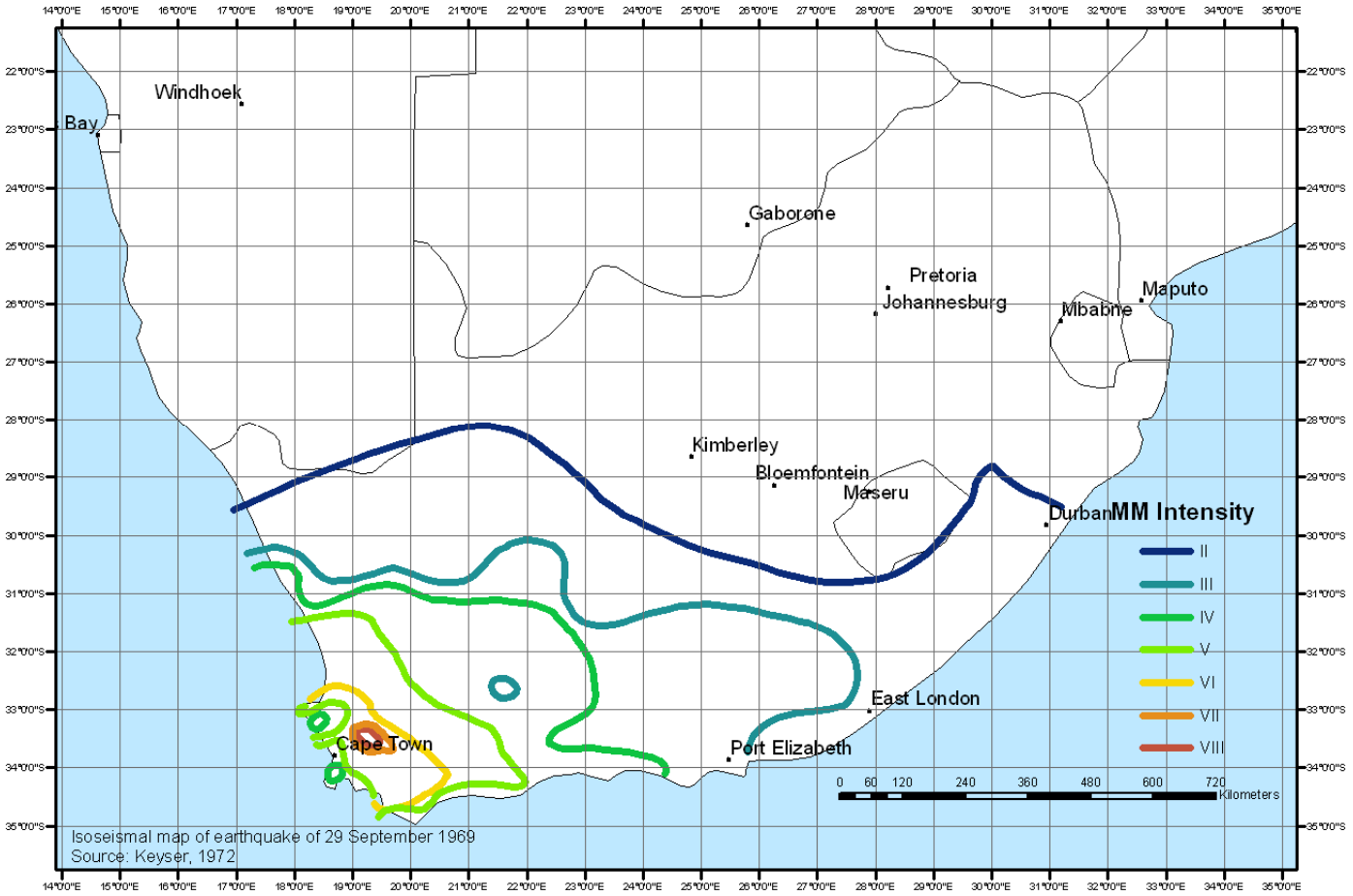



Figure A13 Isoseismal map of earthquake of 29-Sep-1969

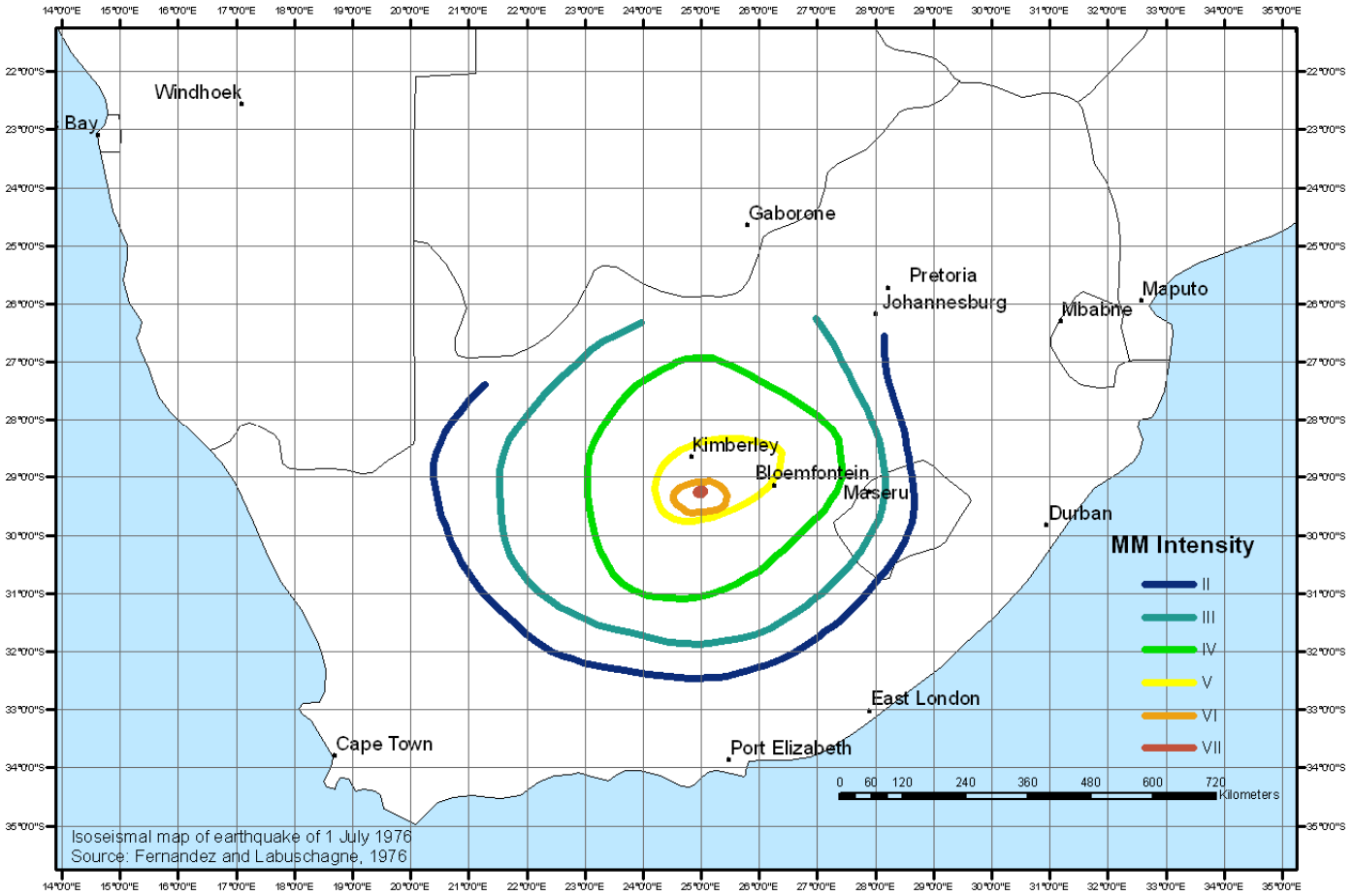



Figure A14 Isoseismal map of earthquake of 1-Jul-1976

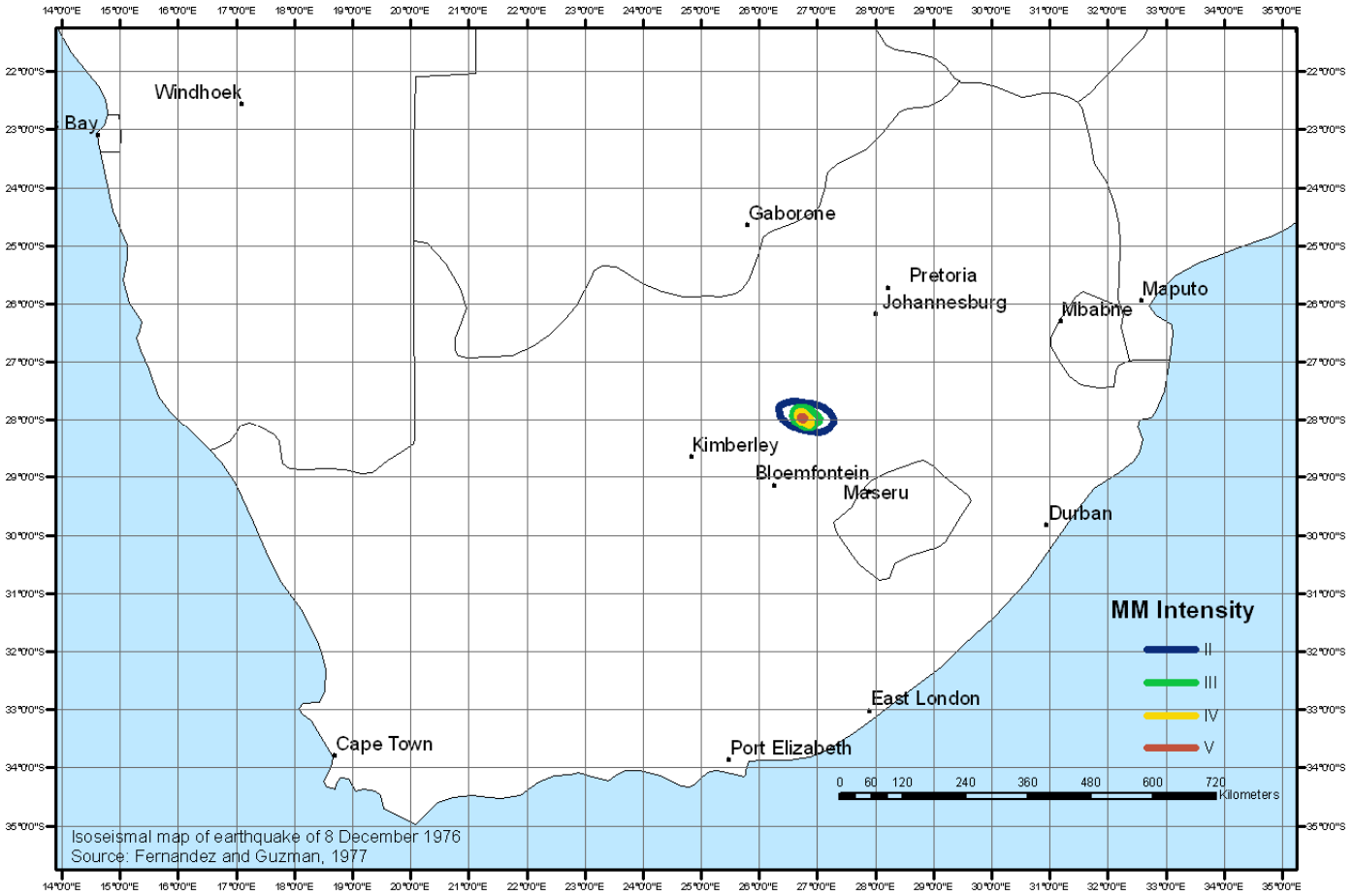



Figure A15 Isoseismal map of earthquake of 8-Dec-1976

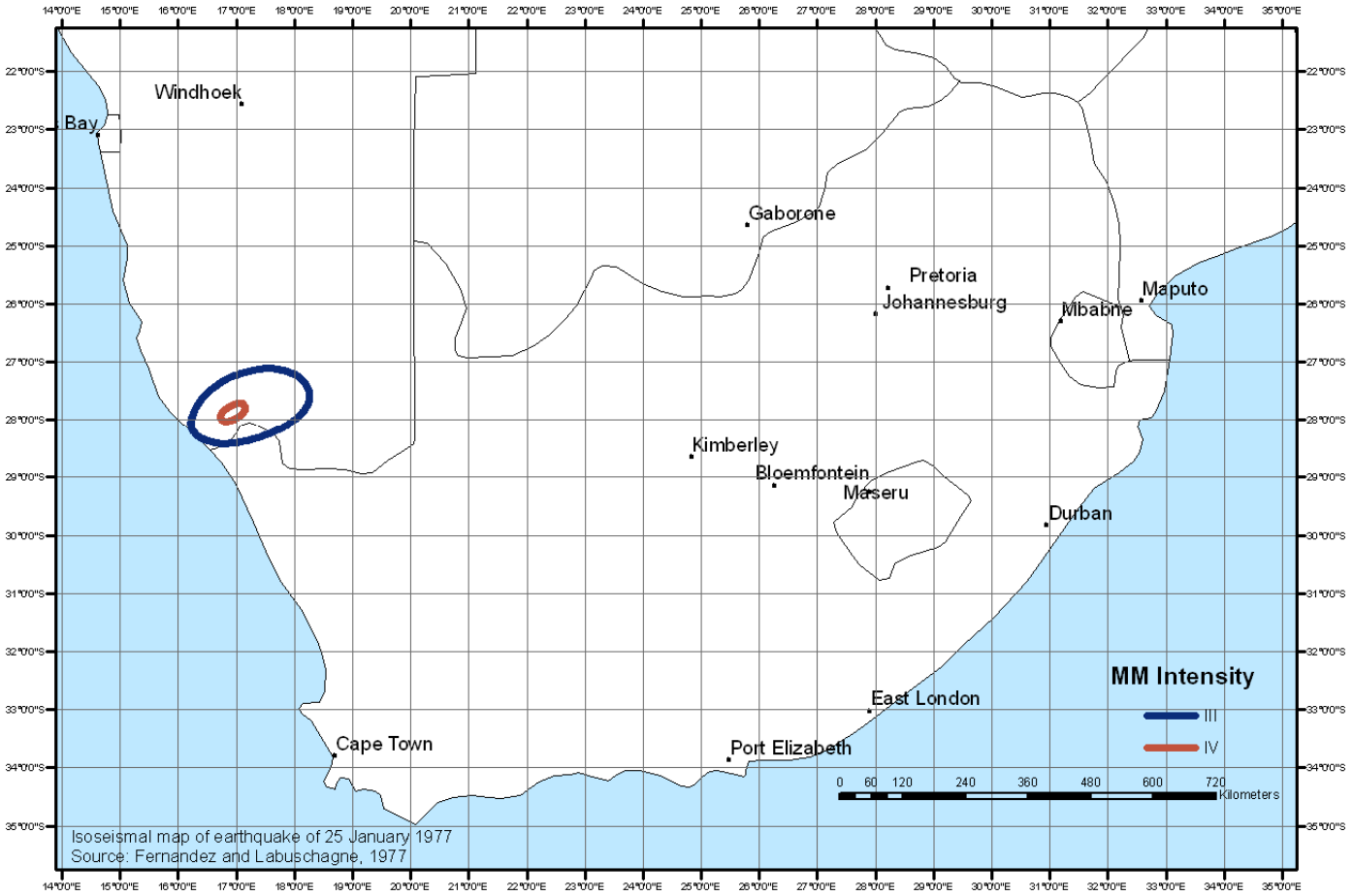



Figure A16 Isoseismal map of earthquake of 25-Jan-1977

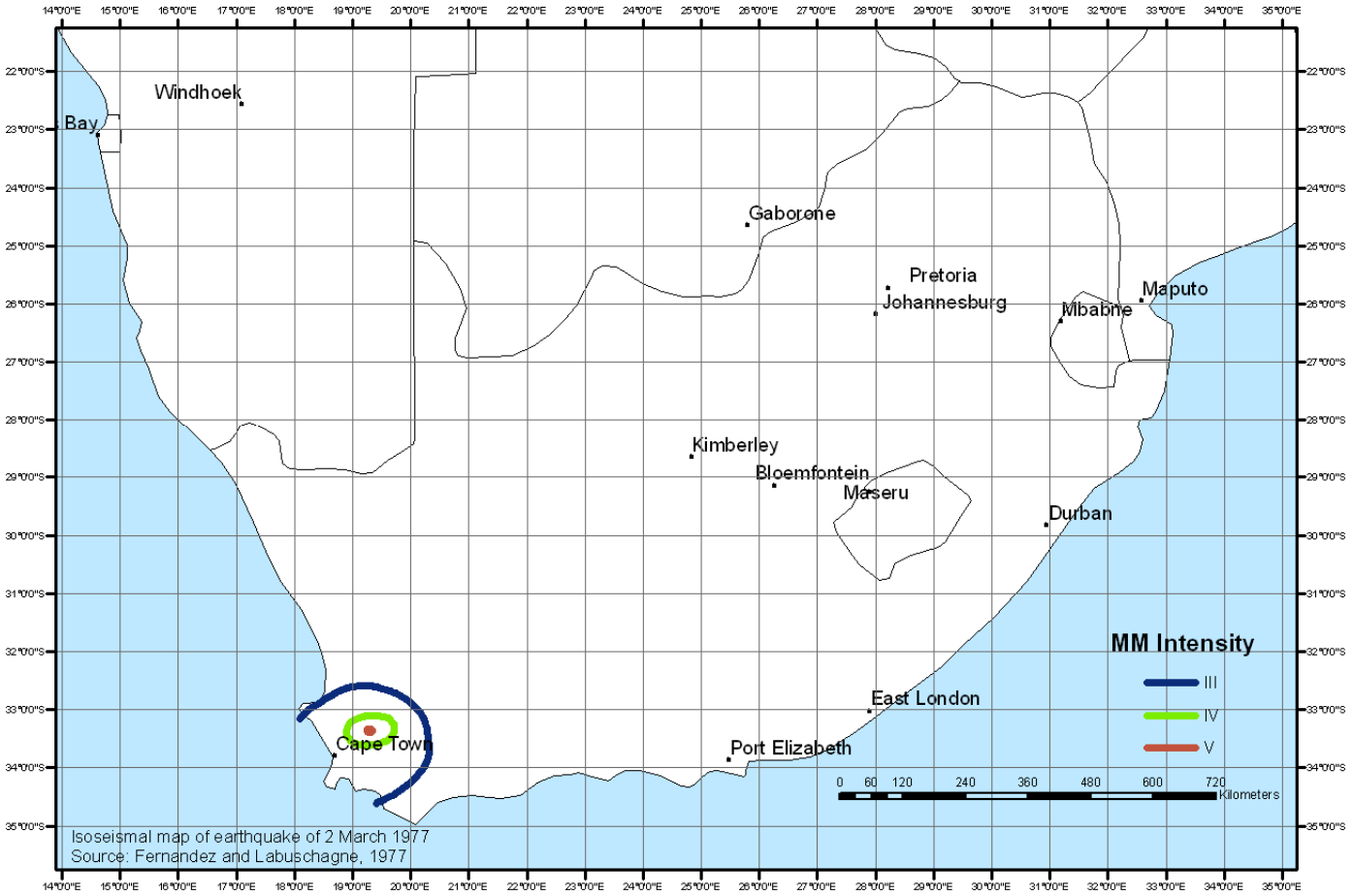



Figure A17 Isoseismal map of earthquake of 2-Mar-1977

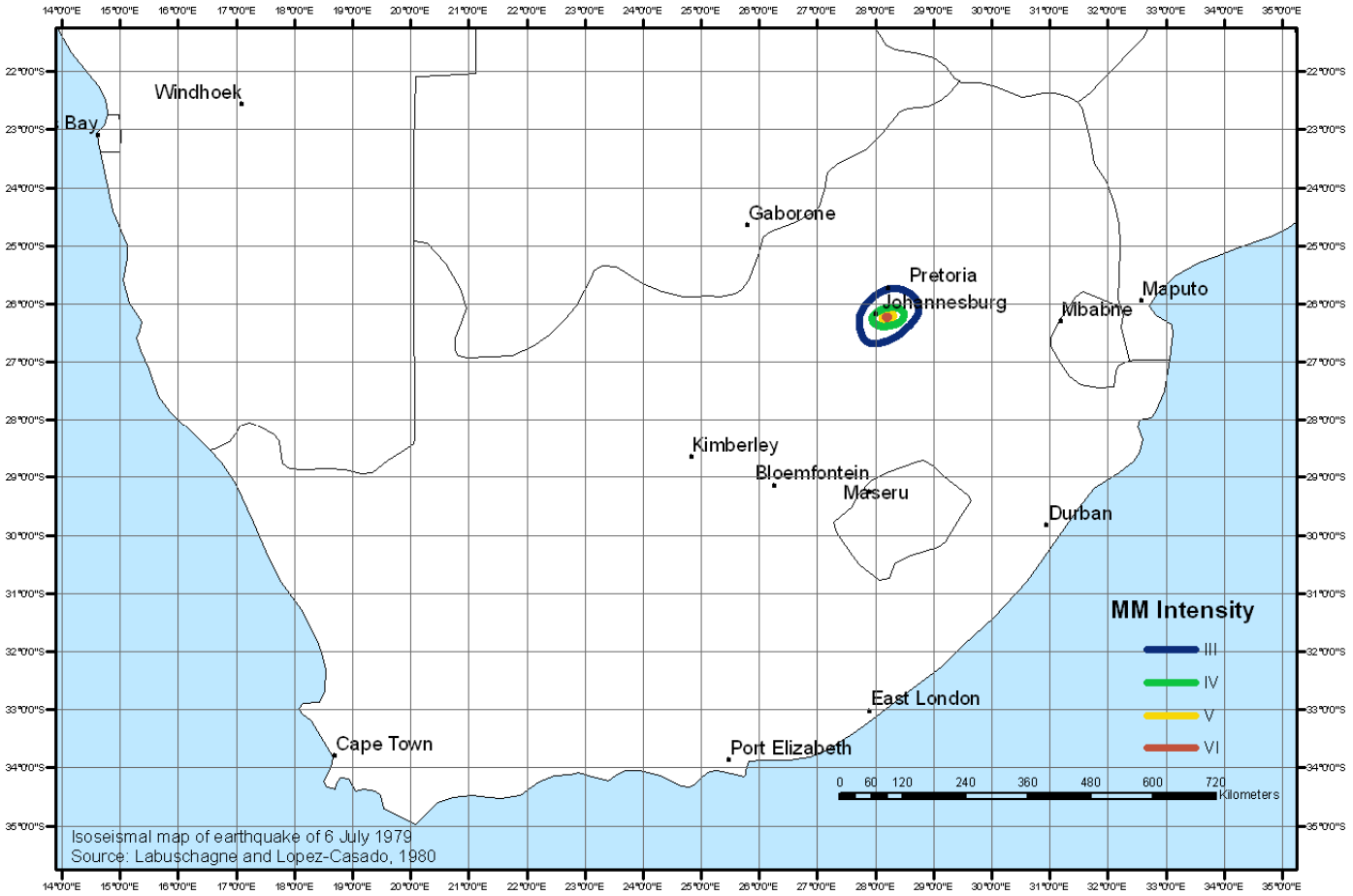



Figure A18 Isoseismal map of earthquake of 6-Jul-1979

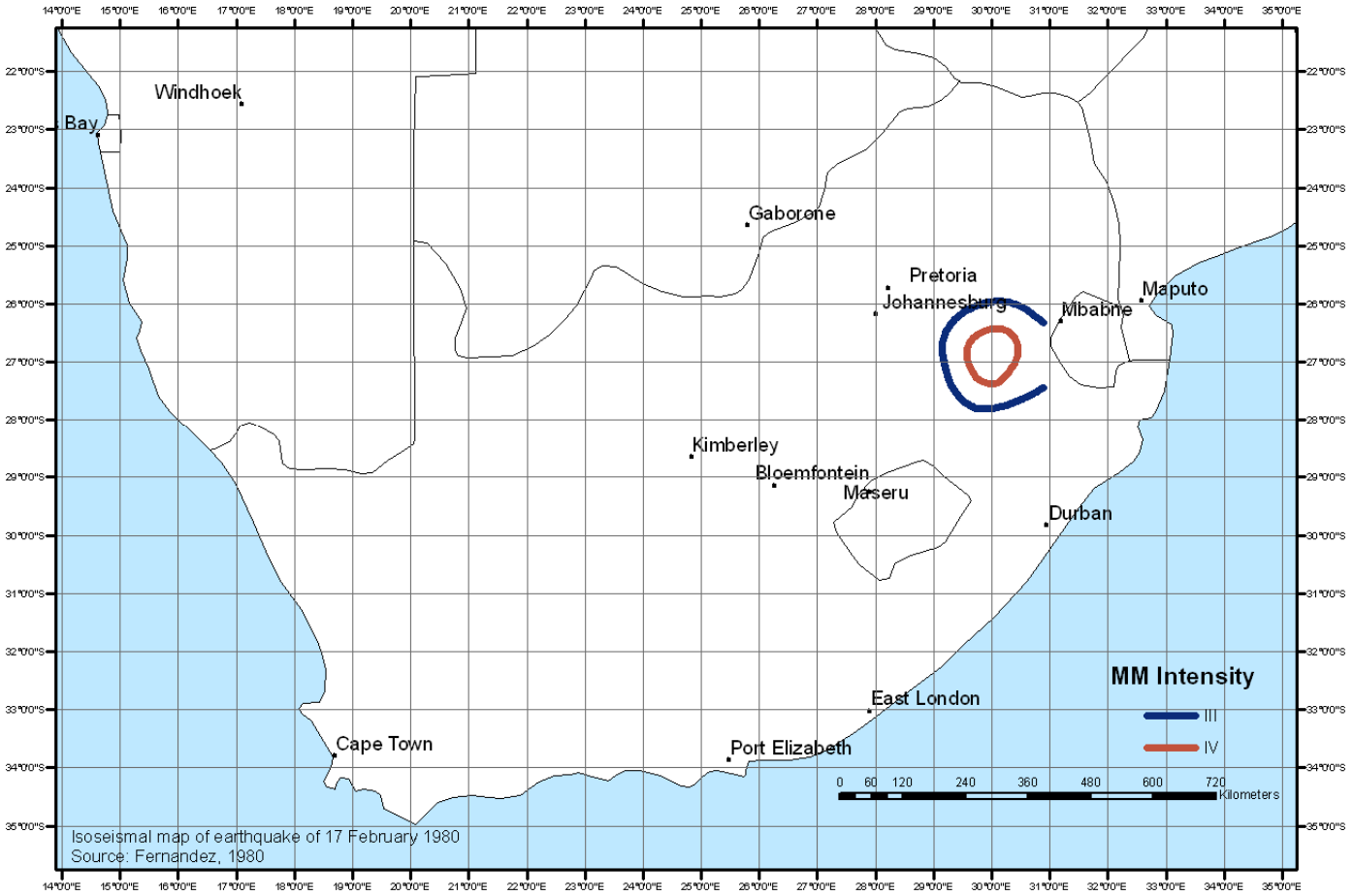



Figure A19 Isoseismal map of earthquake of 17-Feb-1980

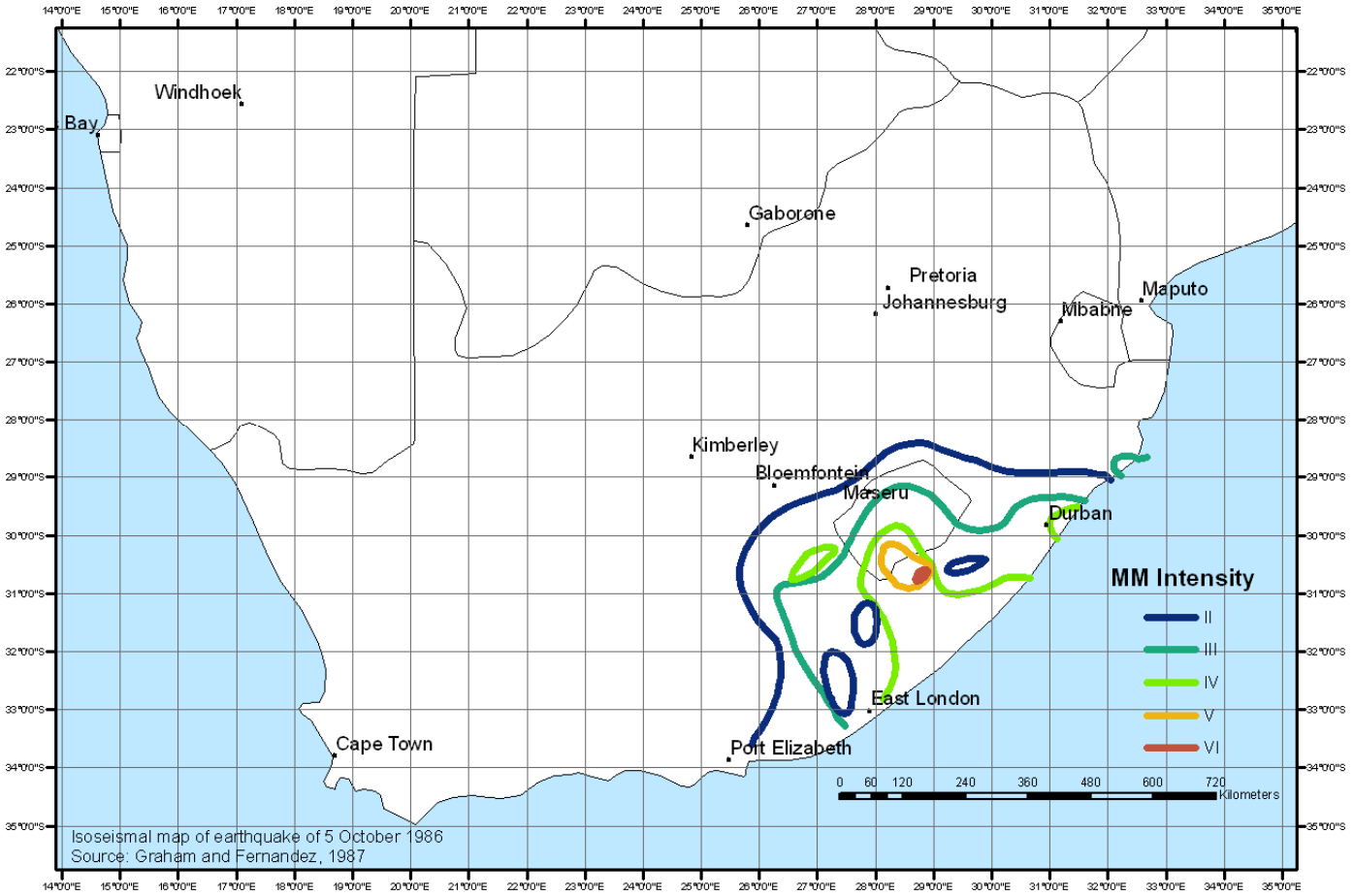



Figure A20 Isoseismal map of earthquake of 5-Oct-1986

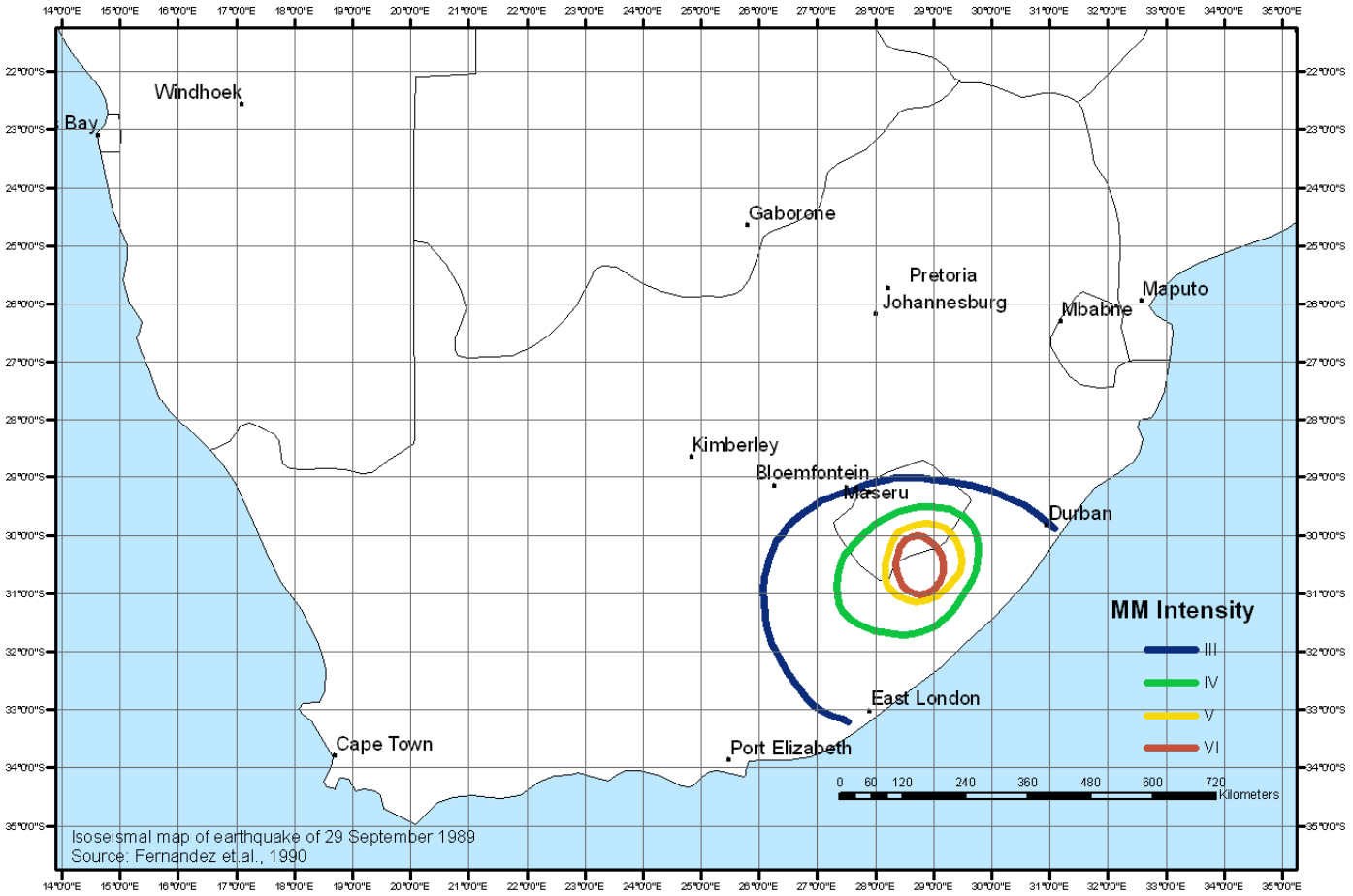



Figure A21 Isoseismal map of earthquake of 29-Sep-1989

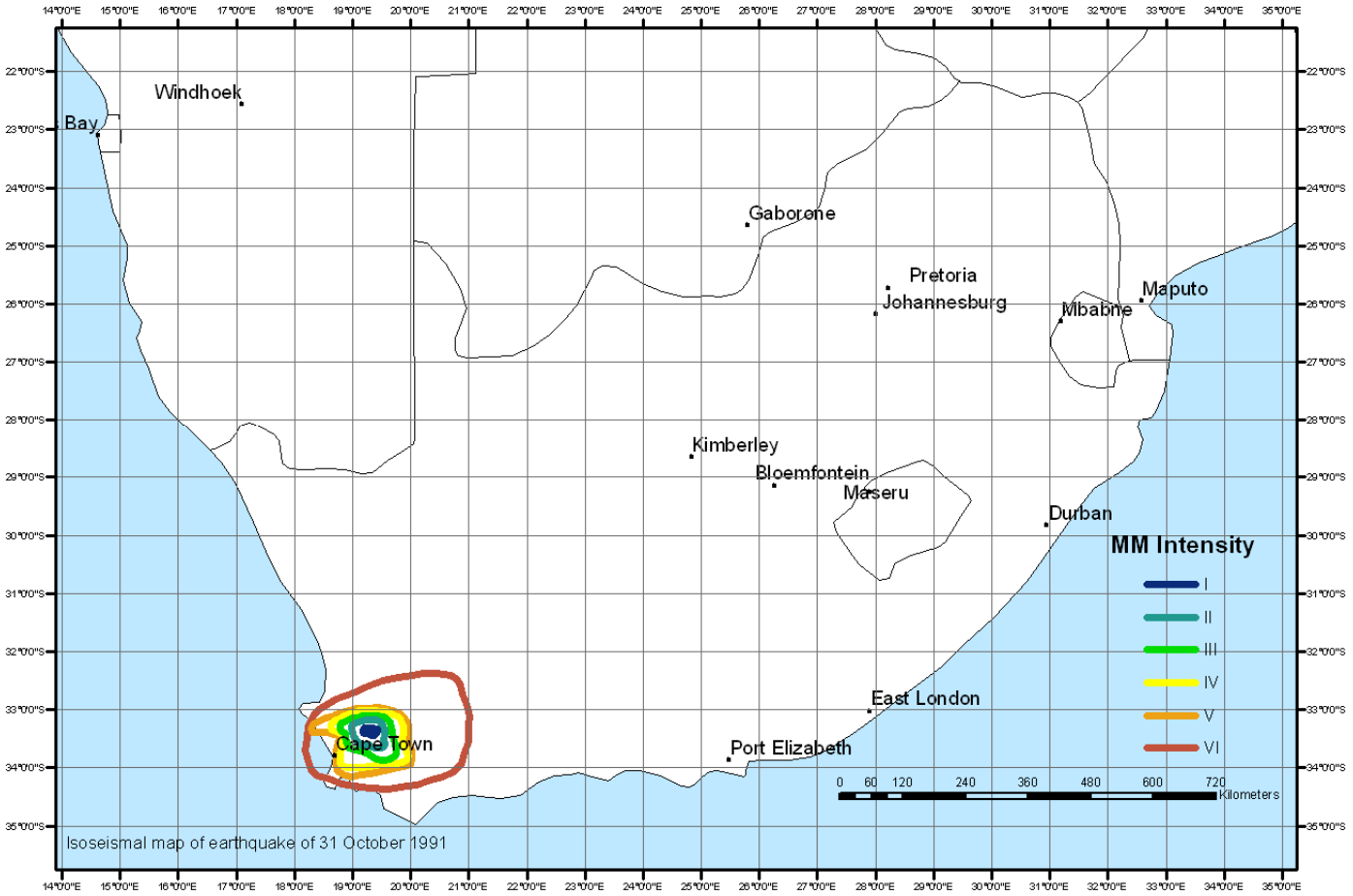



Figure A22 Isoseismal map of earthquake of 31-Oct-1991

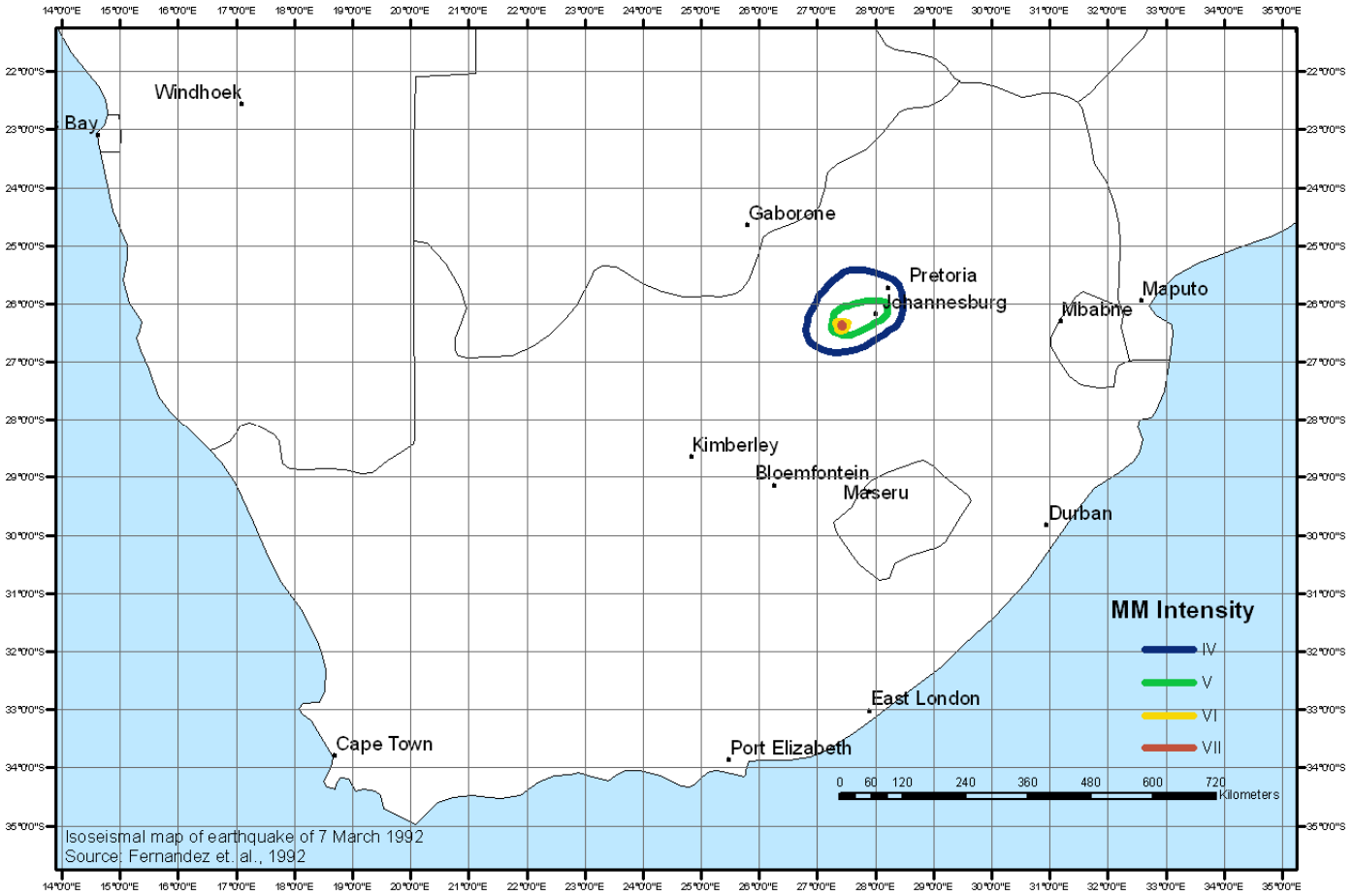



Figure A23 Isoseismal map of earthquake of 7-Mar-1992

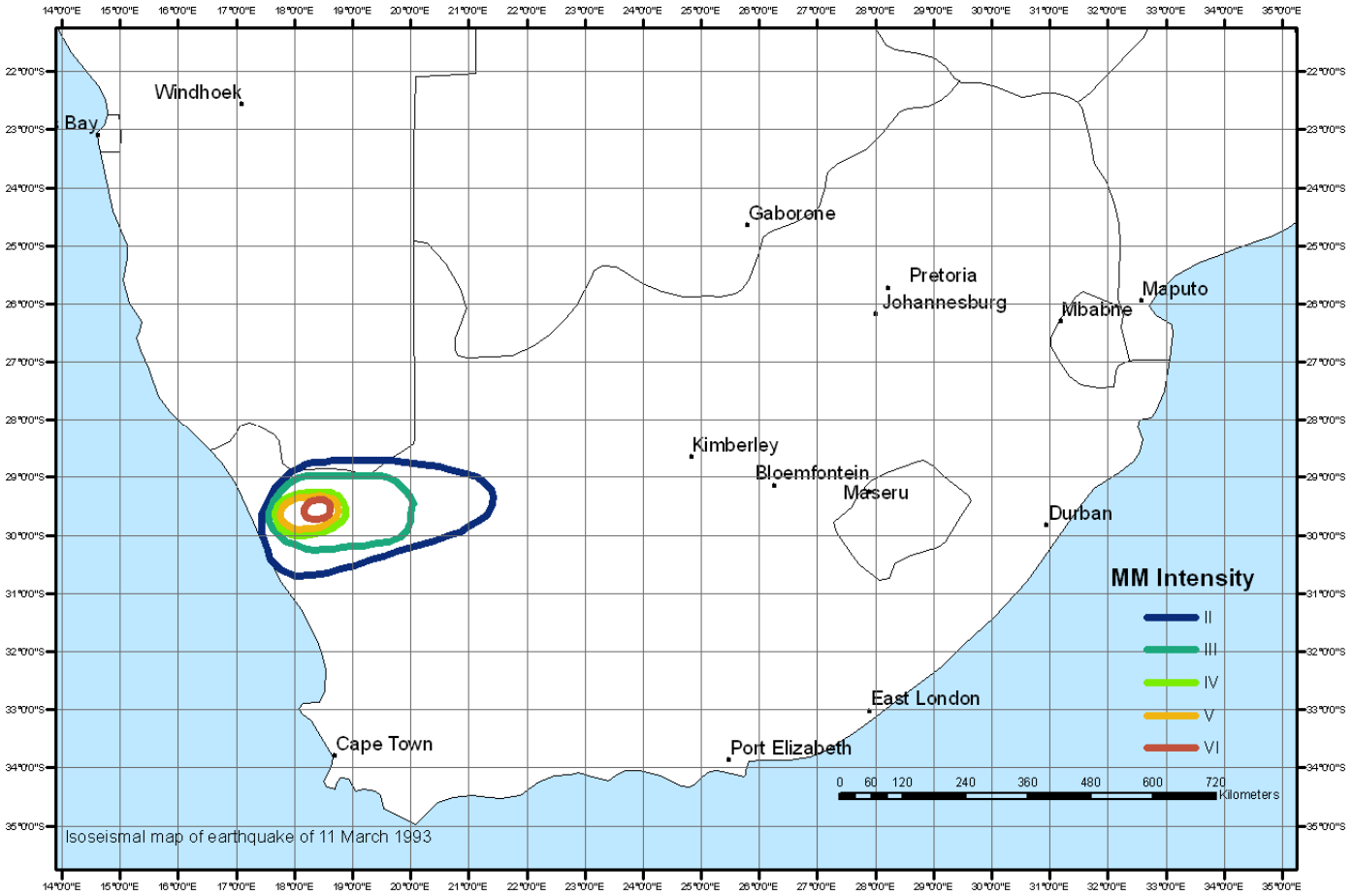



Figure A24 Isoseismal map of earthquake of 11-Mar-1993

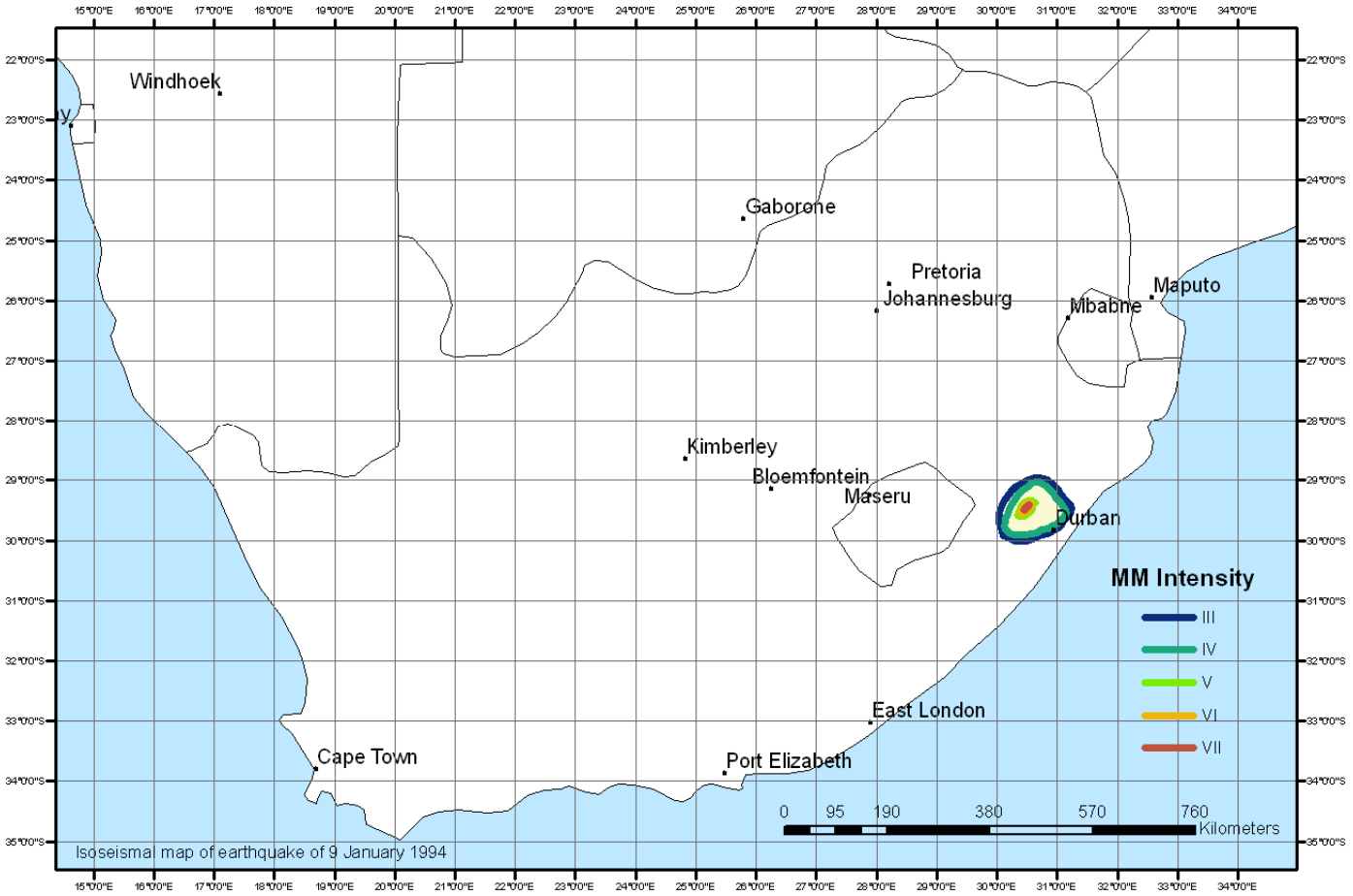



Figure A25 Isoseismal map of earthquake of 9-Jan-1994

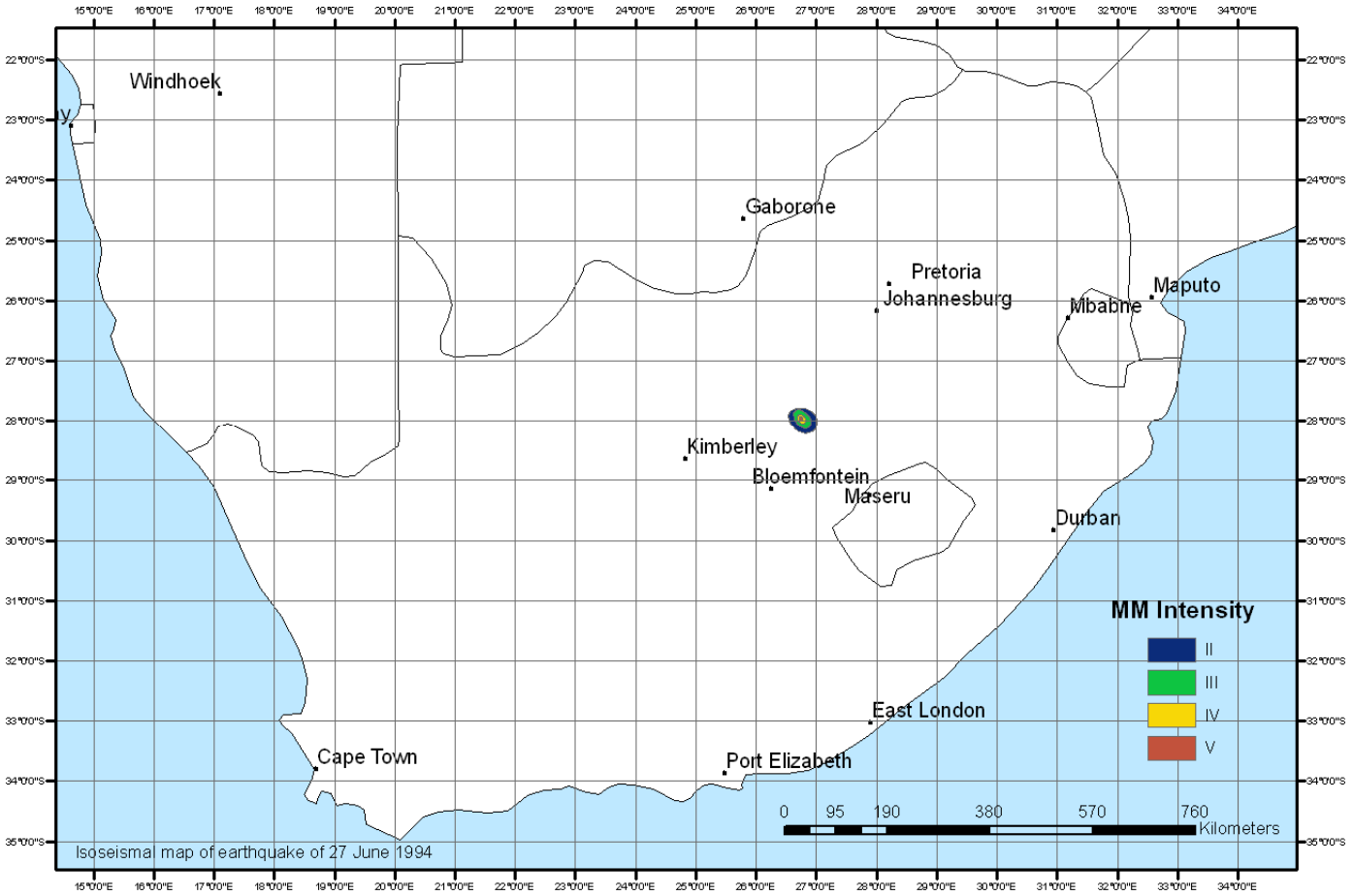



Figure A26 Isoseismal map of earthquake of 27-Jun-1994

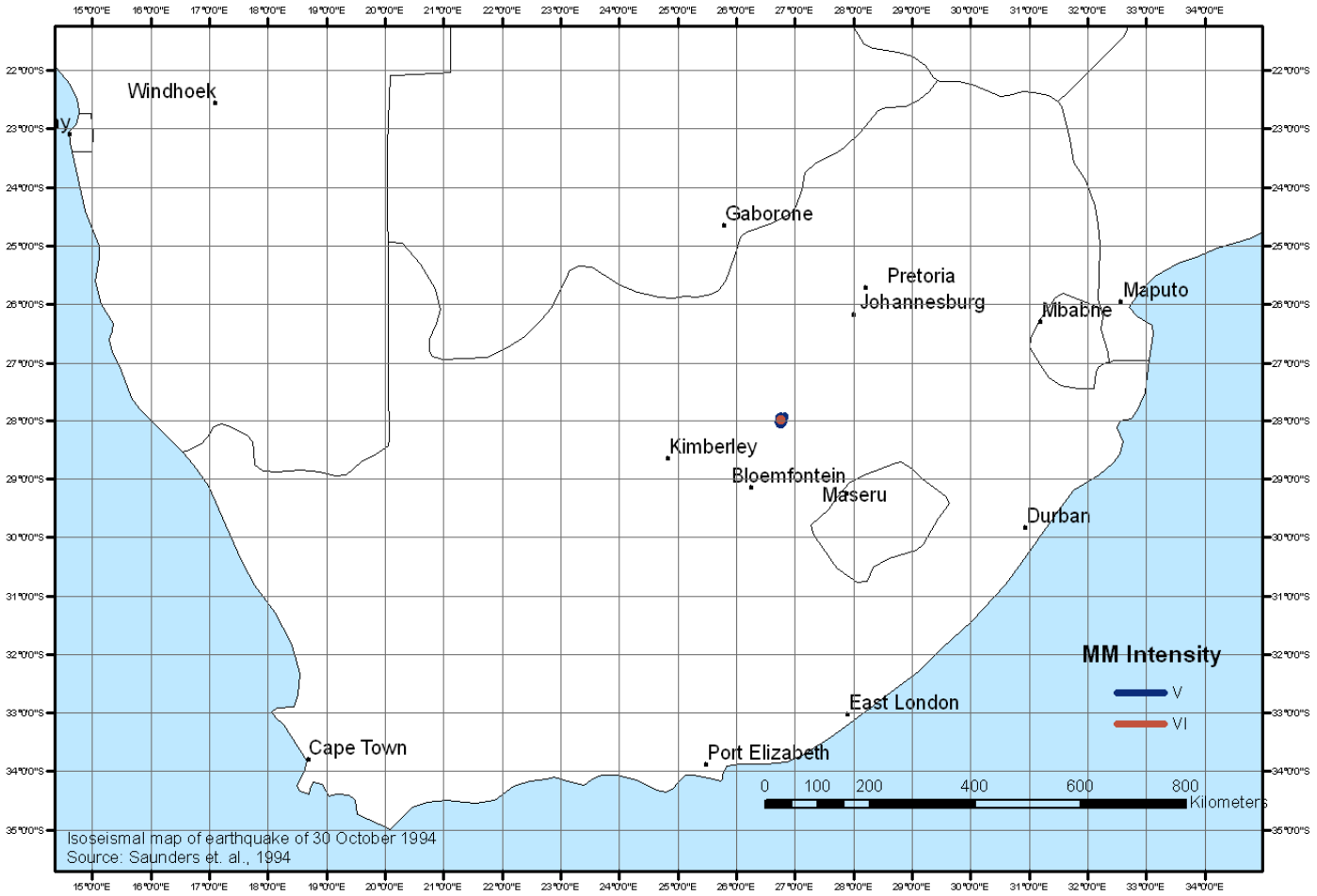



Figure A27 Isoseismal map of earthquake of 30-Oct-1994

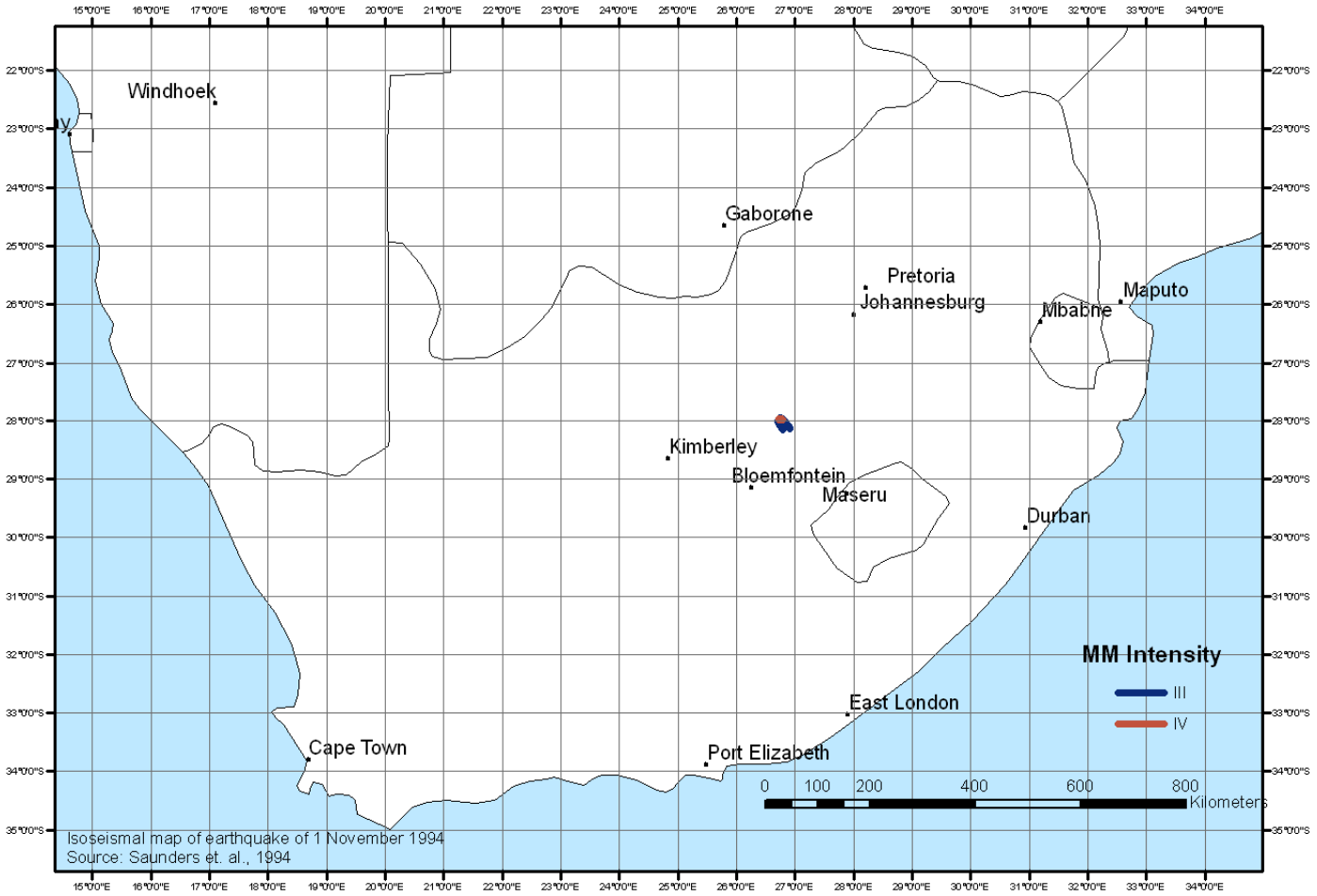



Figure A28 Isoseismal map of earthquake of 1-Nov-1994

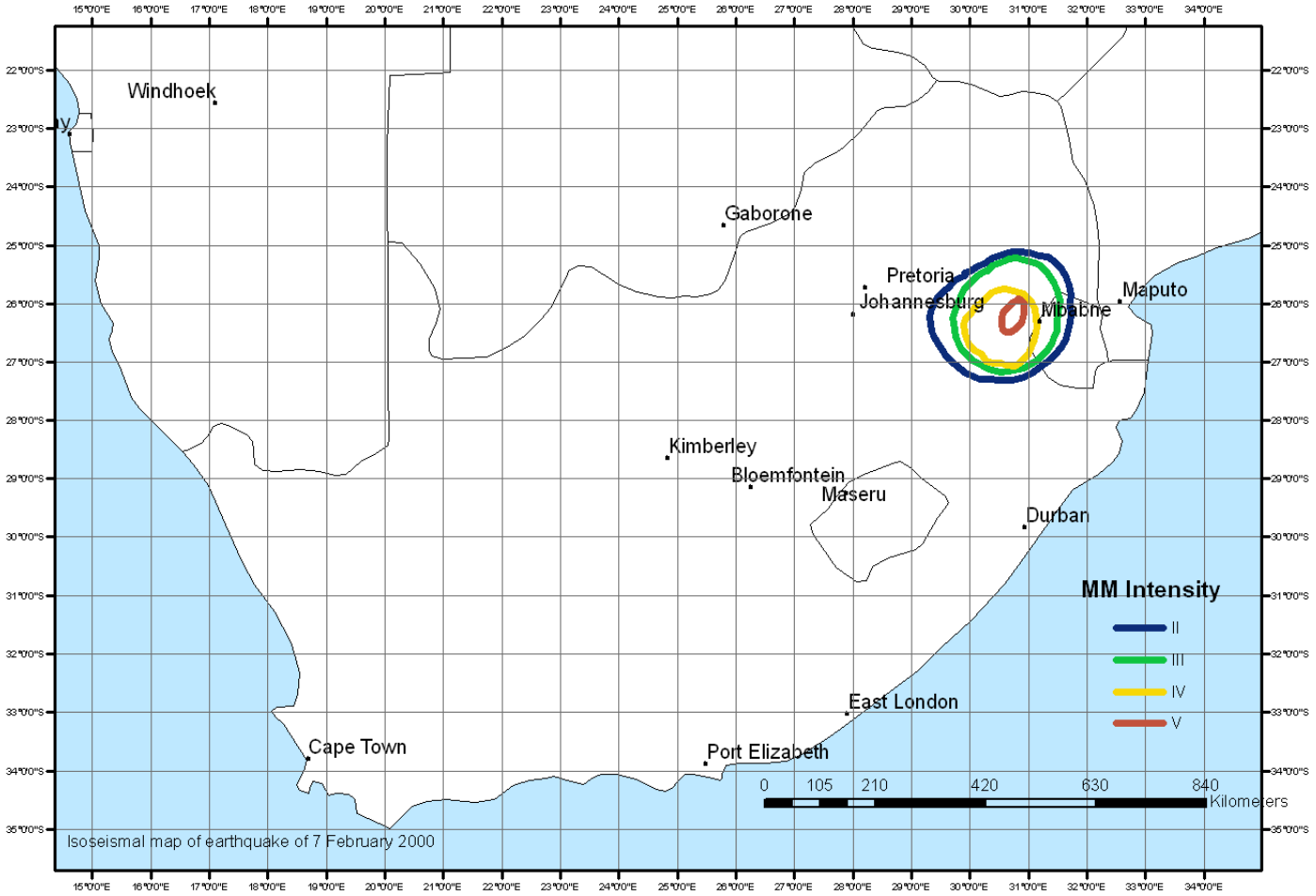



Figure A29 Isoseismal map of earthquake of 7-Feb-2000

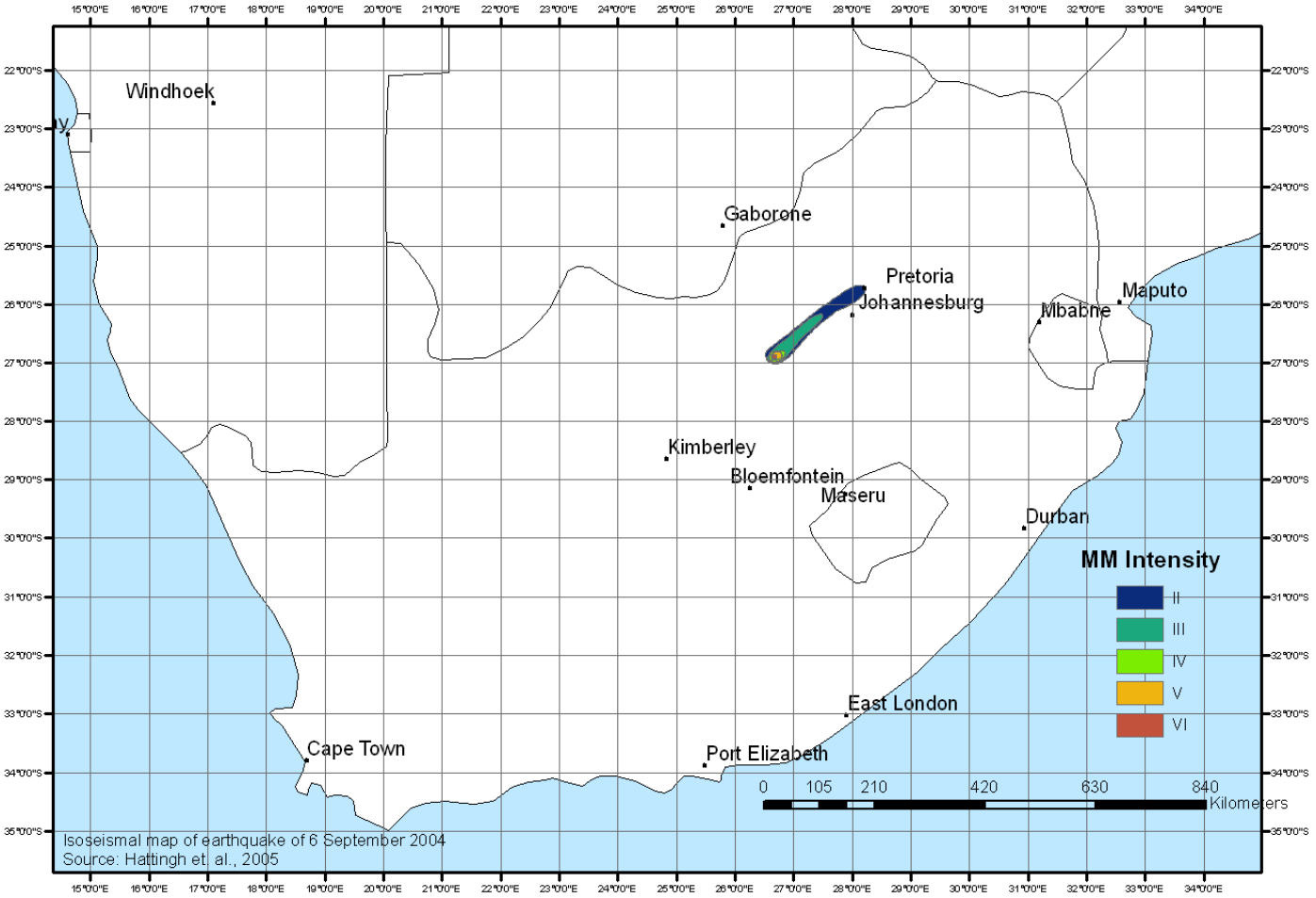



Figure A30 Isoseismal map of earthquake of 6-Sep-2004

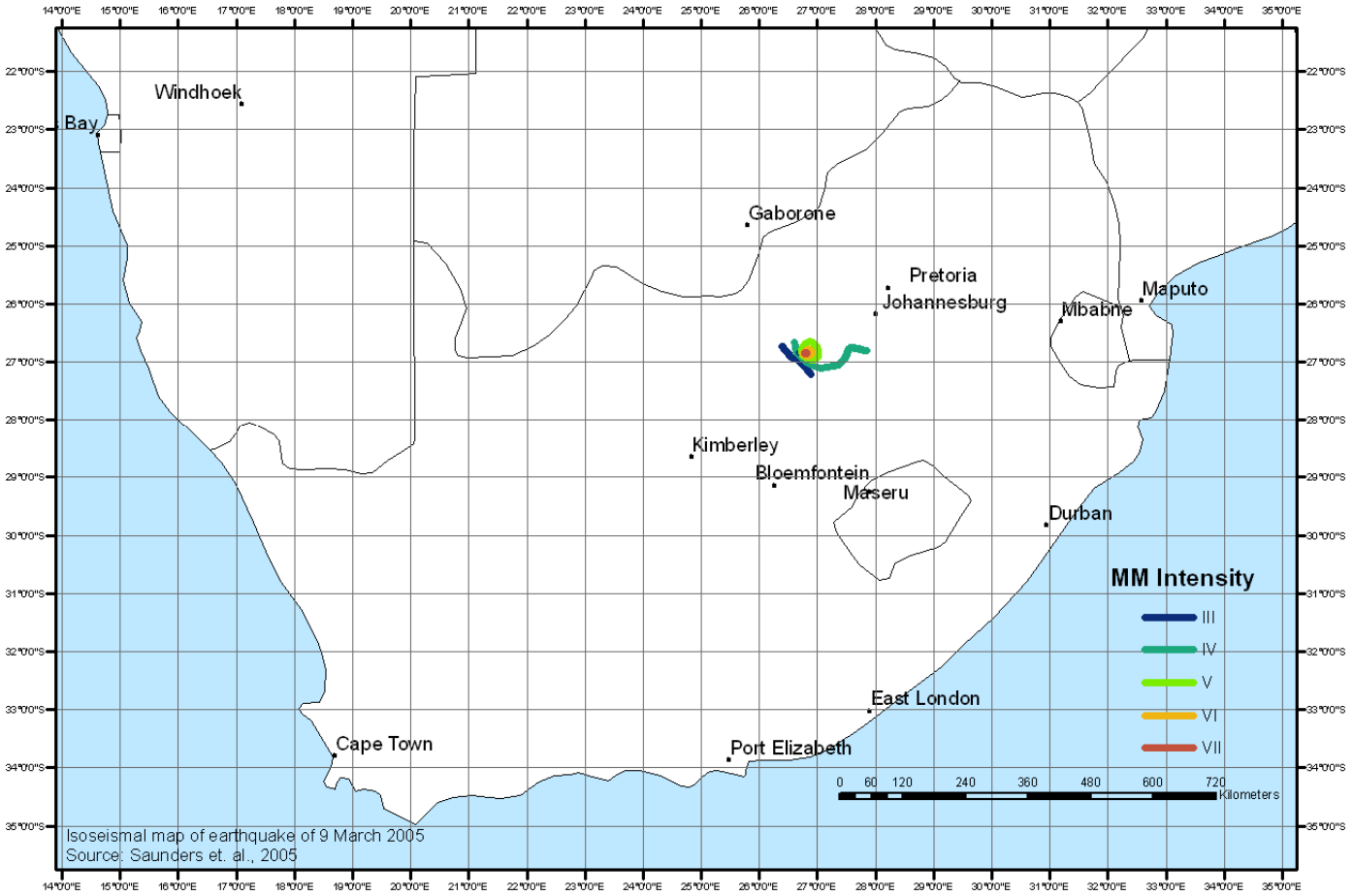



Figure A31 Isoseismal map of earthquake of 9-Mar-2005

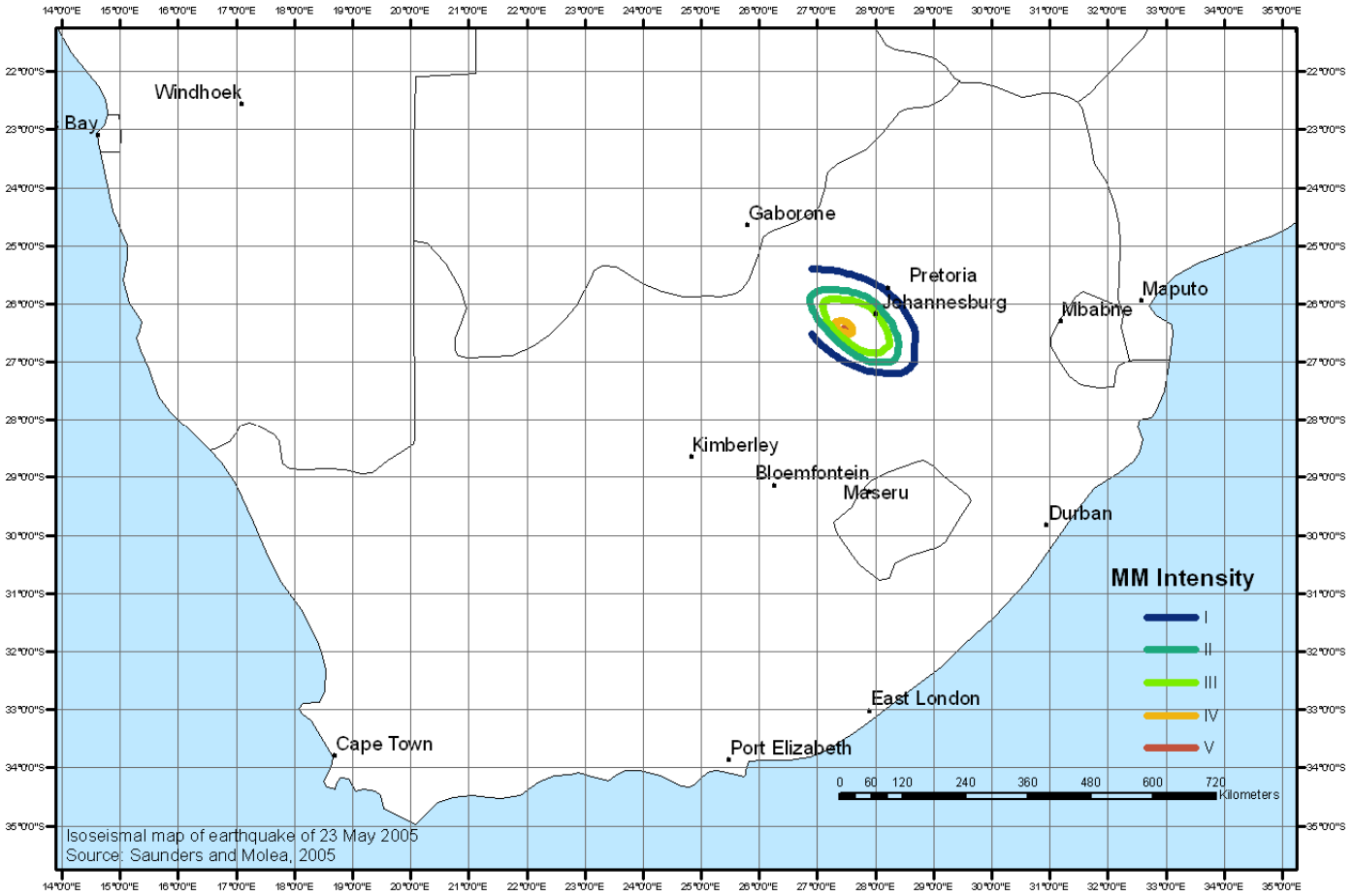



Figure A32 Isoseismal map of earthquake of 23-May-2005

# PART 2

# Collection of Isoseismal Maps for South Africa

**Mayshree Bejaichund[1] and Erna Hattingh**

**[1]Council for Geoscience, South Africa**

**Private Bag X112, Pretoria, 0001, South Africa**

**E-mail: mayshree@geoscience.org.za**

Published in Natural Hazards, 2009, Volume 50. Pages 403-408

