Bull Earthquake Eng (2014) 12:45–78
DOI 10.1007/s10518-013-9562-0

ORIGINAL RESEARCH PAPER

Earthquakes from 1820 to 1936 in Grahamstown and surroundings (Eastern Cape Province, South Africa)

Paola Albini · Fleur O. Strasser · Nicolette S. Flint

Received: 21 June 2013 / Accepted: 23 November 2013 / Published online: 6 February 2014
© Springer Science+Business Media Dordrecht 2014

Abstract The seismicity of Grahamstown, in the Eastern Cape Province of South Africa, for the years between 1820 and 1936 is investigated with recourse to contemporaneous documentary sources, leading to the development of a seismic history incorporating consideration of the broader geo-political context. Individual studies of five regional events that were felt in Grahamstown during that period, and of one that was not, are presented. Each study includes the development of a full set of intensity data points, which are used to determine reappraised epicentral locations and magnitudes, some of which differ significantly from previously listed parameters. The results thus obtained highlight the value of seeking out additional contemporary sources from different language groups when revisiting the source parameters of earthquakes for which no or only very limited instrumental information is available.

Keywords Historical seismicity · Earthquake catalogue · South Africa · Eastern Cape Province · Seismic history · Macroseismic intensity

Disclaimer As explained in the text, the nature of the work presented herein requires the use of sources that are contemporary to the earthquakes studied. These sources may, in some instances, employ terminology or voice views that would be unacceptable in a modern context. Their inclusion in the present study only reflects their use in sources used for assessing the macroseimic effects of the earthquakes under investigation, and by no means constitutes an endorsement, by the authors or their institutions, of aforementioned terminology and views. Wherever possible, modern equivalents have been used, however for reasons of traceability geographic locations and titles have been left in their original form.

P. Albini (✉)
Istituto Nazionale di Geofisica e Vulcanologia (INGV),
Via Edoardo Bassini 15, 20133 Milan, Italy
e-mail: paola.albini@mi.ingv.it

F. O. Strasser
Council for Geoscience (CGS), Private Bag X112, Pretoria, South Africa

N. S. Flint
Council for Geoscience (CGS), Western Cape, P.O. Box 572, Bellville, Cape Town 7535, South Africa

1 Introduction

> *The problem with historical seismicity is that recent years have seen a proliferation of earthquake catalogues with data from one catalogue being absorbed by the next. The single most common failing in this generation of regional and global catalogues has been that few of them are based on original sources of information and most rely on secondary evidence and a slavish repetition of previous lists, errors and all.*
> *It may be that too much effort has been diverted from the retrieval and interpretation of original data from different languages to computer processing of second-hand information, to the extent that the tidying up of input data into a reliable and homogeneous body of information is essential*. (Ambraseys 2004)

The South African earthquake catalogue is a fairly young enterprise, particularly as far as historical and early instrumental events are concerned. The first catalogue for southern Africa including a systematic listing of source parameters such as locations and magnitudes for events up to 1970 was compiled by Fernández and Guzmán (1979), later to be updated by Brandt et al. (2005). On the occasion of the seismic characterization study for a potential new-build nuclear site located at Thyspunt, near Port Elizabeth (Bommer et al. 2013a,b), the early seismicity of the Eastern Cape Province was thoroughly investigated. This paper presents a portion of this work, focused on Grahamstown and its surrounds, one of the earliest and best documented settlements in the Eastern Cape (Fig. 1). The following sections describe the steps of the investigation, and the order in which they were undertaken. Beginning with the identification of relevant documentary sources regarding the occurrence of earthquakes

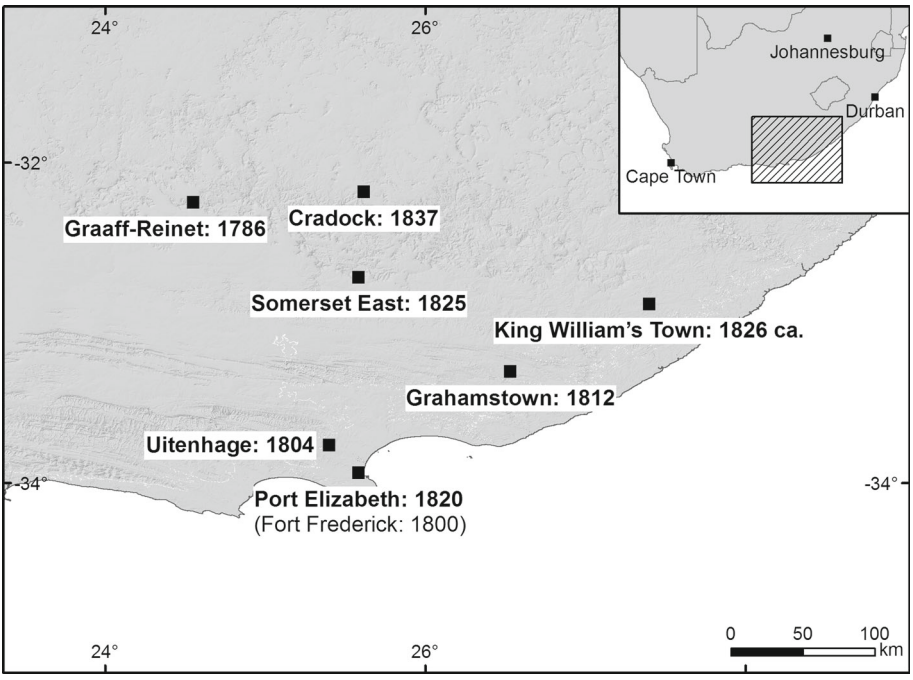


Fig. 1 The area of study, with location and date of establishment of major settlements during the nineteenth century in the then Eastern Districts of the Cape of Good Hope Colony