## Introduction

In this part a collection of isoseismal maps are presented. These maps date as far back as 1932 and capture the damage footprint of the largest earthquakes recorded by our early inhabitants. It is an essential dataset that will be used the characterise the earthquake hazard in subsequent parts of this work.

## Background

Intensity measurements are based on the direct effects of the shock generated by an earthquake on man-made structures and topography. These are often referred to as macroseismic effects. The intensity is greatest within the epicentral area and usually decreases in all directions as distance from the epicentre increases.

Many seismic intensity scales have been developed. One of the most commonly used is the Modified Mercalli (MM) 12-degree intensity scale proposed by Wood and Neumann (1931) and developed further by Richter (1958). This scale provides a detailed description of the earthquake effects on people, buildings and the environment. The European Macroseismic Scale (EMS; Grunthal 1993), most recently updated in 1998, is the basis for evaluation of seismic intensity in European countries. The INQUA scale was

recently proposed (Michetti et al. 2004) with the aim to assess macroseismic intensity on the basis of only seismically induced ground effects.

In order to determine the intensities that prevailed at different places during an earthquake, questionnaires are distributed to the general public and site visits are made to investigate the epicentral region. When all the data on the effects of an earthquake have been accumulated and after these effects are expressed in intensities, the results are usually represented in the form of isoseismal maps with curves delineating areas with different intensities from each other.

## Review of similar collections

The most complete catalogue of earthquake occurrences for South Africa up to 1949 is by Finsen (1950). This catalogue was supplemented with information on early tremors in the vicinity of Cape Town (Theron 1974). Several other works since then dealt with the seismic history of South Africa. A compilation of relevant works was made (Fernandez and Guzman 1976) where a macroseismic catalogue of earthquakes from 1620-1970 was provided. Other work on historical data available includes Fernandez and Guzman (1979), De Klerk and Read (1988) and Brandt *et* al. (2005). Specifically, for this compilation several isoseismal maps were obtained from the compilations of Krige and Maree (1948) and Fernandez and Labuschagne (1977). Since 1977, no such compilation exists. Isoseismal maps were available in isolated publications as listed in Table 1 below.

## Use and potential of the map collection

The isoseismal maps are valuable complements to the instrumental record and are particularly useful in the field of earthquake engineering. South Africa has been identified as being in a stable continental environment. Hence, relatively large earthquakes occur fairly infrequently. With information from this collection one can then quickly identify those regions having experienced large ground motion historically. This ground motion is recorded as a

macroseismic effect and has thus a direct association with infrastructure damage that was experienced at the time of the earthquake. Furthermore the damage footprint is recorded in the isoseismal traces which can be very useful in modelling earthquake propagation in these regions. In addition, these maps can be used to identify targets for future palaeoseismic and neotectonic investigations. Possible improvements that will be made to this collection are the provision of a detailed catalogue of macroseismic observations from the original reports and corresponding seismograms, where available.

## Compilation Procedure

When there was a large tremor, questionnaires were distributed to local towns to assess the severity of the tremor and the damage it caused. These questionnaires were then analysed, after which isoseismal maps were drawn. These isoseismal maps available in historical reports were revisited and digitised for this study. Five isoseismal maps were prepared by the authors for this study based on questionnaires alone. Most isoseismal maps in the historical record use the MM scale. All maps are therefore provided according to this scale.

## Final Maps

Isoseismal maps listed in this collection date as far back as 1932. The most recent event included here is the event of 23 May 2005 that occurred in the mining district of Carletonville.

The characteristics of each event (figure ID, date, location, epicentral intensity and source) are given in Table 1 below. A map showing location of the epicentre of each event is given in Figure 1. Each isoseismal event is then illustrated in the accompanying appendix.

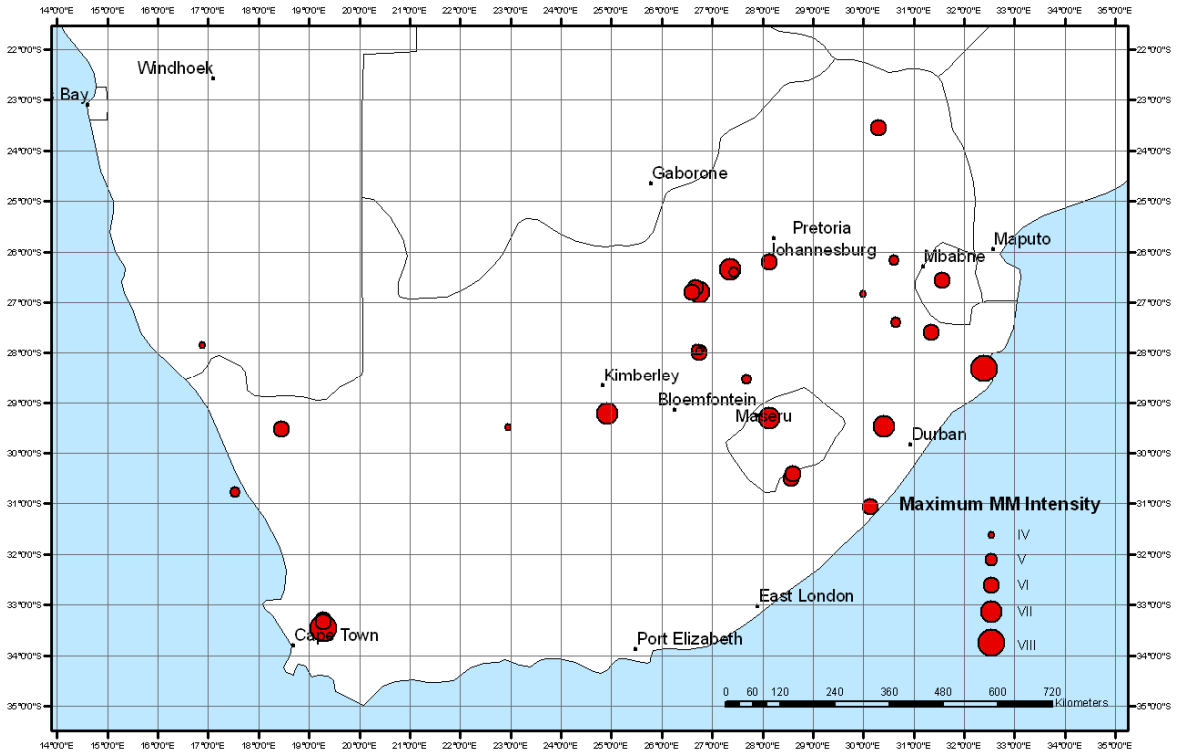



Figure 1 Map of epicentres showing maximum intensities for all events

Table 1 List of characteristics of each isoseismal event included in the collection

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| A1 | 31-Dec-1932 | -28.32 | 32.40 | VIII | Off Cape St. Lucia, RSA | The Zululand Earthquake of 31 December 1932 (Krige and Venter 1933). |
| A2 | 12-Jan-1936 | -26.57 | 31.57 | VI | Mooihoek, Swaziland | The Swaziland and Fauresmith Earthquakes of January 1936 (Krige 1936) |
| A3 | 16-Jan-1936 | -29.32 | 28.13 | VII | Fauresmith, Free State | The Swaziland and Fauresmith Earthquakes of January 1936 (Krige 1936) |
| A4 | 10-Feb-1938 | -27.60 | 31.35 | VI | Zululand | Earthquakes in South Africa (Krige and Maree 1948) |
| A5 | 29-Feb-1940 | -27.83 | 38.60 | V | Harrismith | Earthquakes in South Africa (Krige and Maree 1948) |
| A6 | 19-May-1940 | 32.33 | -24.33 | VI | Mozambique | Earthquakes in South Africa (Krige and Maree, 1948) |
| A7 | 10-Nov-1940 | -23.55 | 30.30 | VI | Tzaneen | An intensity survey following the earthquake of 17 February 1980 in the South-Eastern Transvaal. (Fernandez 1980) |
| A8 | 23-Oct-1941 | -30.78 | 17.53 | V | Namaqualand | Earthquakes in South Africa (Krige and Maree 1948) |
| A9 | 1-Nov-1942 | -31.07 | 30.13 | VI | Port Shepstone | Earthquakes in South Africa (Krige and Maree |

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| | | | | | | 1948 |
| A10 | 24-Nov-1943 | -29.50 | 22.95 | IV | Prieska | Earthquakes in South Africa (Krige and Maree 1948). |
| A11 | 17-Sep-1944 | -27.40 | 30.65 | V | Vryheid | Earthquakes in South Africa (Krige and Maree 1948). |
| A12 | 12-Nov-1944 | -28.53 | 27.68 | V | Ladybrandt | Earthquakes in South Africa (Krige and Maree 1948). |
| A13 | 29-Sep-1969 | -33.47 | 19.28 | VIII | Tulbagh | Some Macroseismic Observations in the Meizoseismal Area of the Boland Earthquake of 29 September 1969 (Keyser 1972) |
| A14 | 1-Jul-1976 | -29.22 | 24.92 | VII | Koffiefontein | Catalogue of Earthquakes in Southern Africa and Surrounding Oceans for 1976 (Fernandez and Labuschagne 1976) |
| A15 | 8-Dec-1976 | -27.93 | 26.75 | V | Welkom gold mines | The Earthquake of the 8th December 1976 at Welkom, Orange Free State (Fernandez and Guzman 1977). |
| A16 | 25-Jan-1977 | -27.85 | 16.88 | IV | Rosh Pinah, Namibia | Catalogue of Earthquakes in Southern Africa and surrounding Oceans for 1977 (Fernandez and Labuschagne 1977) |

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| A17 | 2-Mar-1977 | -33.30 | 19.28 | VI | Ceres | Catalogue of earthquakes in Southern Africa and surrounding oceans for 1977 (Fernandez and Labuschagne 1977) |
| A18 | 6-Jul-1979 | -26.20 | 28.13 | VI | East Rand Gold Mines | An intensity survey following the seismic event of 6 July1979 on the East Rand (Labuschagne and Lopez-Casado 1980). |
| A19 | 17-Feb-1980 | -26.83 | 30.00 | IV | Ermelo | An intensity survey following the earthquake of 17 February 1980 in the South-Eastern Transvaal. (Fernandez 1980). |
| A20 | 5-Oct-1986 | -30.50 | 28.57 | VI | Transkei | The Transkei Earthquake of 5 October 1986 (Graham and Fernandez 1987) |
| A21 | 29-Sep-1989 | -30.42 | 28.60 | VI | Transkei | An Investigation on the Seismic Intensities generated by the Transkei Earthquake of 29 September 1989 (Fernandez et al.1990) |
| A22 | 31-Oct-1991 | -33.33 | 19.28 | VI | Ceres | Isoseismal map compiled for this study |
| A23 | 7-Mar-1992 | -26.35 | 27.35 | VII | Far West Rand Gold Mines | The Carletonville Earth Tremor of 7 March 1992 (Fernandez et al. 1992). |
| A24 | 11-Mar-1993 | -29.53 | 18.45 | VI | Springbok | Isoseismal map compiled for this study |
| A25 | 9-Jan-1994 | -29.48 | 30.42 | VII | Howick | Isoseismal map compiled for this study |

| Figure ID | Date | Latitude | Longitude | Maximum Intensity | Region | Source |
|---|---|---|---|---|---|---|
| A26 | 27-Jun-1994 | -27.93 | 26.68 | V | Welkom | Isoseismal map compiled for this study |
| A27 | 30-Oct-1994 | -28.00 | 26.75 | VI | Free State gold mines | Visit to the Welkom – Virginia area following the occurrence of the earthquakes of 30 October and 1 November 1994 (Saunders et. al.1994). |
| A28 | 1-Nov-1994 | -27.95 | 26.75 | IV | Free State gold mines | Visit to the Welkom – Virginia area following the occurrence of the earthquakes of 30 October and 1 November 1994 (Saunders et. al. 1994). |
| A29 | 7-Feb-2000 | -26.17 | 30.62 | V | Lothair | Isoseismal map compiled for this study |
| A30 | 6-Sep-2004 | -26.80 | 26.60 | VI | Klerksdorp gold mines | The mining event of 6 September 2004, Klerksdorp, South Africa (Hattingh et al. 2005) |
| A31 | 9-Mar-2005 | -26.80 | 26.75 | VII | Klerksdorp gold mines | A preliminary appraisal of the effect of a magnitude $M_L$=5.3 event of 9 March 2005, Klerksdorp, South Africa (Saunders et. al. 2005) |
| A32 | 23-May-2005 | -26.40 | 27.43 | V | Far West Rand Gold Mines | Tremor of magnitude ML=4.0 on 23 May 2005 Carletonville (Saunders and Molea 2005). |

## References


Brandt MBC, Bejaichund M, Kgaswane EM, Hattingh E, Roblin DLR (2005) Seismic History of Southern Africa. Seismological Series of the Council for Geoscience. No 37.

De Klerk WJ, Read J (1988) An account of historical seismicity in Southern Africa with emphasis on the southern and eastern coastal belts in: Investigation for the siting of nuclear power stations: Progress Report No. 9. Atomic Energy Corporation of South Africa Limited. Report AEC-33/89

Fernandez LM (1980) An intensity survey following the earthquake of 17 February 1980 in the South-eastern Transvaal. Geological Survey Report Number 1980-0209.

Fernandez LM, Guzman JA (1976) The seismic history of Southern Africa, Geological Survey Report Number Gh2173.

Fernandez LM, Guzman JA (1977) The Seismic Event of the 8th December 1976 at Welkom, Orange Free State. Geological Survey Report Number Gh2259, 18pp.

Fernandez LM, Guzman JA (1979) Seismic History of Southern Africa, Geological Survey of South Africa, Seismologic Series 9, pp. 1-38.

Fernandez LM, Labuschagne PGA (1976) Catalogue of Earthquakes in Southern Africa and Surrounding Oceans for 1976. Geological Survey Seismological Series 8.

Fernandez LM, Labuschagne PGA (1977) Catalogue of Earthquakes in Southern Africa and Surrounding Oceans for 1977. Geological Survey Seismological Series 11.

Fernandez LM, Craill C, Molea T (1990). An Investigation on the Seismic Intensities generated by the Transkei Earthquake of 29 September 1989. Geological Survey Report Number 1990-0005, 9pp.

Fernandez LM, Graham G, du Plessis A (1992) The Carletonville Earth Tremor of 7 March 1992. Council for Geoscience. Report no: 1992-0134.

Finsen WS (1950), The geological Distribution of some South African Earthquakes" Circular No. 110, Union Observatory, Johannesburg

Graham G, Fernandez LM (1987) The Transkei earthquake of 5 October 1986. Geological Survey Report Number 1987-0163, 20pp.

Grünthal G, (1993) European Macroseismic Scale 1992 (up-dated MSK-scale), Cahiers du Centre Europeén de Géodynamique et de Séismology 7: 1–79.

Hattingh E, Saunders I, Roblin DL, Keyser N, Molea TT, Sutherland BE (2005) The mining event of 6 September 2004, Klerksdorp, South Africa. Council for Geoscience Report Number 2005-0149.

Keyser AW (1979) Some Macroseismic Observations in the Meizoseismal Area of the Boland Earthquake of 29 September 1969 in The Earthquake of 29 September 1969 in the South-western Cape Province, South Africa. 1975. Seismologic Series 4. Geological Survey., 53pp.

Krige LG (1936) The Swaziland and Fauresmith Earthquakes of January 1936. Trans. Geol. Soc. South Africa, 39: 429-440.

Krige LJ, Maree BD (1948) Earthquakes in South Africa. Bull. Geol. Surv. South Africa., 20, 14p.

Krige LJ, Venter FA (1933). The Zululand Earthquake of the 31st December 1932. Trans. Geol. Soc. South Africa, 36: 101-112.

Labuschagne PGA, Lopez-Casado C (1980) An intensity survey following the seismic event of 6 July 1979 on the East Rand. Geological Survey Report Number 1980-0069.

Michetti AM, Esposito E, Gürpinar A, Mohammadioun B, Porfido S, Rogozhin E, Serva L, Tatevossian R, Vittori E, Audemard F, Comerci V, Marco S, McCalpin J, Mörner NA (2004) The INQUA scale. In: Vittori, E., Comerci, V., (Eds.), An innovative approach for assessing earthquake intensities based on seismically induced ground effects in natural environment. Special paper APAT, Mem. Descr. Carta geol. d'Italia, LXVII.

Richter CF (1958) Elementary Seismology, Freeman W.H., San Francisco 768pp

Saunders I, Molea TT (2005) Tremor of magnitude ML=4.0 on 23 May 2005 Carletonville, South Africa. Council for Geoscience Report Number 2005-0168.

Saunders I, Brandt MBC, Kgawsane E, Molea TT (2005) A preliminary appraisal of the effect of a magnitude $M_L$=5.3 event of 9 March 2005, Klerksdorp, South Africa. Council for Geoscience Report Number 2005-0066.

Saunders I, Brandt MBC, Nel W M (1994) Visit to the Welkom – Virginia area following the occurrence of the earthquakes of 30 October and 1 November 1994. Council for Geoscience Report Number 1994-0188.

Theron JN (1974) "Die Seismiese Geskiedenis van die Suid-westelike Kaapprovinsie". Die Aardbewing van 29 September 1969 in die Suidwestelike Kaapprovinsie, Suid Afrika. Seismologiese Reeks 4 Geological Survey, Pretoria.

Wood HO, Neumann F (1931) Modified Mercalli intensity scale of 1931, Bulletin, Seismological Society of America 21: 277–283.

# APPENDIX

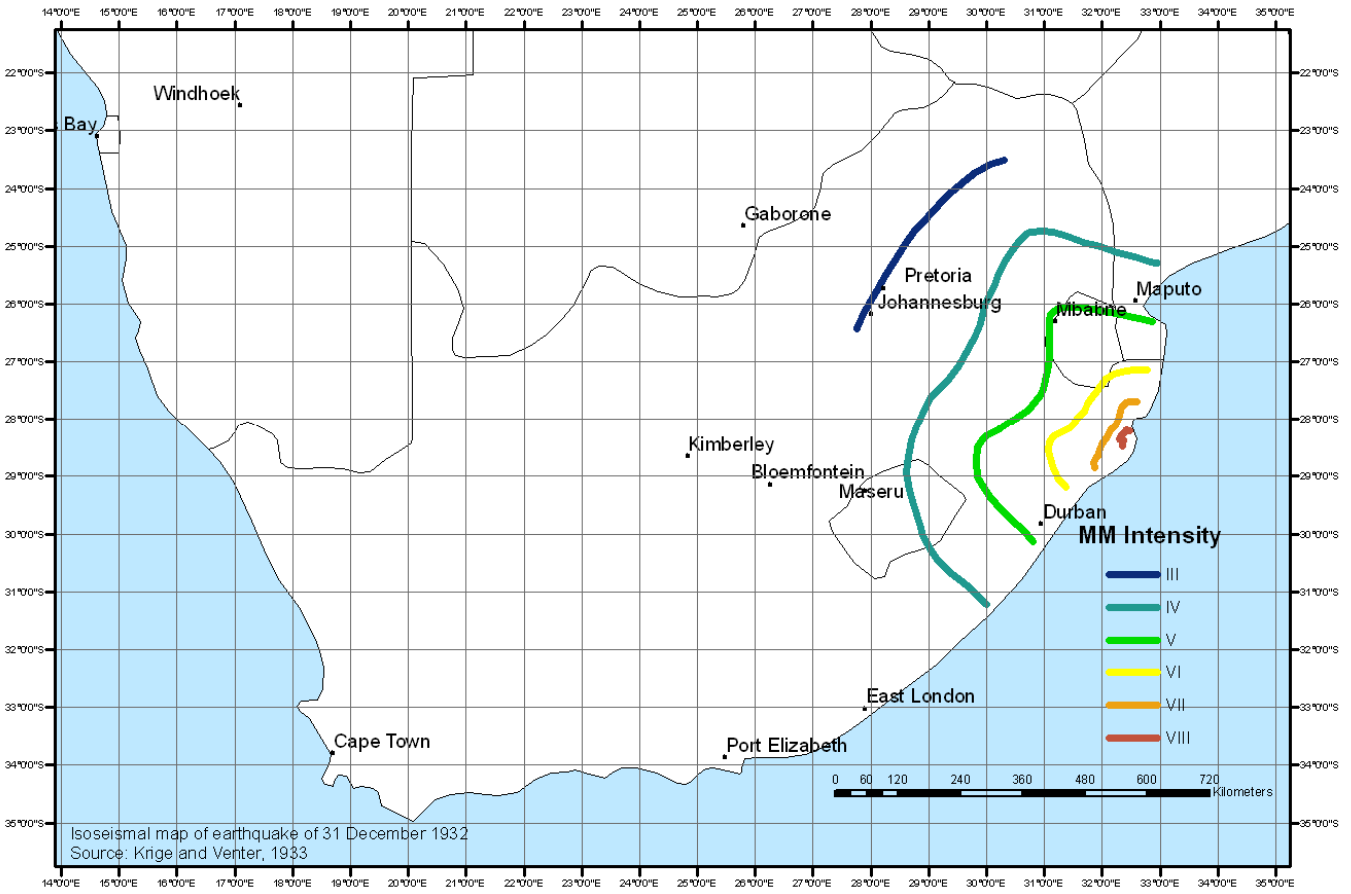



Figure A1 Isoseismal map of earthquake of 31-Dec-1932

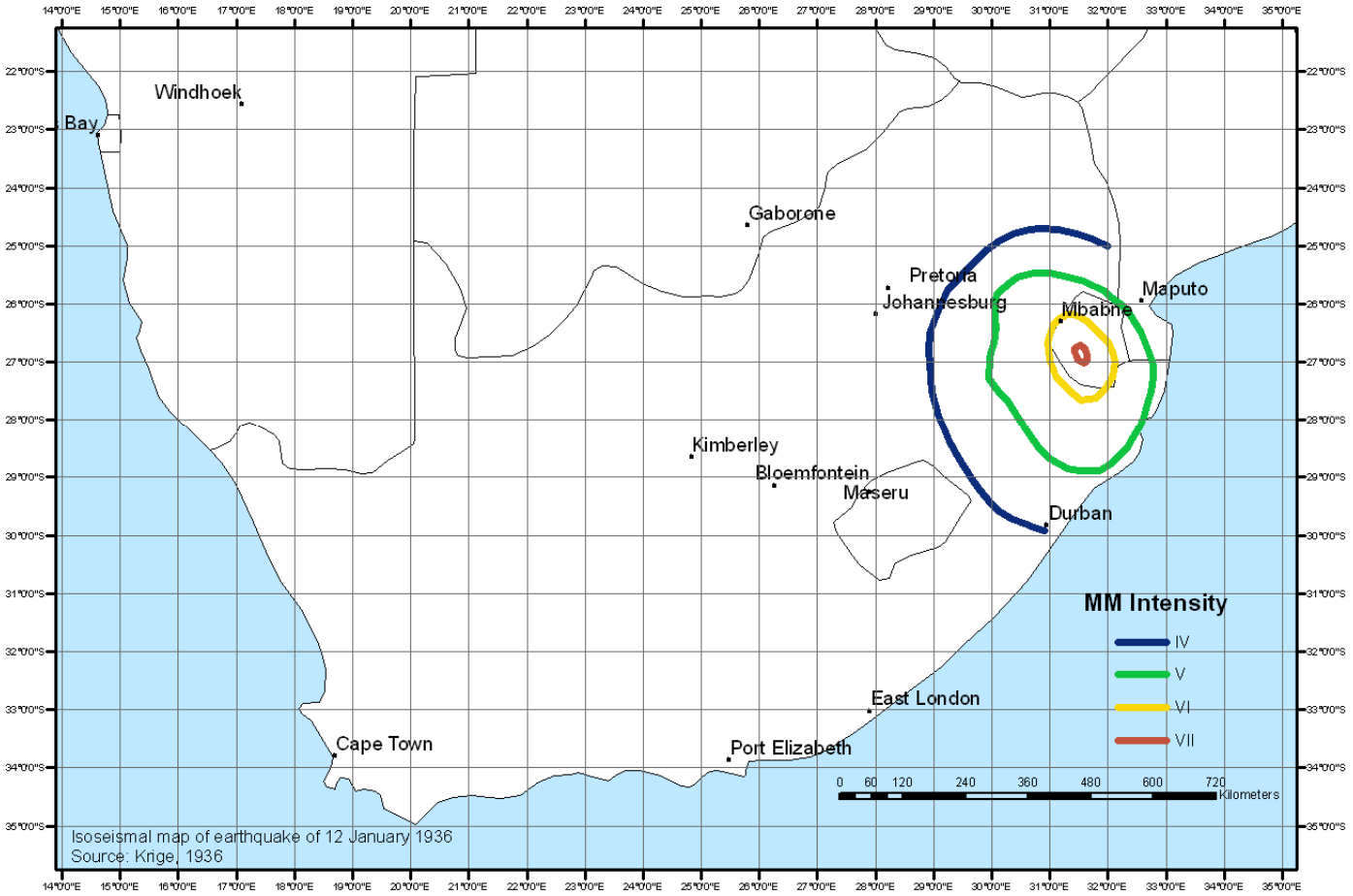



Figure A2 Isoseismal map of earthquake of 12-Jan-1936

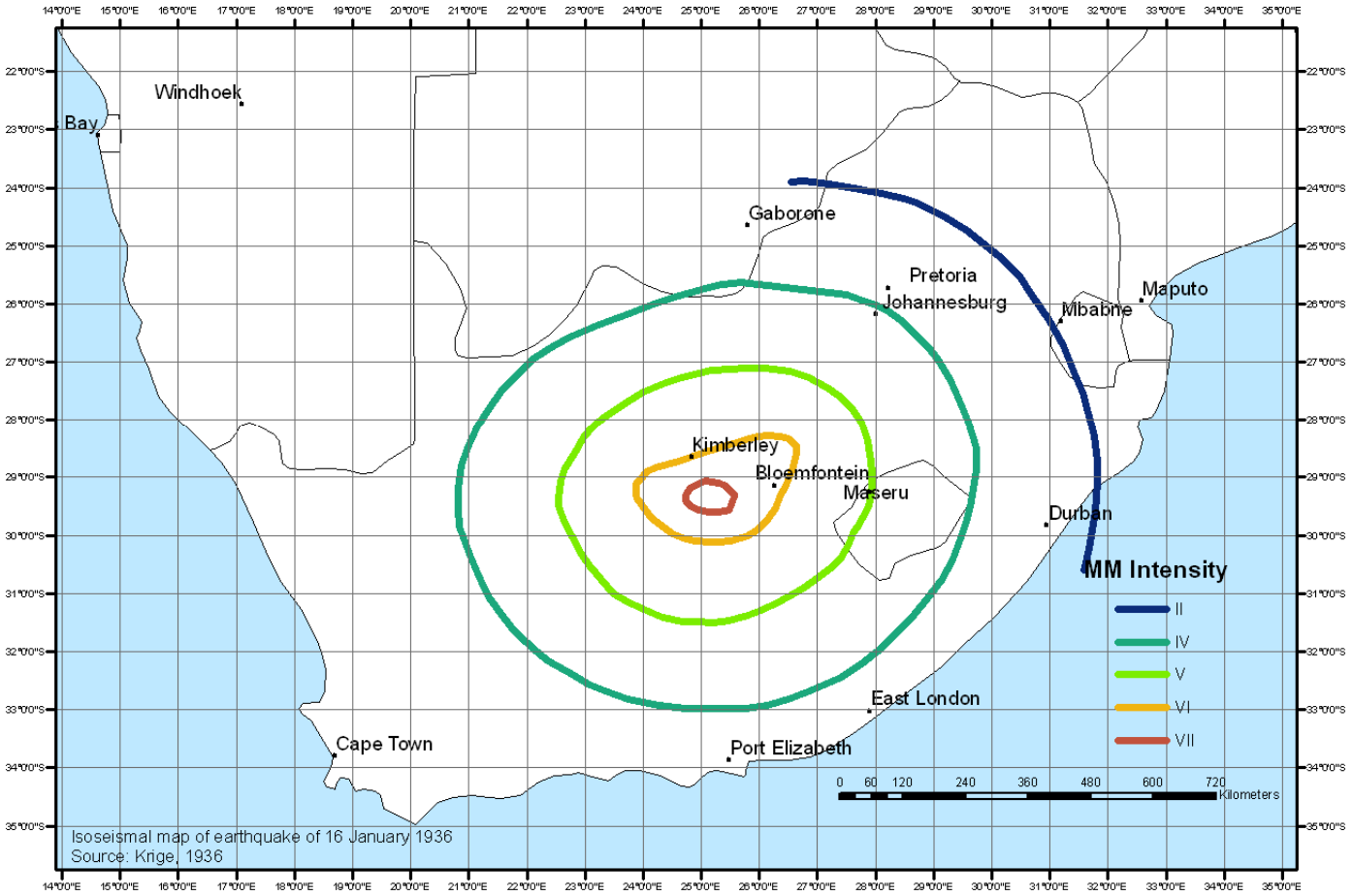



Figure A3 Isoseismal map of earthquake of 16-Jan-1936

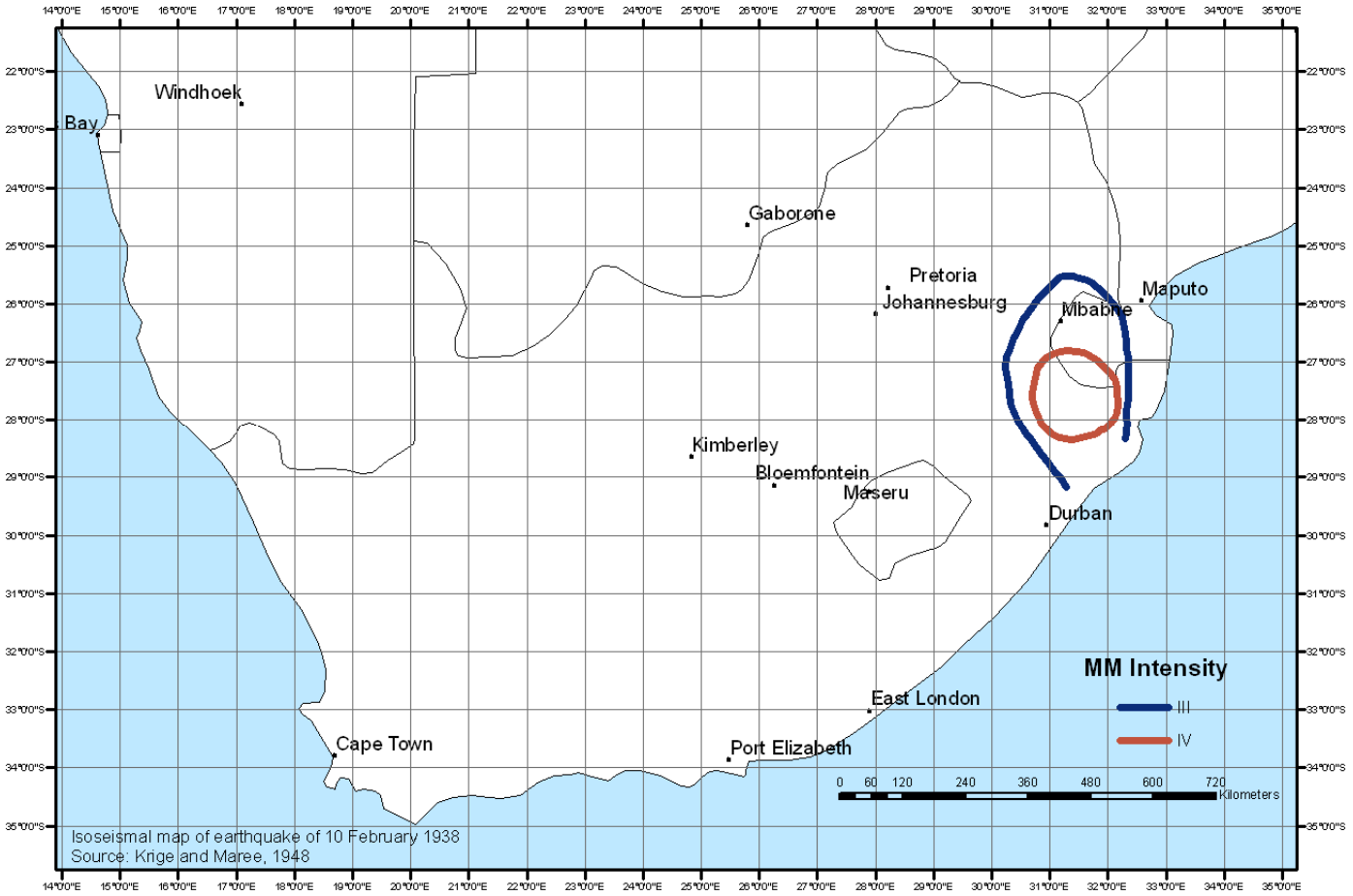



Figure A4 Isoseismal map of earthquake of 10-Feb-1938

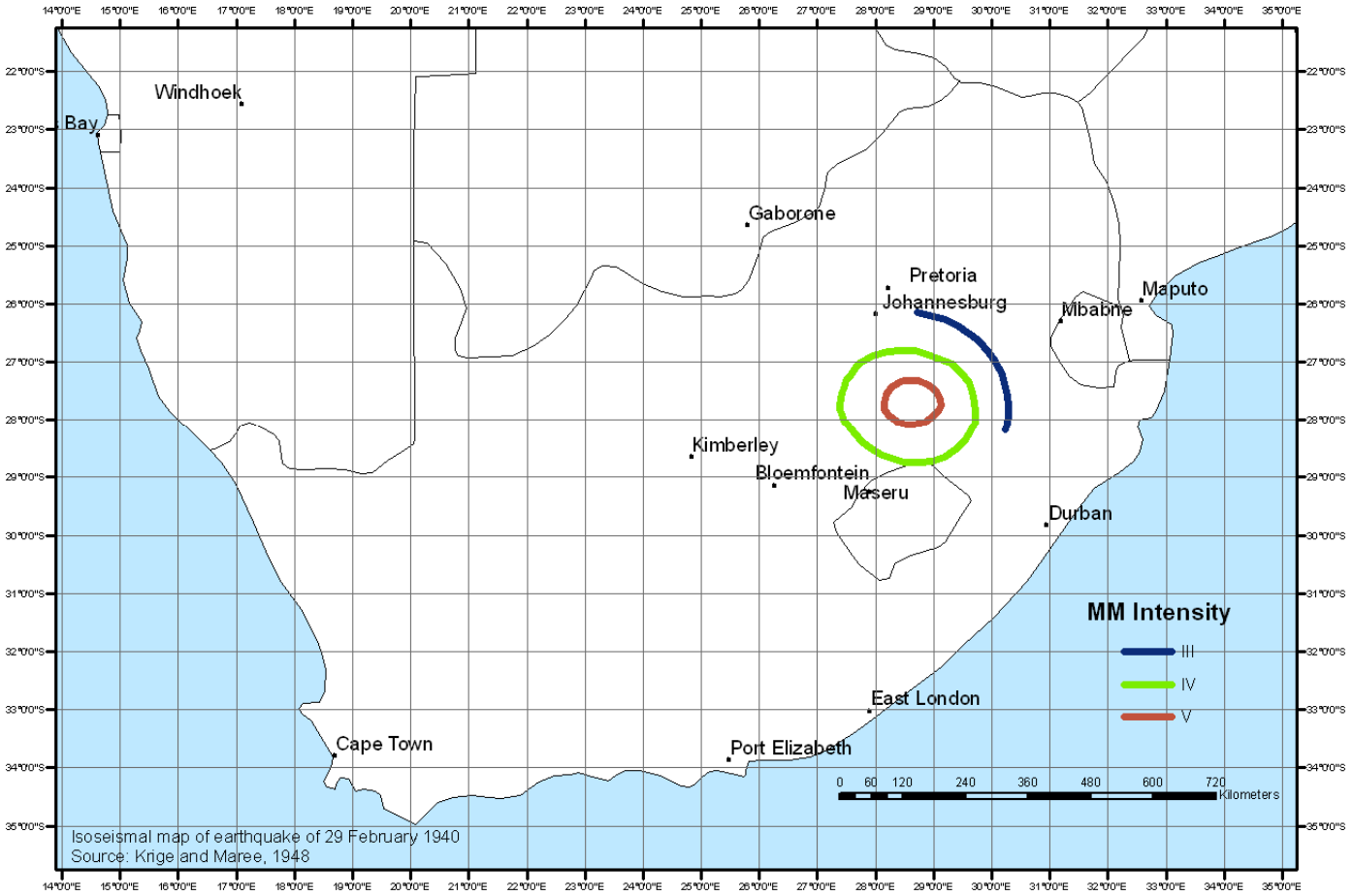



Figure A5 Isoseismal map of earthquake of 29-Feb-1940

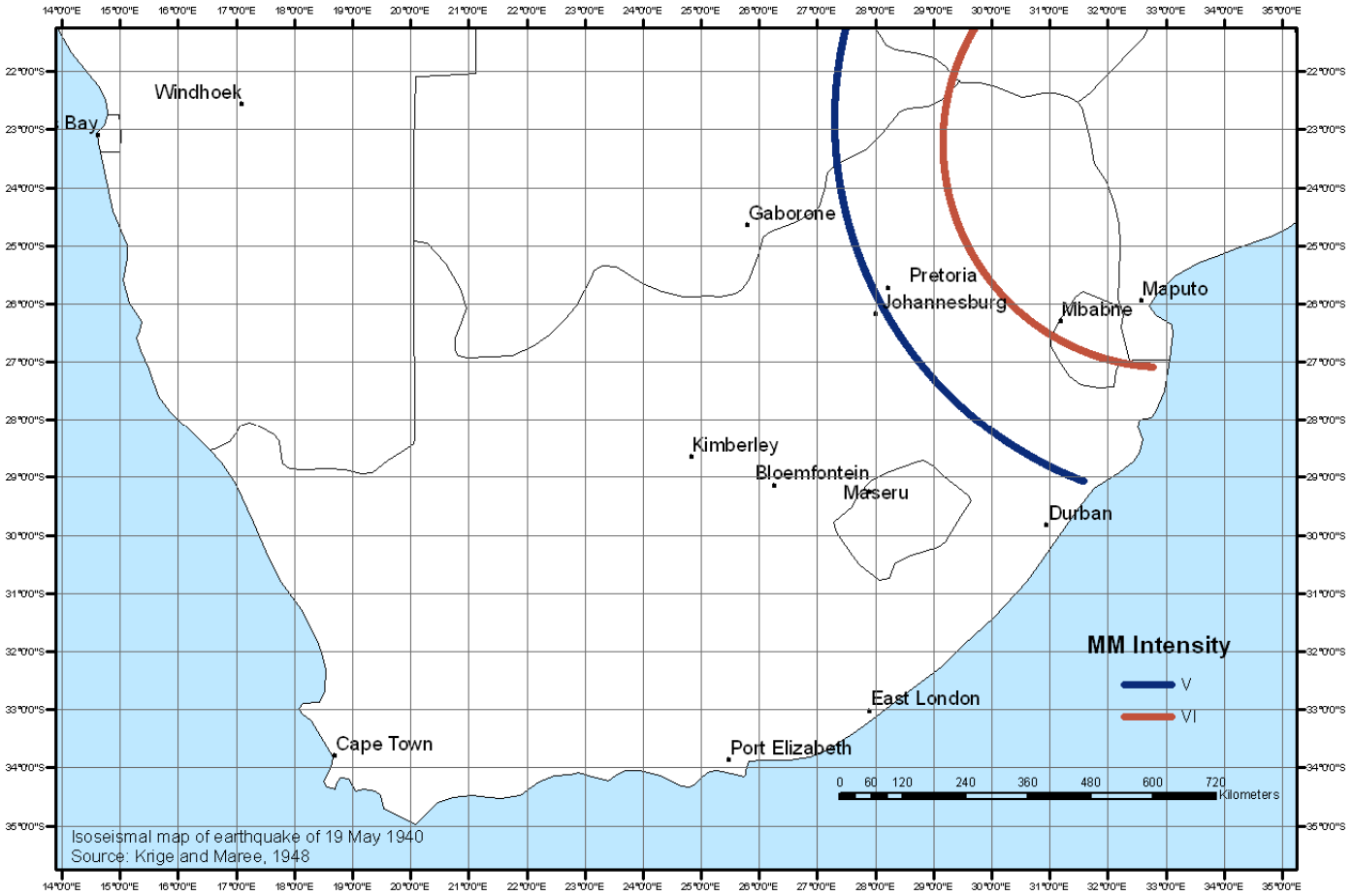



Figure A6 Isoseismal map of earthquake of 19-May-1940

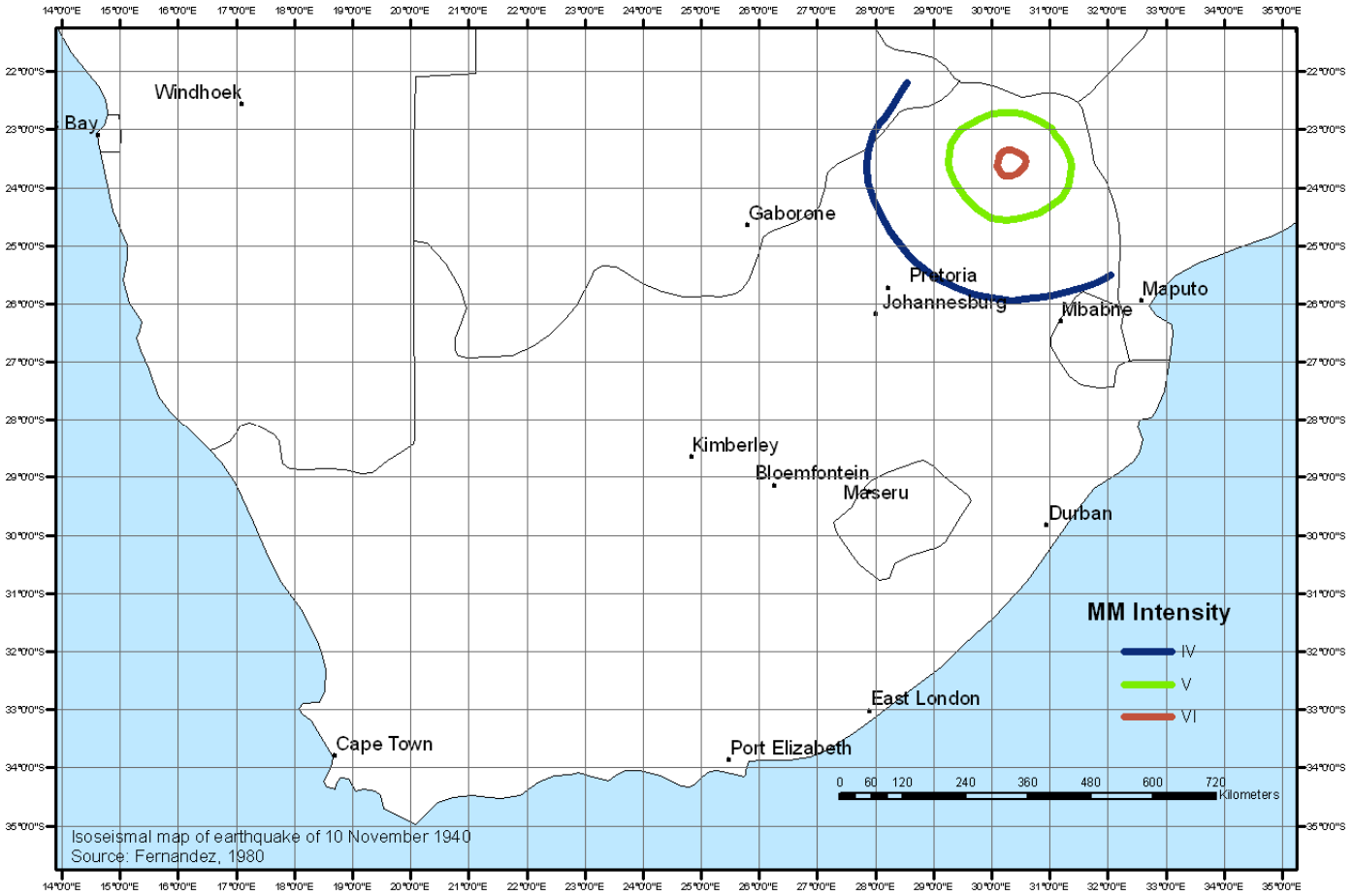



Figure A7 Isoseismal map of earthquake of 10-Nov-1940

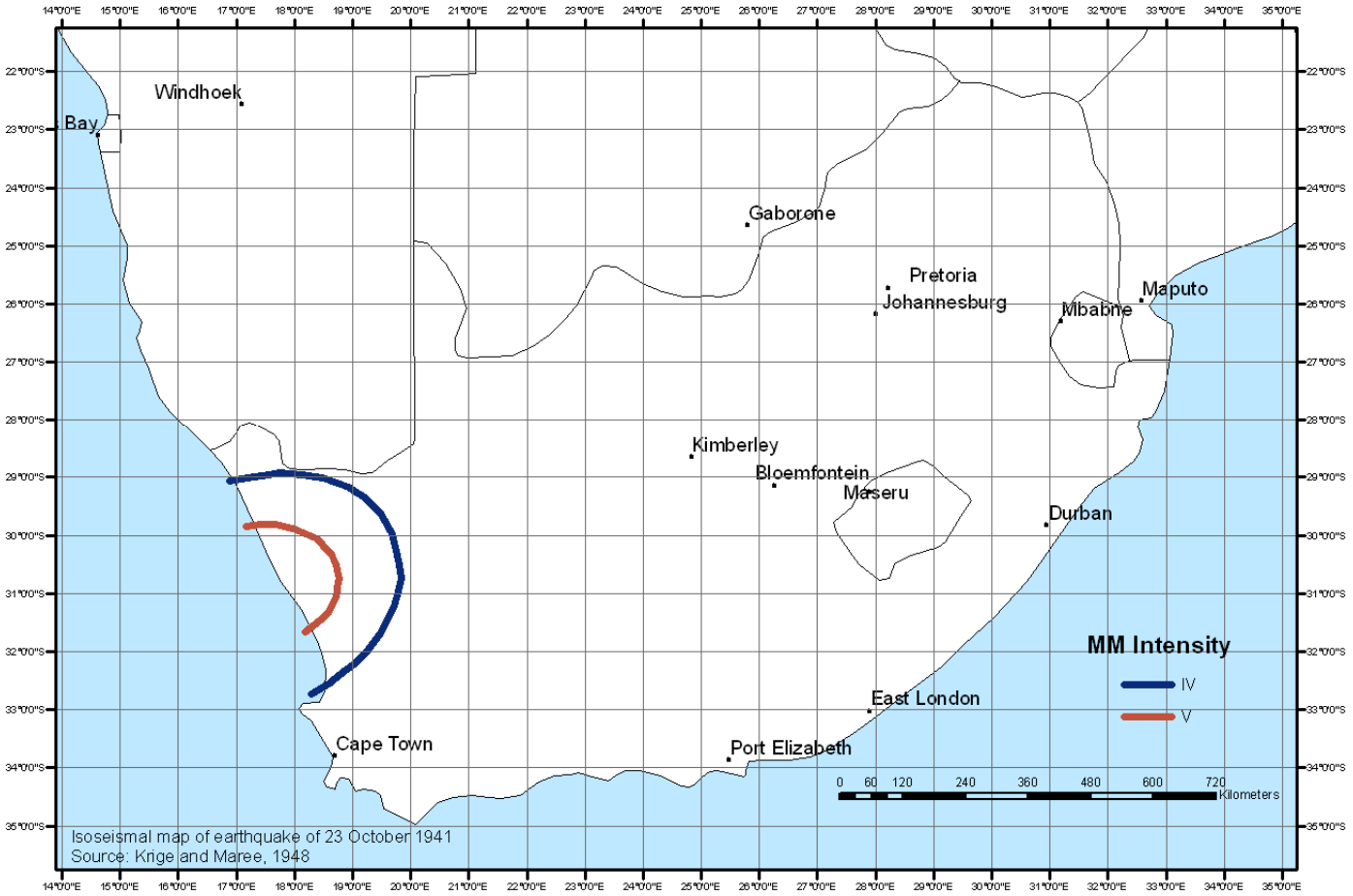



Figure A8 Isoseismal map of earthquake of 23-Oct-1941

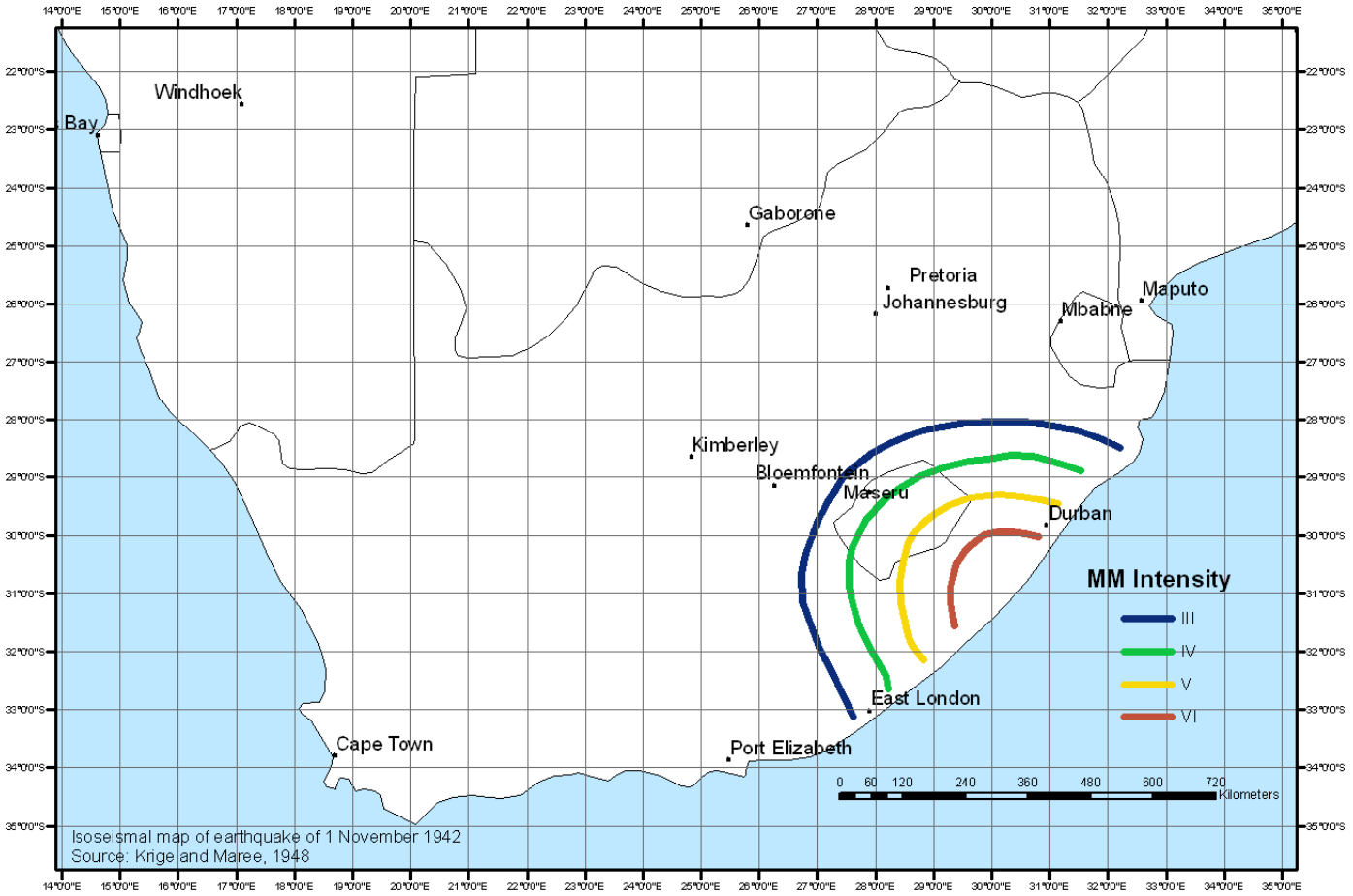



Figure A9 Isoseismal map of earthquake of 1-Nov-1942

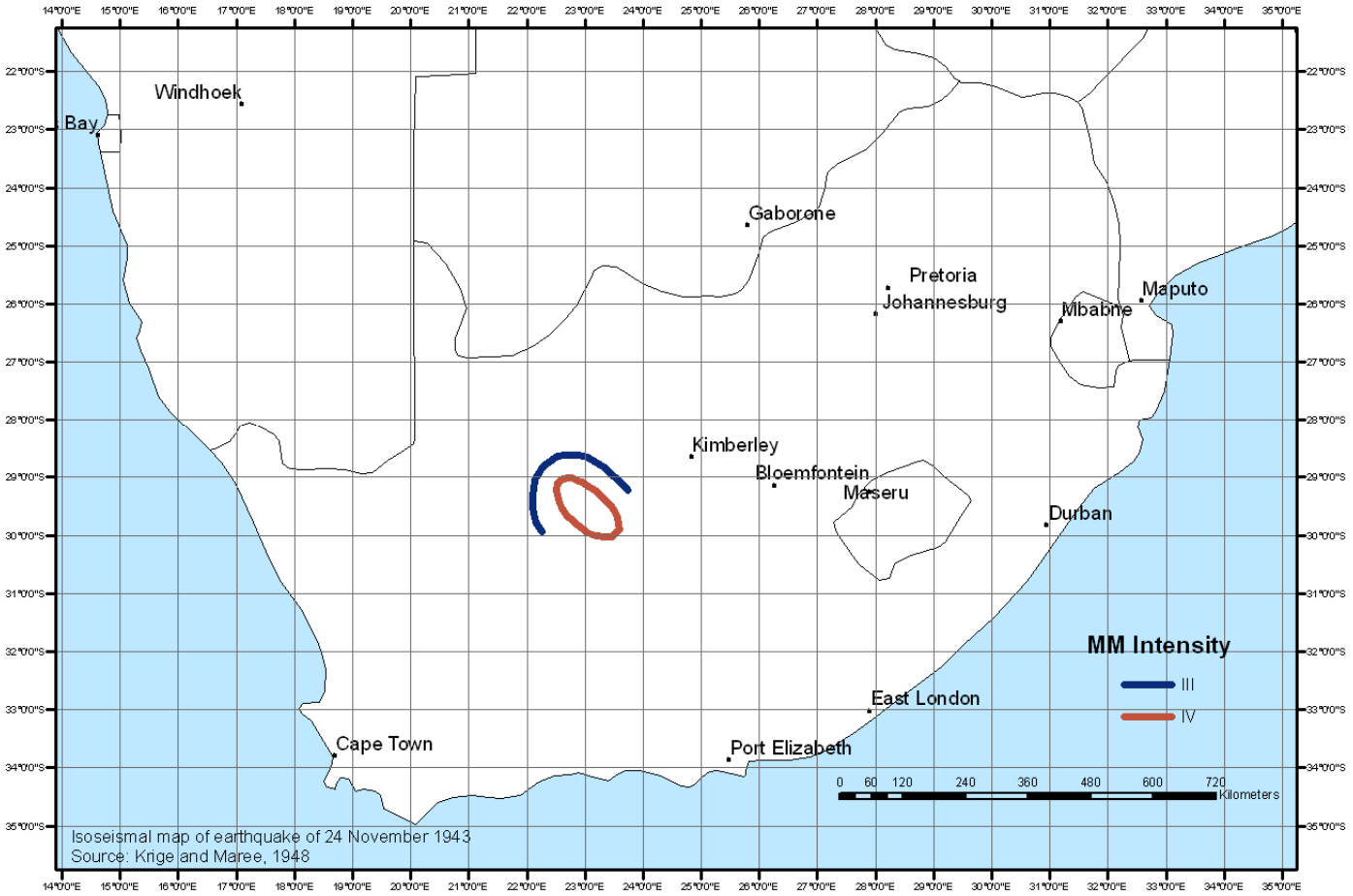



Figure A10 Isoseismal map of earthquake of 24-Nov-1943

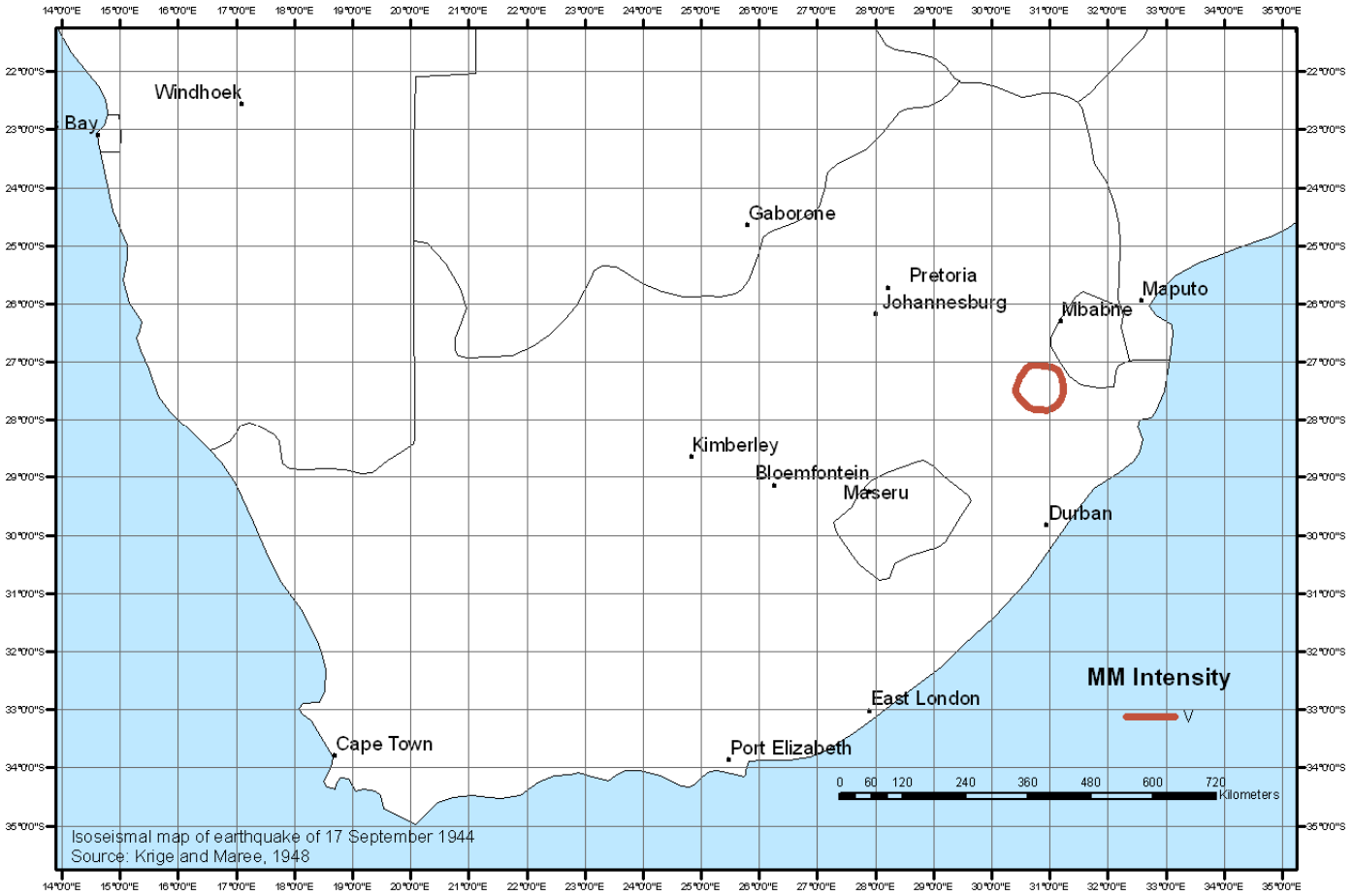



Figure A11 Isoseismal map of earthquake of 17-Sep-1944

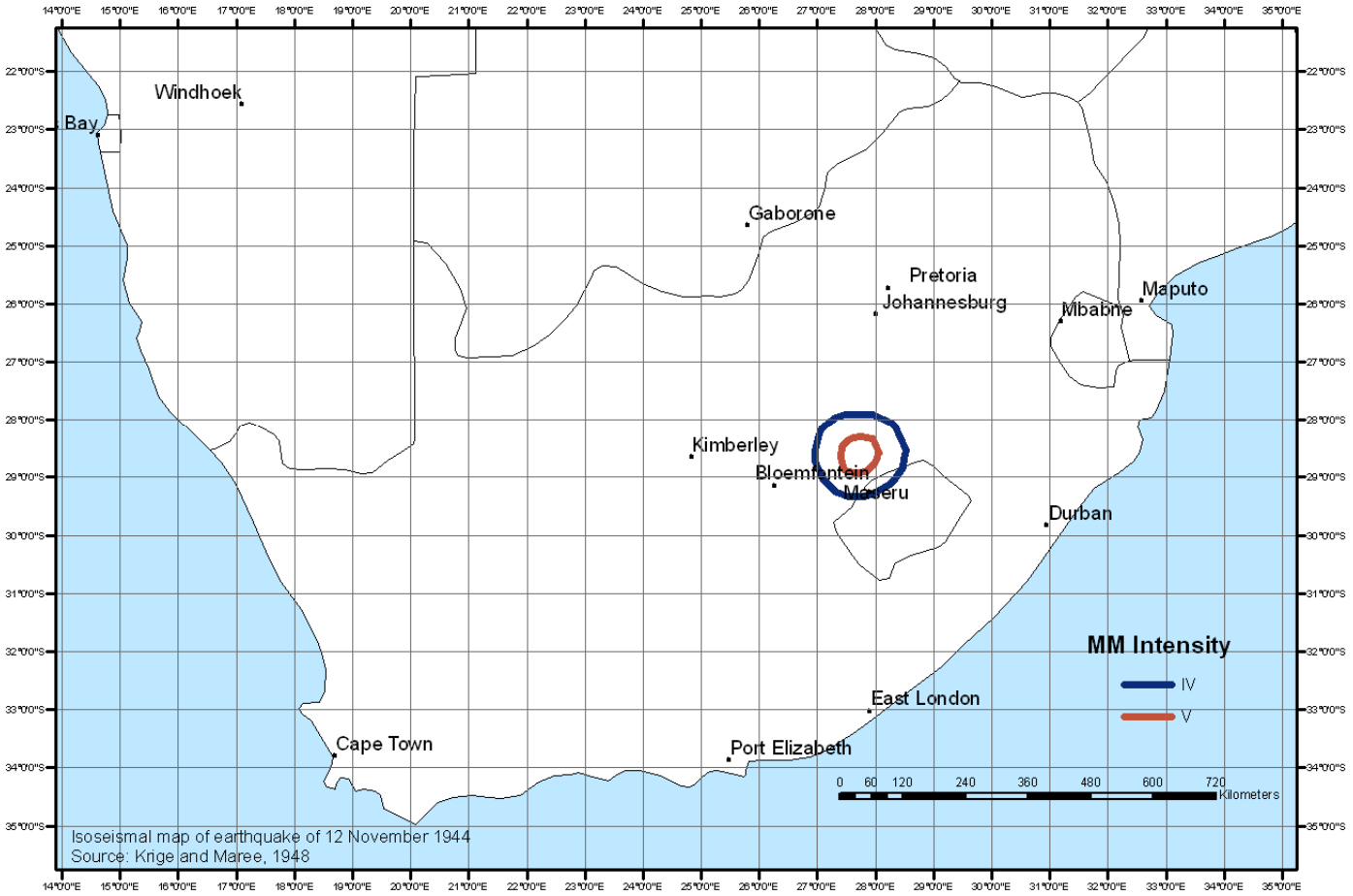



Figure A12 Isoseismal map of earthquake of 12-Nov-1944

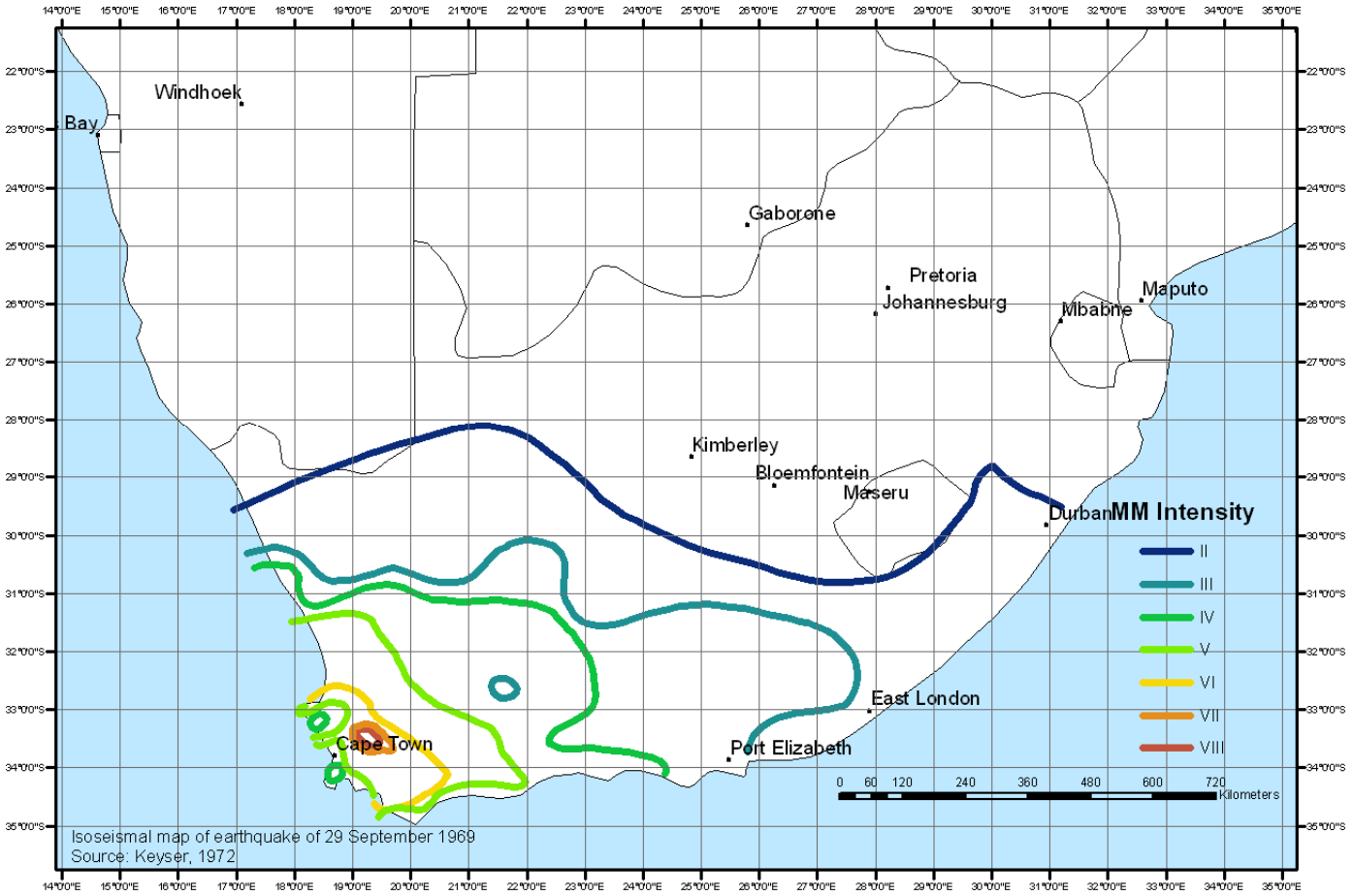



Figure A13 Isoseismal map of earthquake of 29-Sep-1969

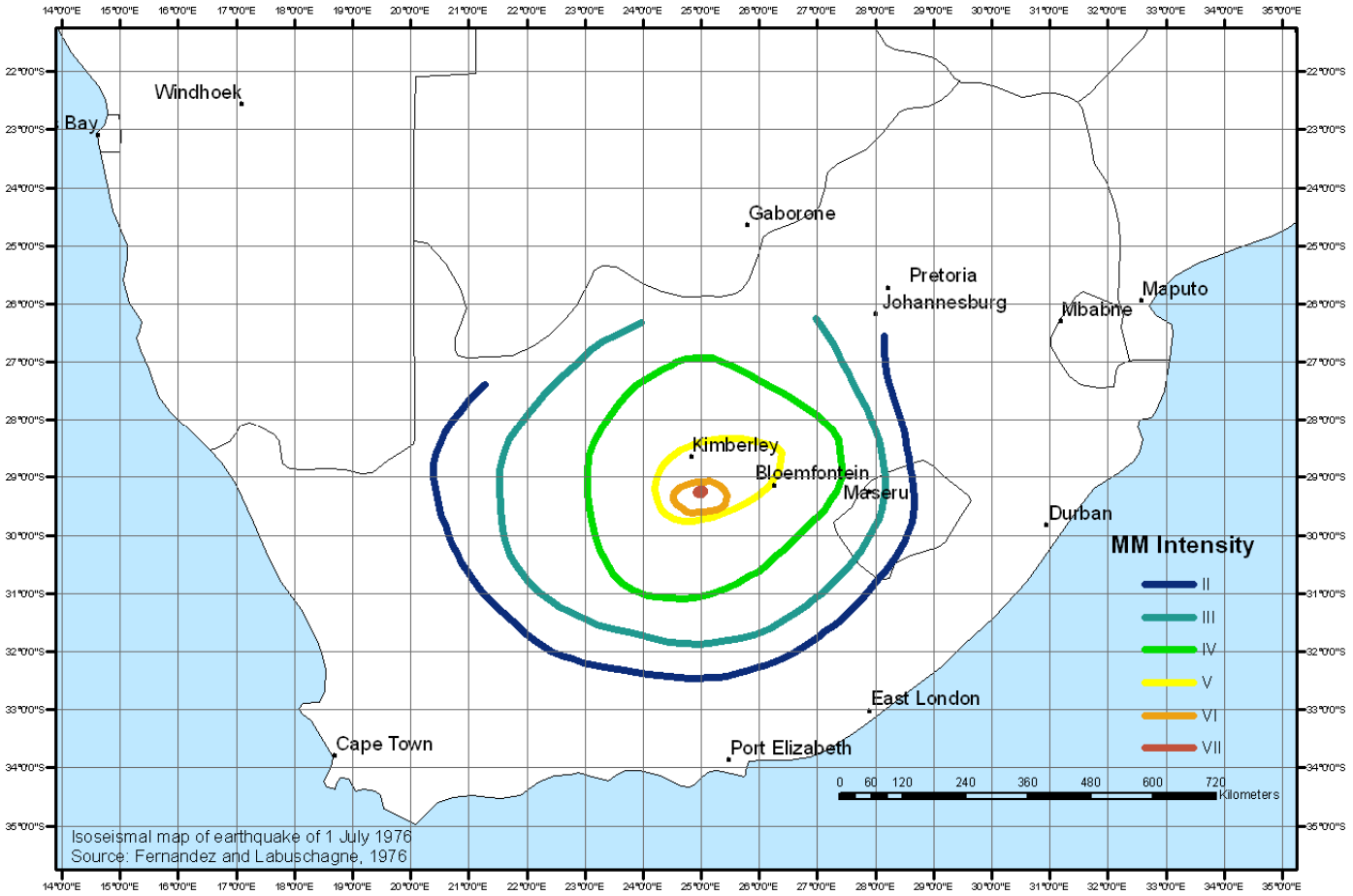



Figure A14 Isoseismal map of earthquake of 1-Jul-1976

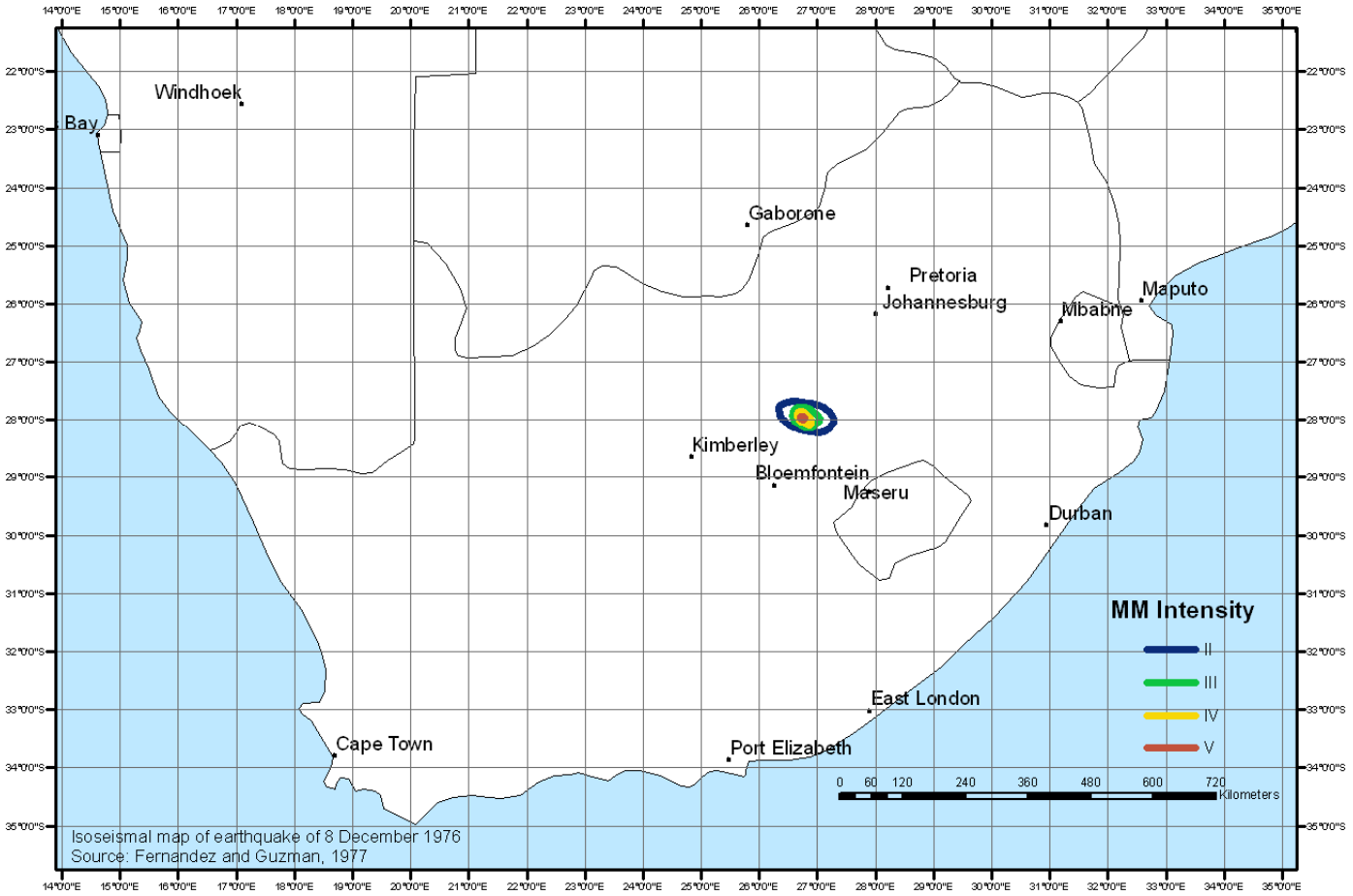



Figure A15 Isoseismal map of earthquake of 8-Dec-1976

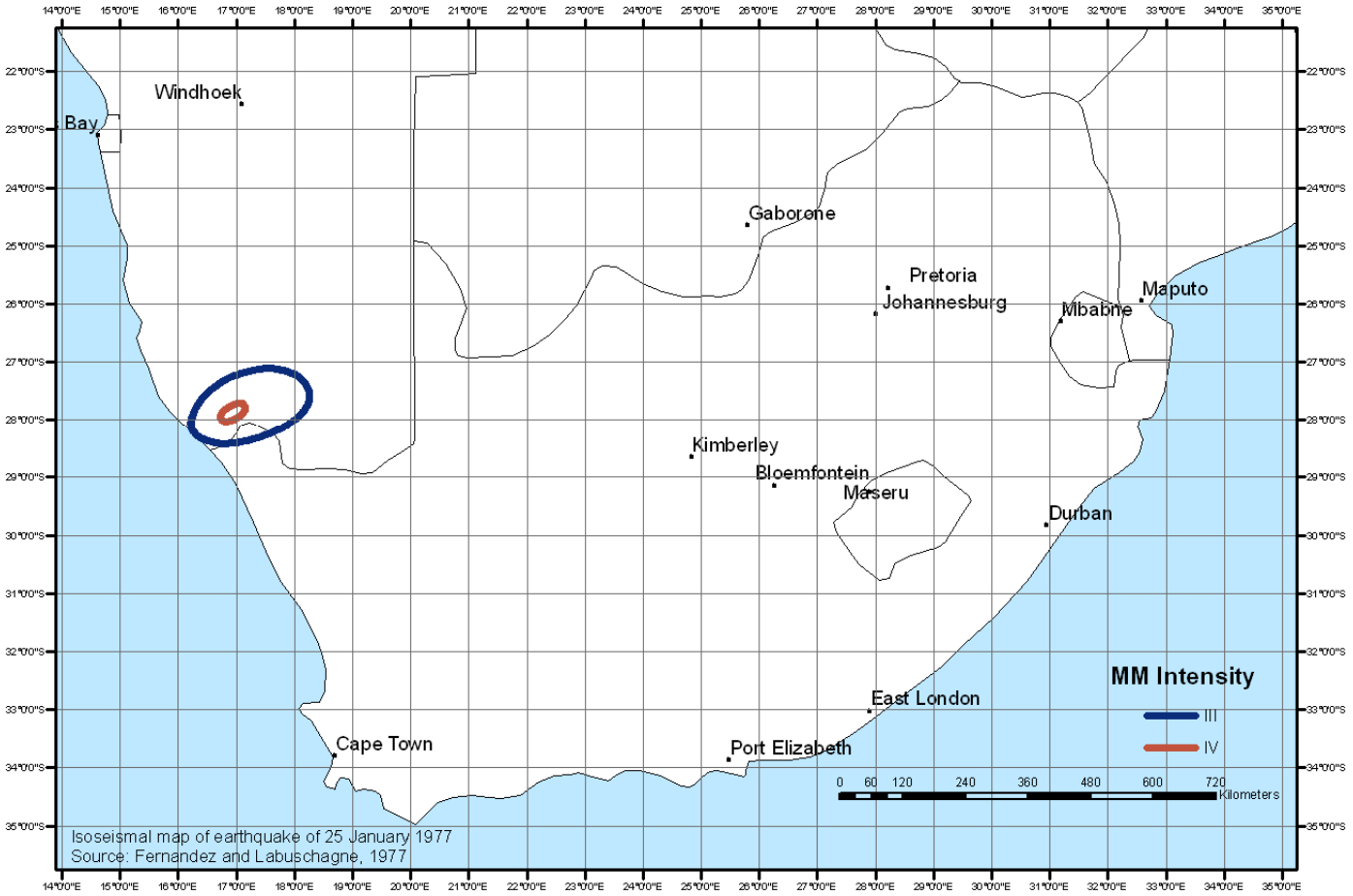



Figure A16 Isoseismal map of earthquake of 25-Jan-1977

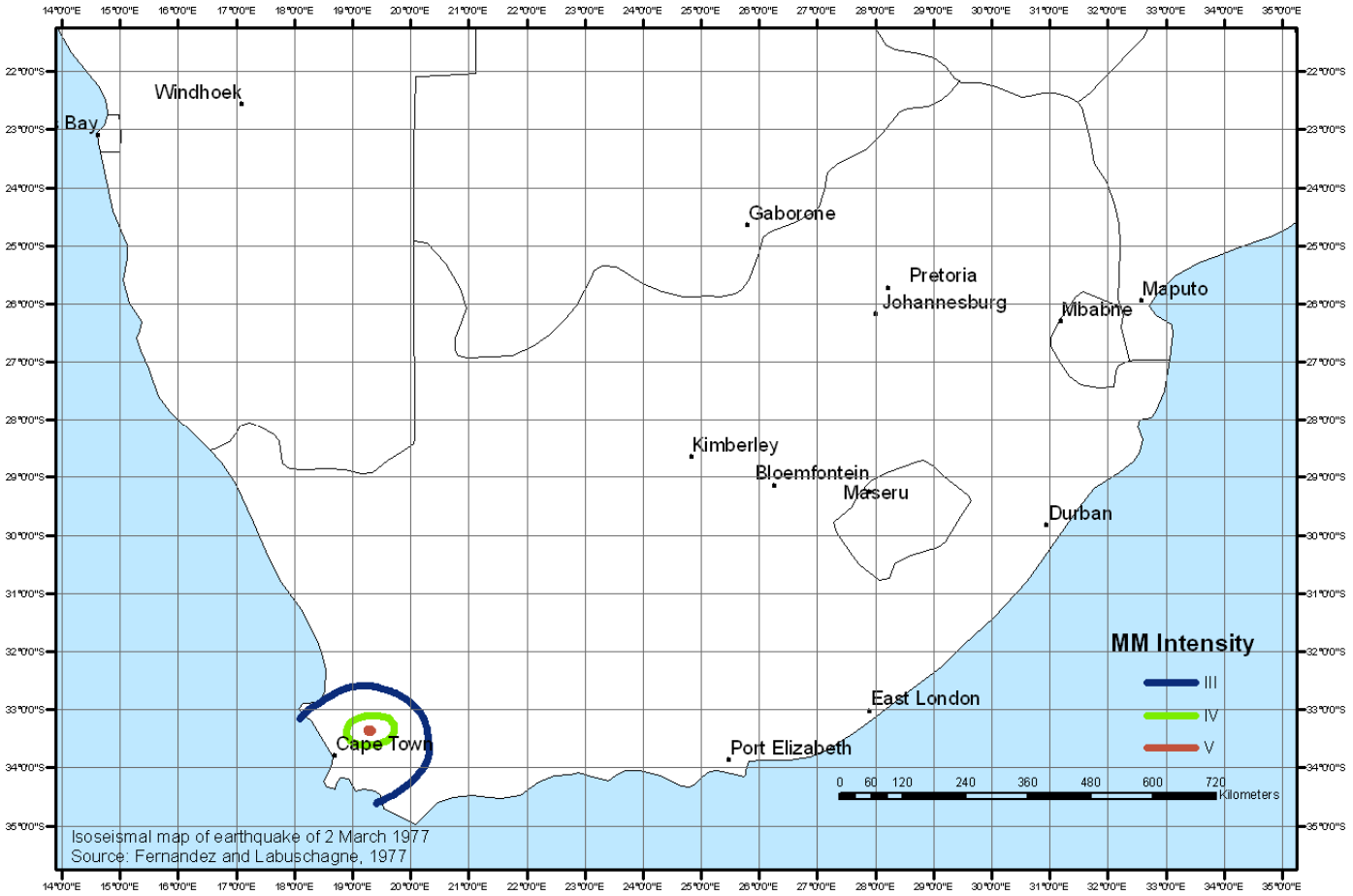



Figure A17 Isoseismal map of earthquake of 2-Mar-1977

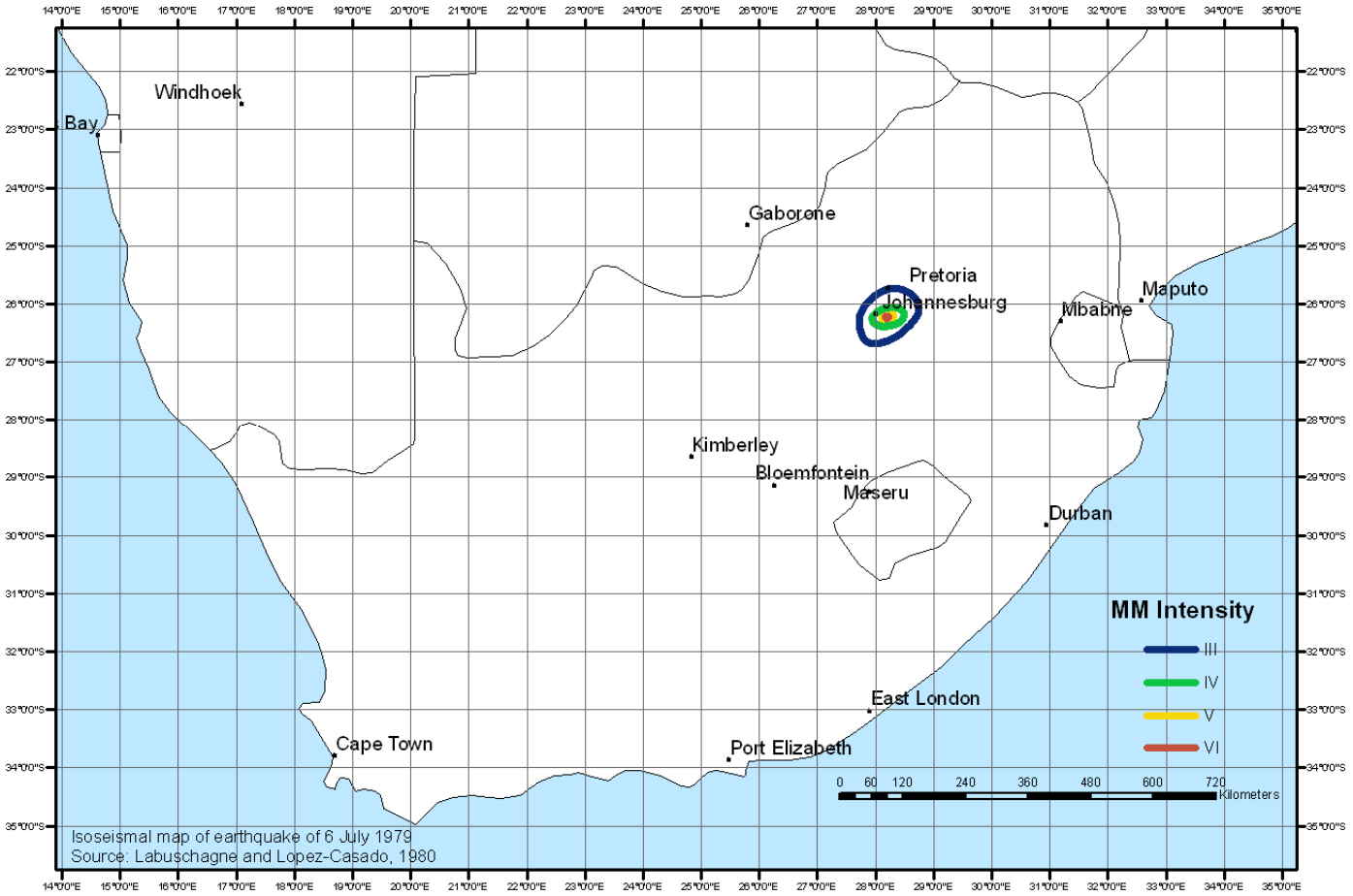



Figure A18 Isoseismal map of earthquake of 6-Jul-1979

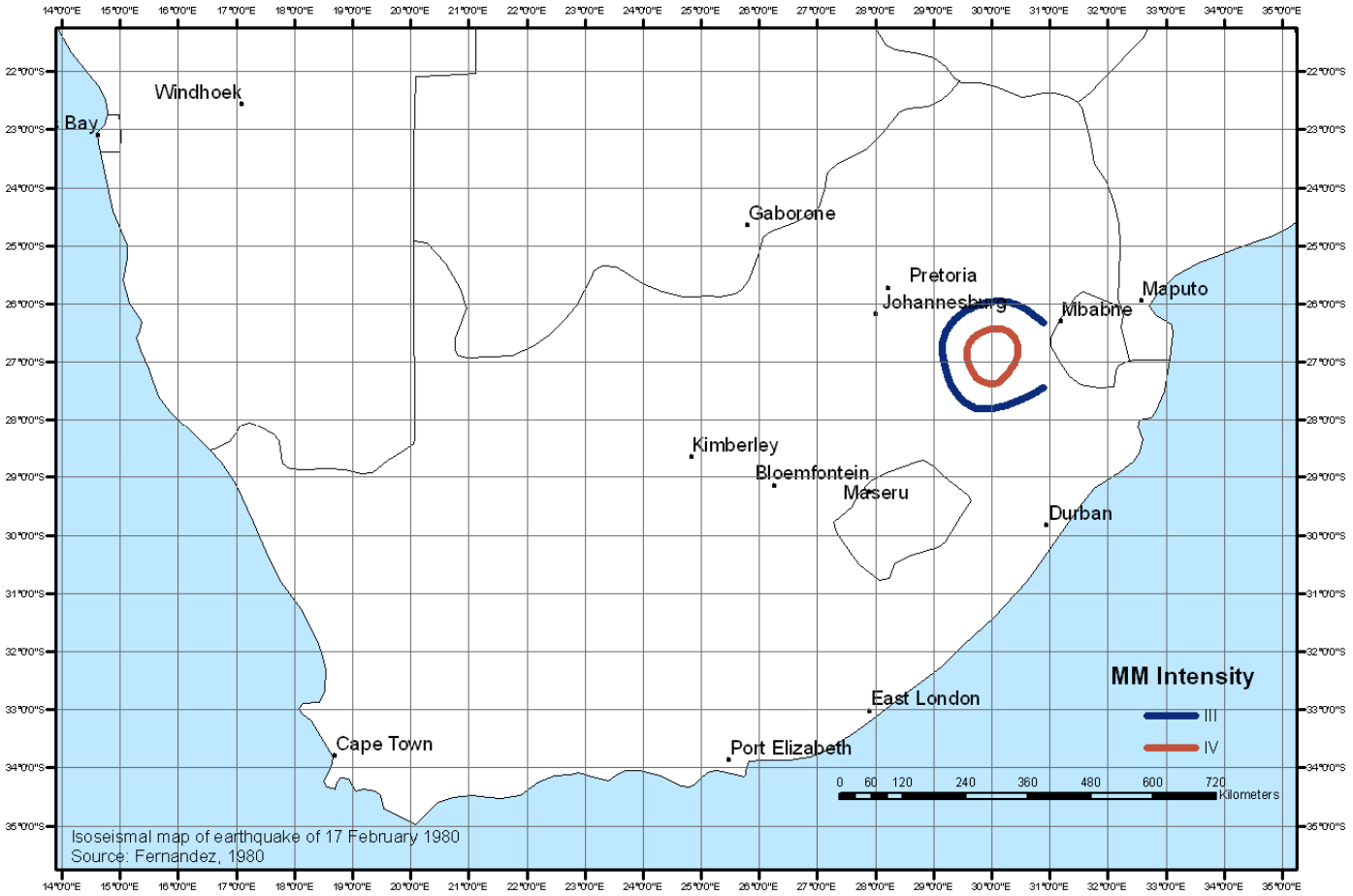



Figure A19 Isoseismal map of earthquake of 17-Feb-1980

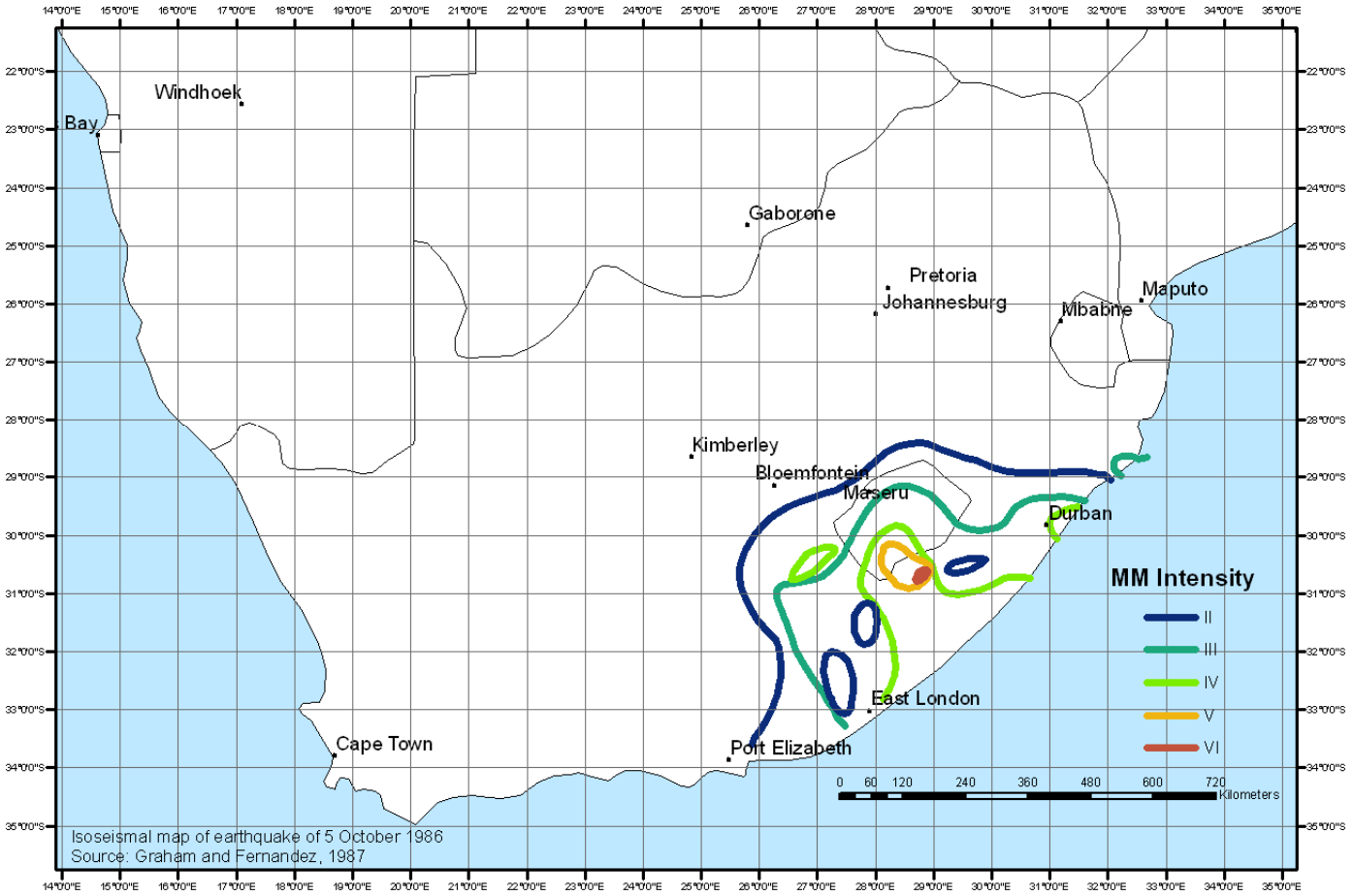



Figure A20 Isoseismal map of earthquake of 5-Oct-1986

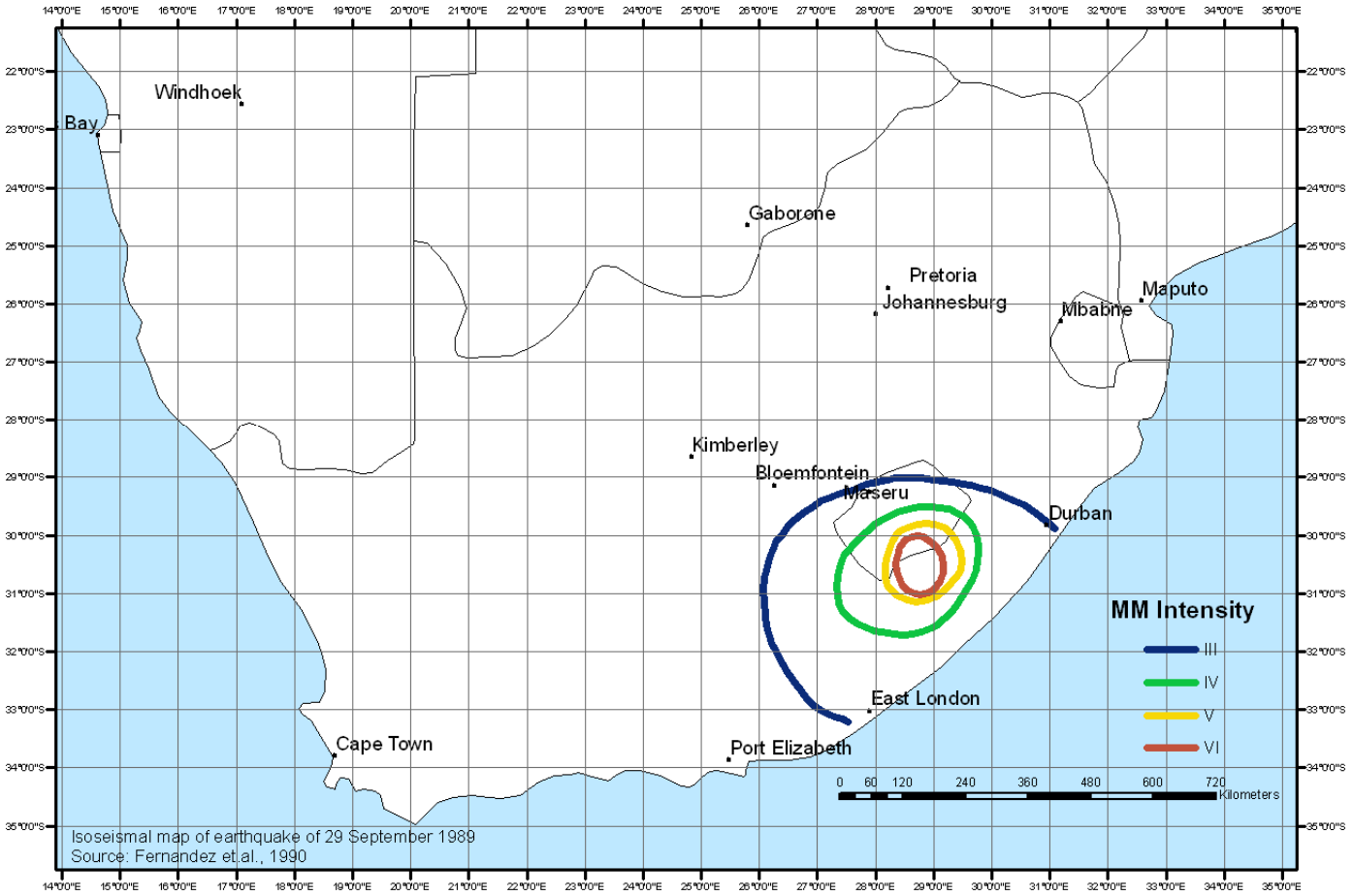



Figure A21 Isoseismal map of earthquake of 29-Sep-1989

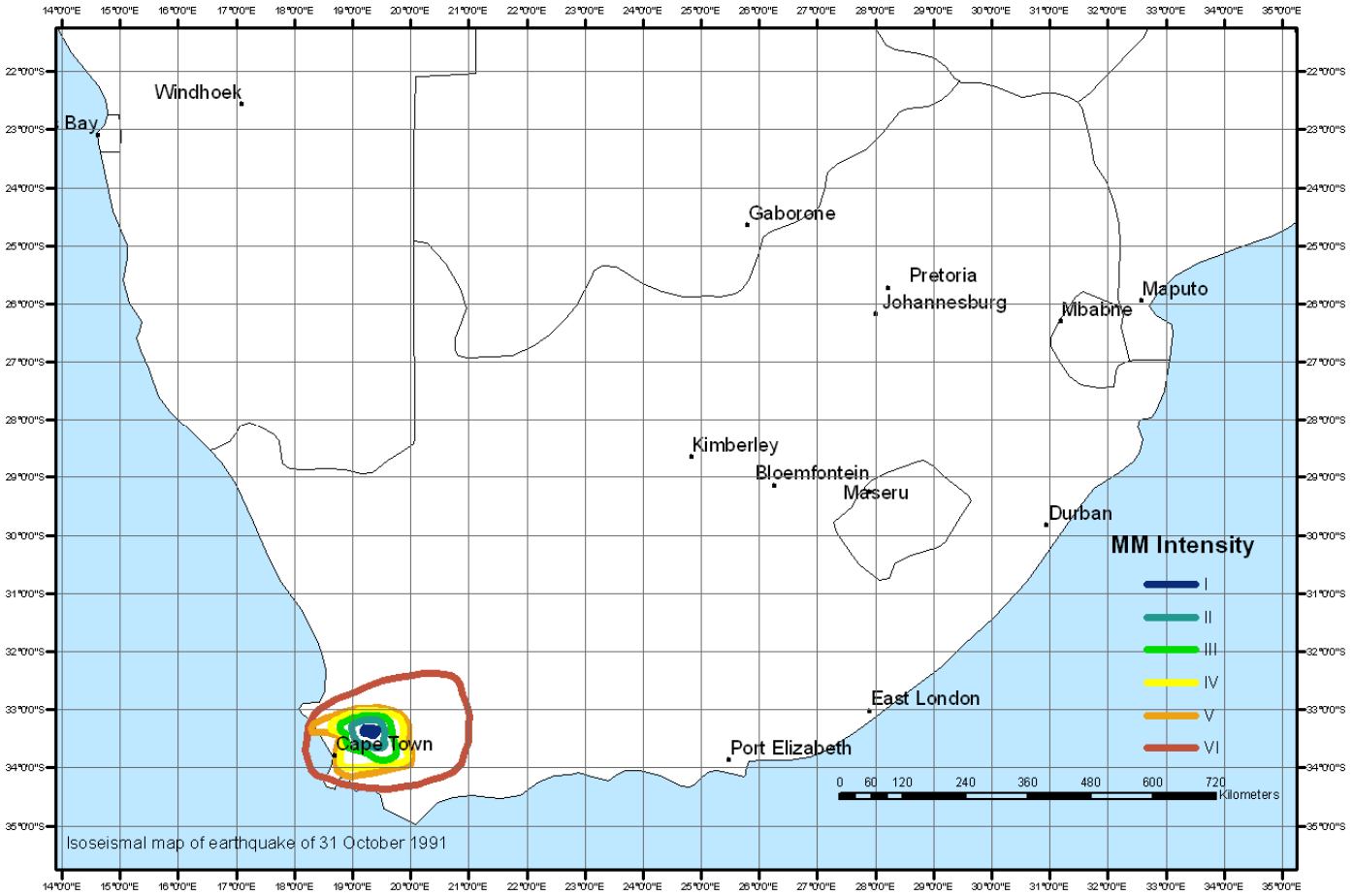



Figure A22 Isoseismal map of earthquake of 31-Oct-1991

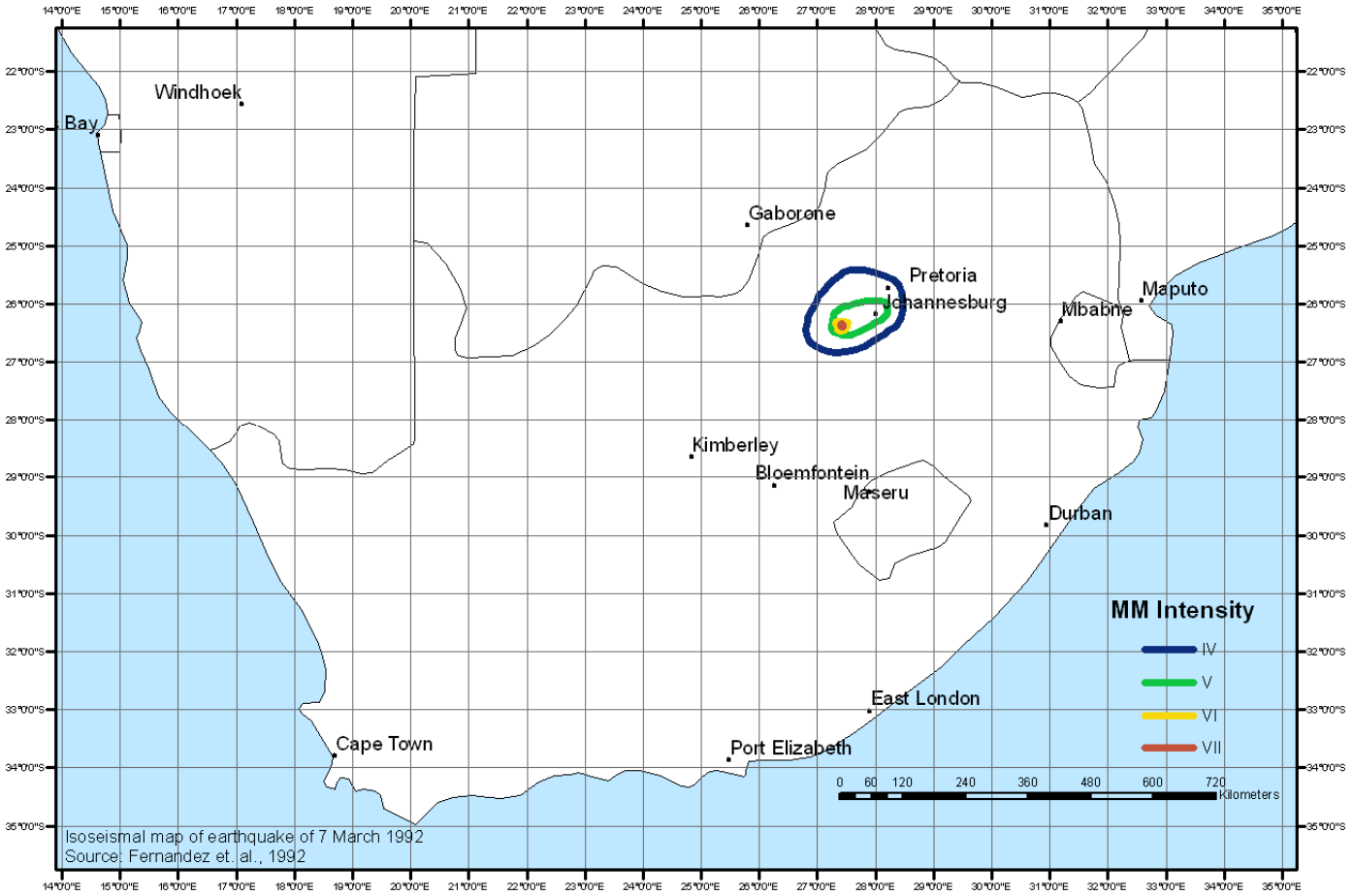



Figure A23 Isoseismal map of earthquake of 7-Mar-1992

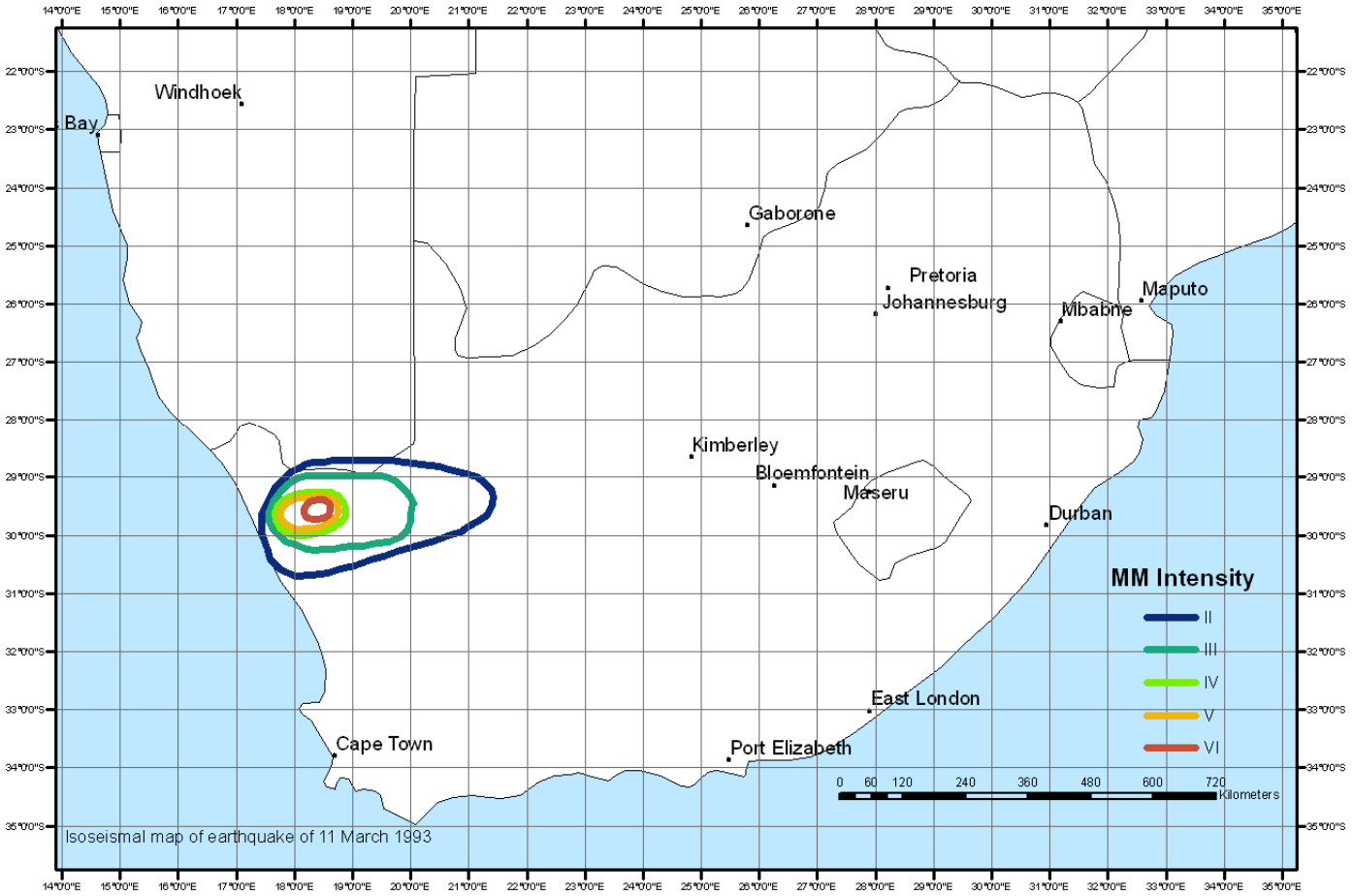



Figure A24 Isoseismal map of earthquake of 11-Mar-1993

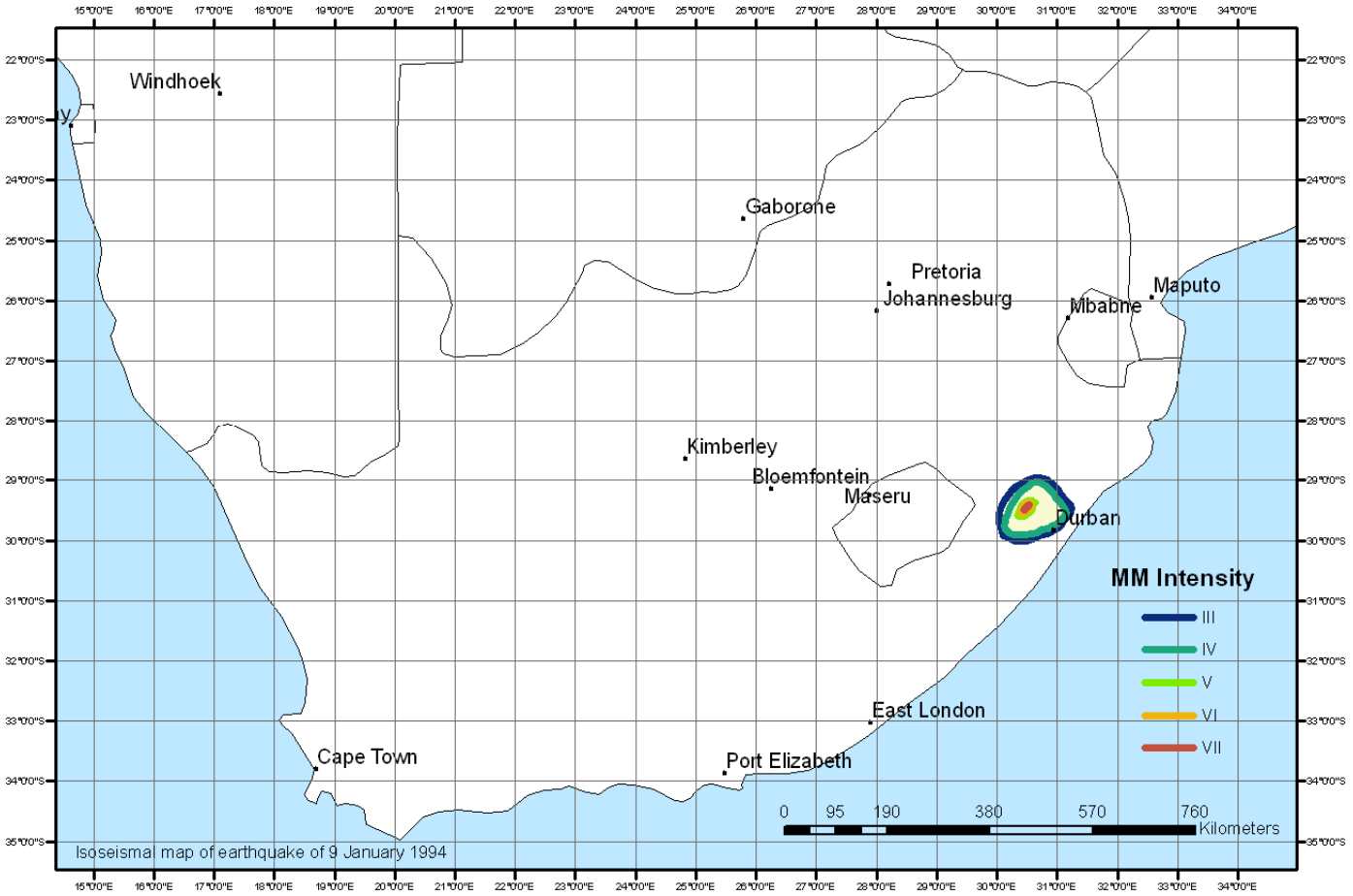



Figure A25 Isoseismal map of earthquake of 9-Jan-1994

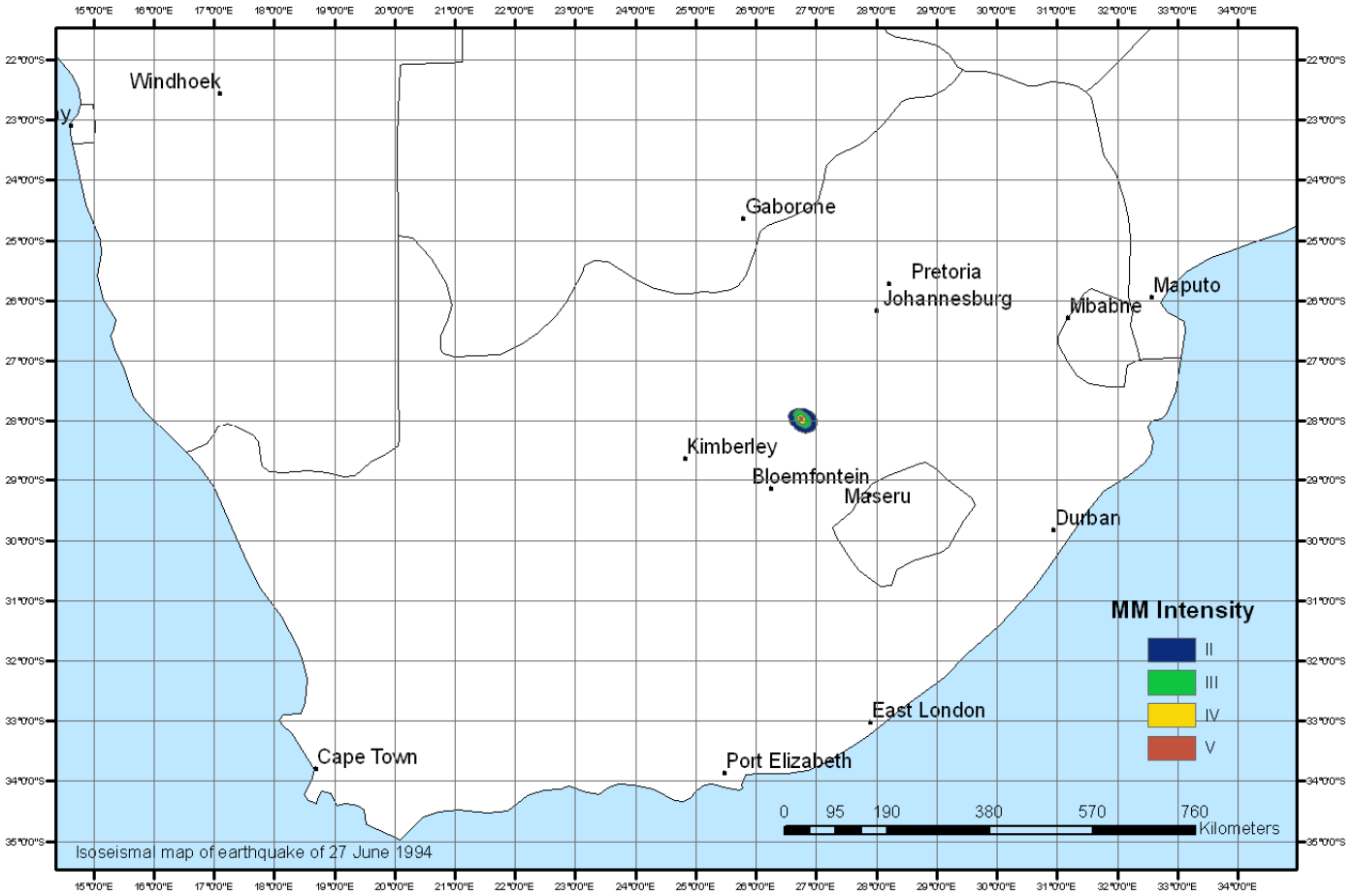



Figure A26 Isoseismal map of earthquake of 27-Jun-1994

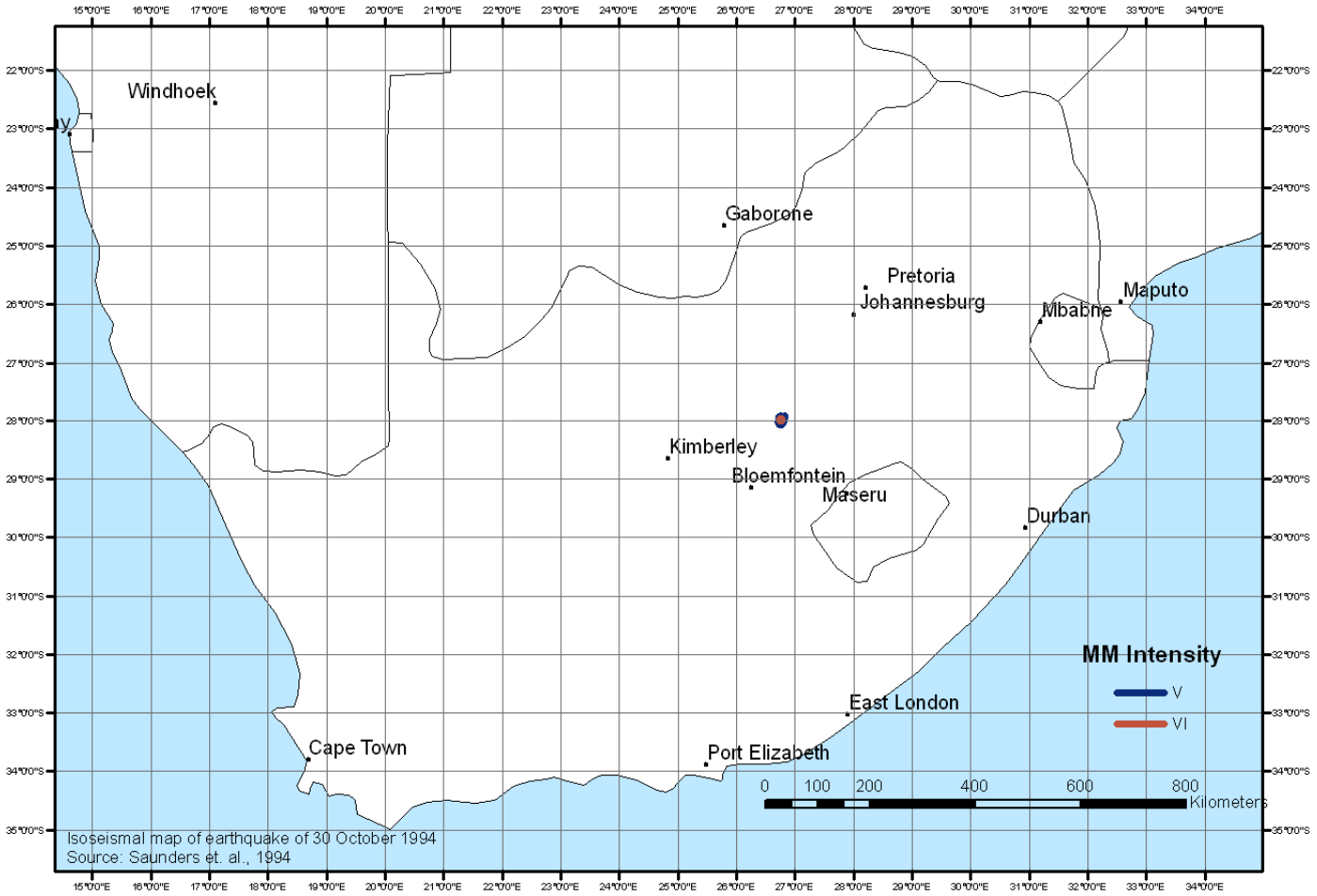



Figure A27 Isoseismal map of earthquake of 30-Oct-1994

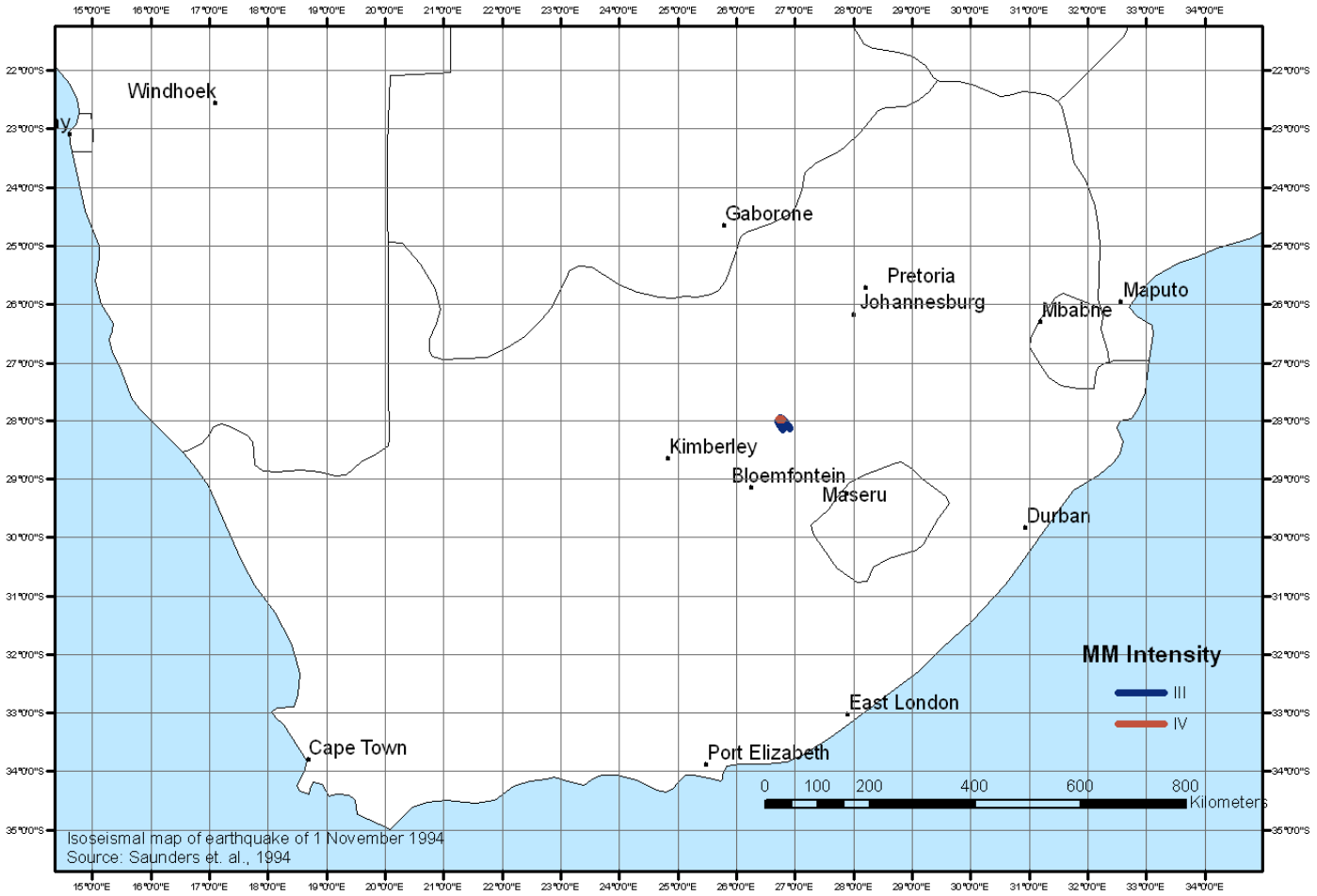



Figure A28 Isoseismal map of earthquake of 1-Nov-1994

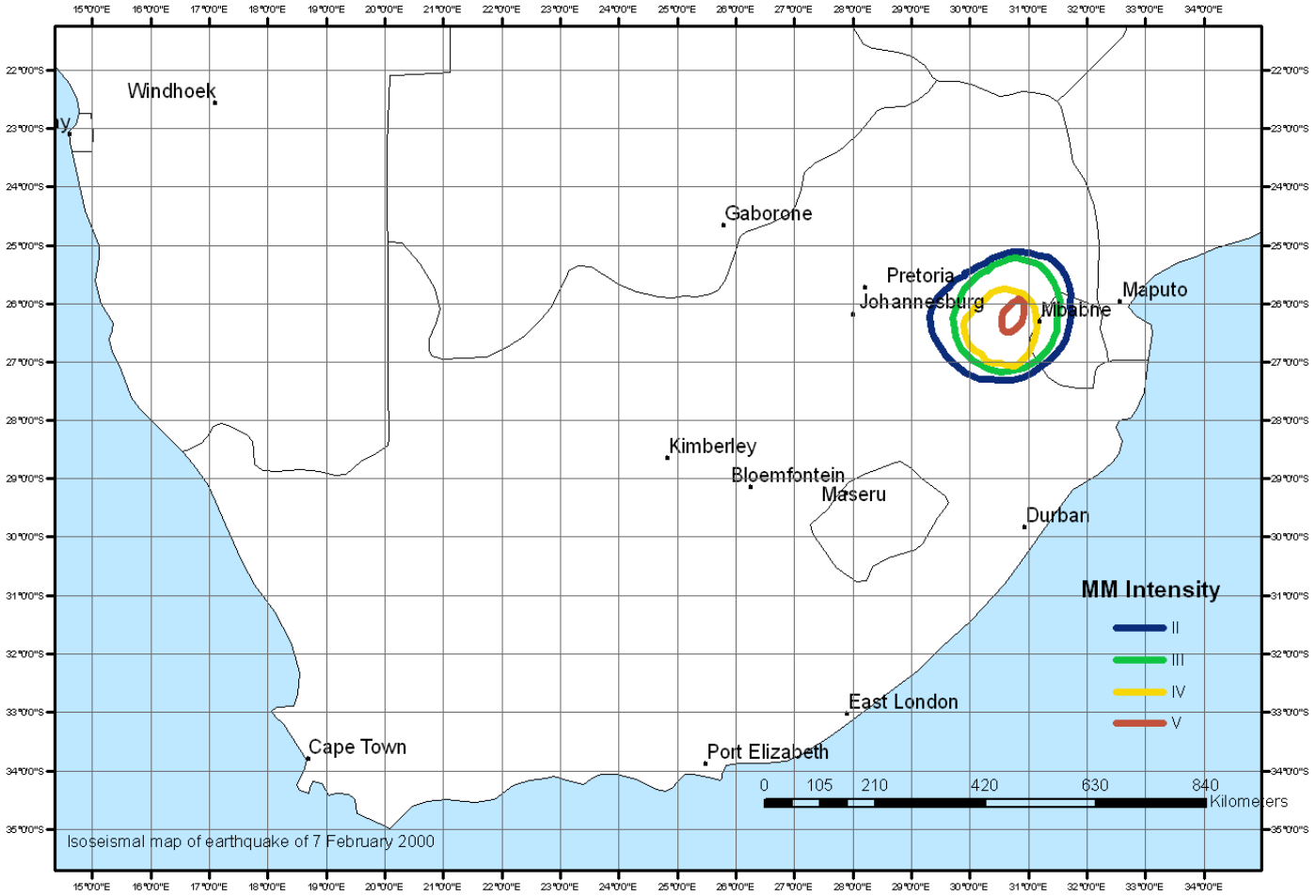



Figure A29 Isoseismal map of earthquake of 7-Feb-2000

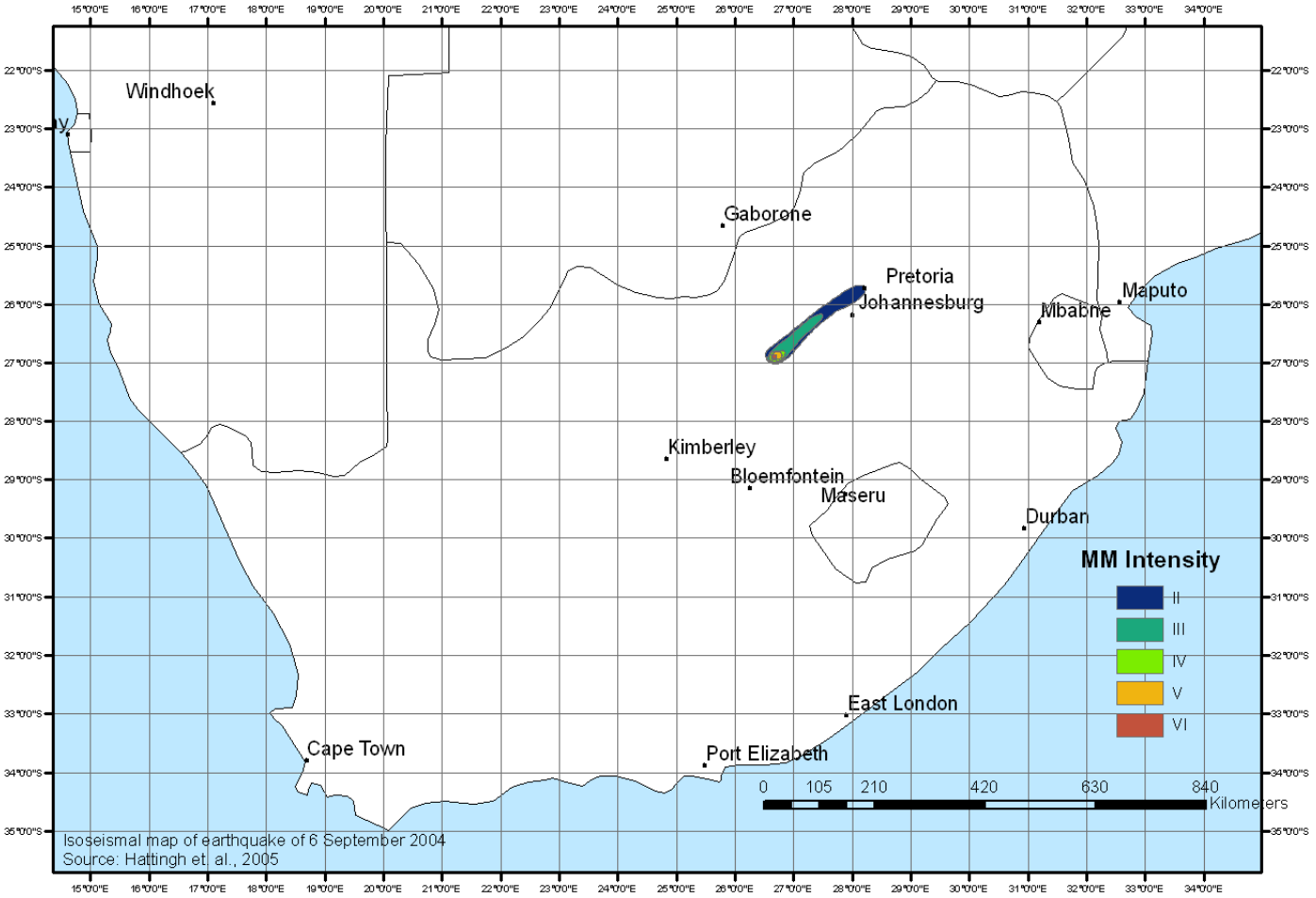



Figure A30 Isoseismal map of earthquake of 6-Sep-2004

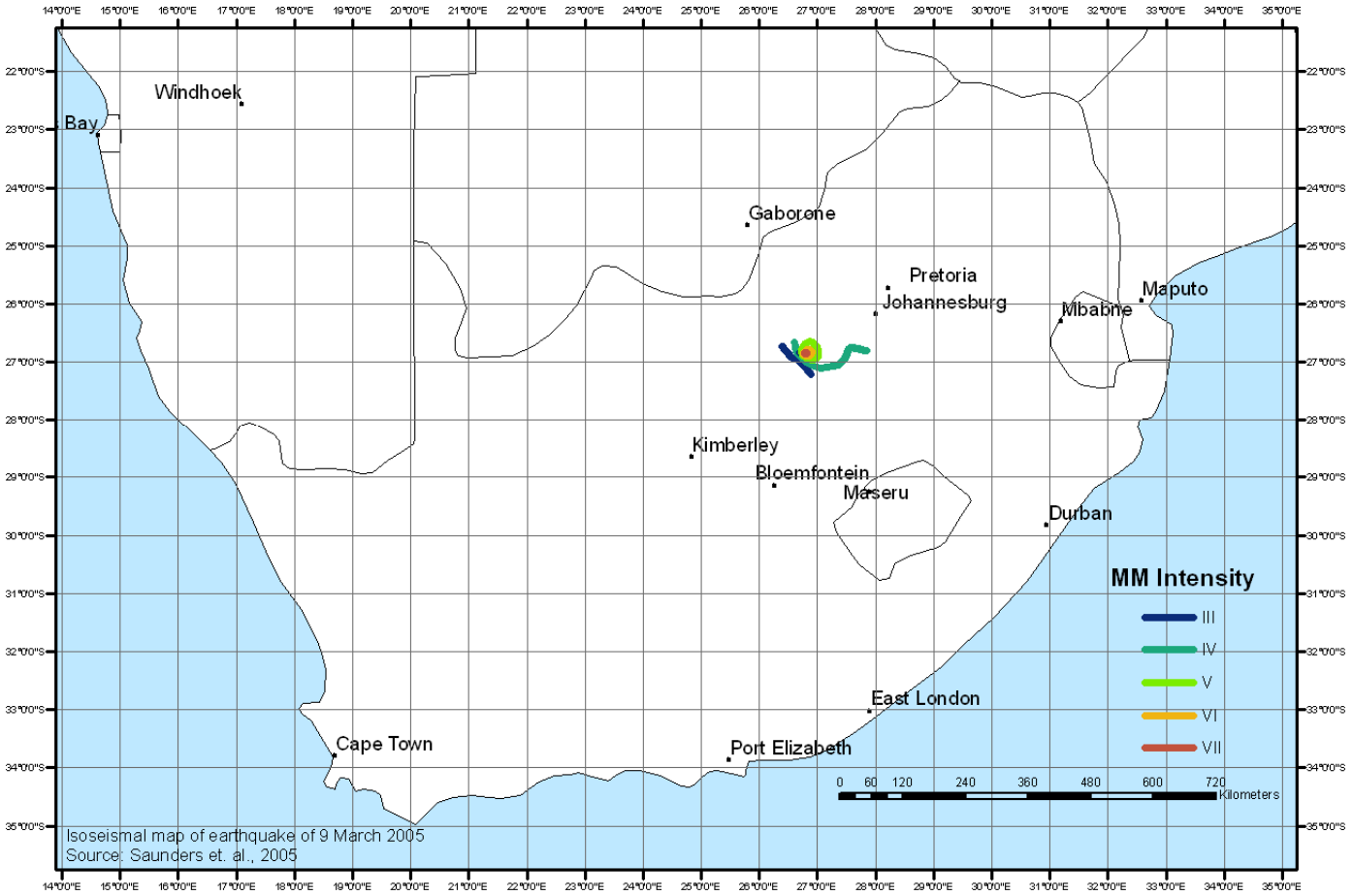



Figure A31 Isoseismal map of earthquake of 9-Mar-2005

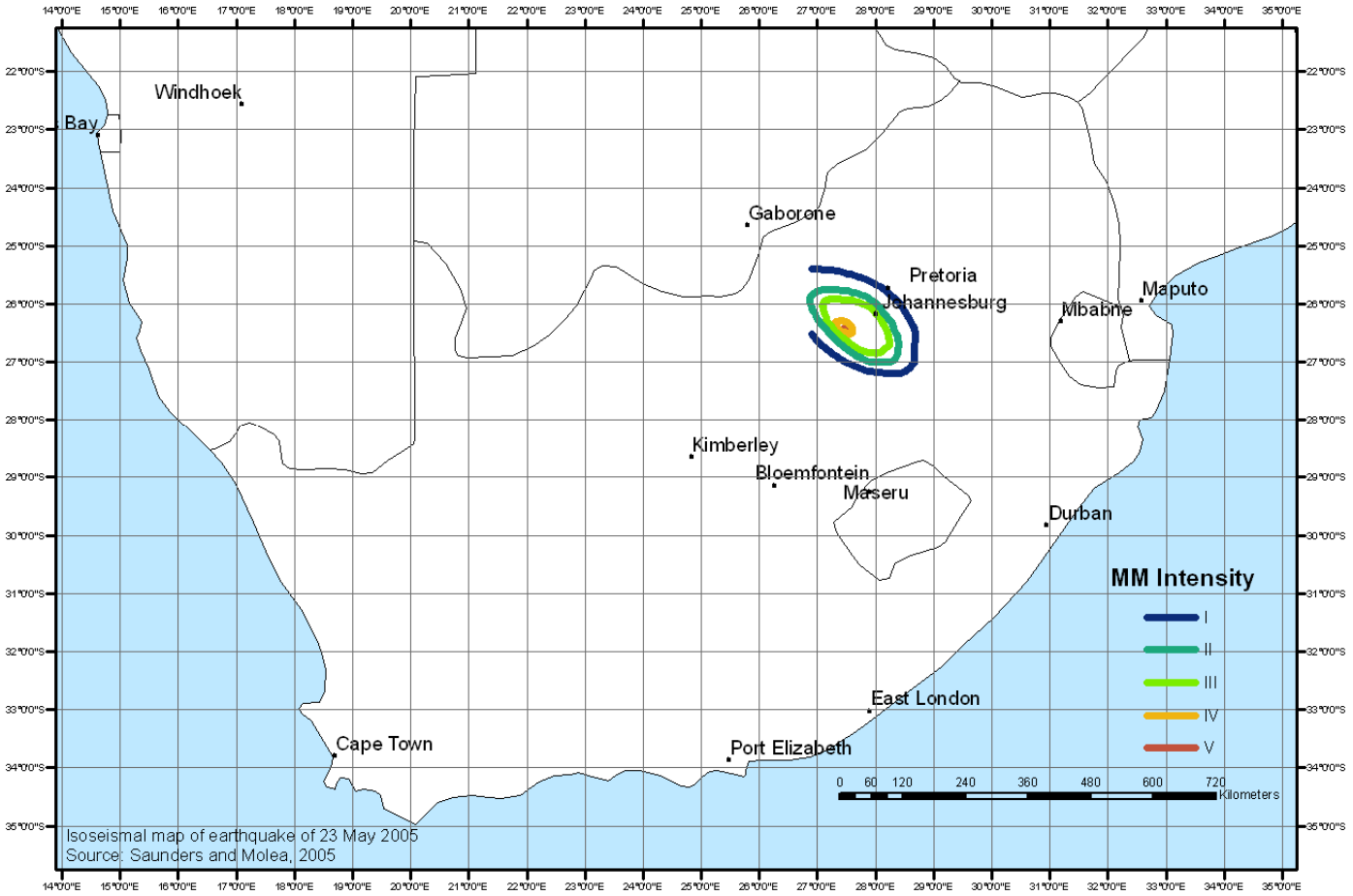



Figure A32 Isoseismal map of earthquake of 23-May-2005