and the broader geo-political context, and the identification of the past earthquakes that affected the territory based on the aforementioned catalogues, the effects of these earthquakes described in documentary sources were evaluated in terms of the MMI-56 intensity scale (Richter 1958). These newly assessed intensity data points (IDPs) were then used to reappraise earthquake source parameters, which are discussed in the light of their determinations in previous studies and catalogues. This leads to a comprehensive overview of the seismic history of Grahamstown for the time span investigated.

2 Sources versus the geo-political context

2.1 Methodological approach

The investigation of the historical seismicity of the Eastern Cape Province in the period from 1820 to 1936 began with a careful consideration of the geo-political context, as an indispensable step towards identifying the potential observers of earthquake effects and retrieving the sources containing their observations. To this end, some South African and European libraries and archives were visited, to (1) become acquainted with the available historical sources, and (2) select those sources potentially useful to investigate the past seismicity in the area of study.

This process of investigation took into account as many different types of sources as possible. Both the documents that did and those that did not supply any earthquake observations have been referenced. In some cases, their importance as sources on earthquakes in the time-period and area of interest (Fig. 1) has been briefly documented. The records were then assessed in the light of the socio-political context in the Eastern Cape at that time and the extent of the sources available.

2.2 The geo-political context

The starting date of the period considered here was not randomly chosen. The investigation of past seismicity in historical times, or historical seismology, relies on records contained in the written documents that have survived and are available to us. The compilation of available records, taken altogether, should constitute a corpus of quasi-continuous observations of the natural events of the territory, and hereby reduce the influence of the intrinsic incompleteness of recording as much as possible. Thus, the year 1820 was an obligatory choice as a starting date, as the date corresponds to the first appreciable accumulation of documentation on the Grahamstown area. Such documentation goes back to the early years of the nineteenth century, and coincides with the eastward expansion of the British colonisation of the Cape after 1806 (the second British occupation of the Cape).

As noted by Wilson and Thompson (1969, p.233), "[t]he Eastern Cape frontier is a vaguely defined area lying eastward of the Gamtoos river. It is important in South African history because it was here that black Africans, speaking a Bantu language, first encountered white settlers (as distinct from traders and missionaries)". Grahamstown itself was established in 1812 as a military post, by Lieutenant-Colonel John Graham (1778–1821). Between 1813 and 1819 the control over the area was maintained by an eastward-moving line of British military posts along the shifting boundary of the Cape Colony. In 1820 the expansion of the eastern frontier was reinforced by the settlement of the Albany district (by the so-called "1820 Settlers") in what is today considered a complex colonisation action (Bergh and Visagie 1985), characterised by a series of wars with the local Xhosa people. The last of the Xhosa

Wars (or Cape Frontier Wars) is usually considered the War of Mlanjeni (or the Eighth Xhosa War), which lasted from 1850 to 1853.

A slim pocket book published in 1842 supplies one of the earliest descriptions of the "Eastern Districts", and its title is fully explicative of the author's aims: "Sketches of the Eastern Districts of the Cape of Good Hope as they are in 1842. Compiled by the Editor of the 'Graham's Town Journal', with a view to assist the emigrant and to serve as a Hand Book for Travellers" (Godlonton 1842). Though the 1842 Eastern Districts do not exactly correspond to what is today the Eastern Cape Province, the "Sketches" provide an accurate portrayal of the distribution of settlements in the area, as well as details on the number of their inhabitants and buildings. The volume was published anonymously, and we learnt the author's name from a sort of companion book published only 1 year later by Centilivres Chase (1843, p. 33), who referenced the "Sketches" as "the labours of the editor of the *Graham's Town Journal*, R. Godlonton Esq., whose description, drawn on the spot, […] may be depended upon for its fidelity."

As part of the Colony of the Cape of Good Hope, the Eastern Districts (or divisions or counties) numbered six, namely Albany, Somerset, Cradock, Colesberg, Graaff-Reinet and Uitenhage (Godlonton 1842). In a table entitled "Return of the Extent, Population and Stock of the Colony of the Cape of Good Hope for the year 1841", Centilivres Chase (1843) reported that the six districts taken together had a population of 60,842, and he divided the inhabitants between "White" with a share of about 43 % (26,032) and "Coloured" with 57 % (34,810). The most populated district was the Albany district. With a total of 19,777 inhabitants it was both the smallest in extent (1/4 of the area of the Graaff-Reinet district, for instance) and the most densely populated. Grahamstown was located at its centre, at the very core of the Eastern Province.

A recurring literary setting is to take the reader by the hand and then to unveil Grahamstown by looking down from the summit of the hill, framing its western approach (Fig. 2).

Fig. 2 Grahamstown in 1842, from Binnington Boyce, 1875, face to p. 77

A short description of Grahamstown, including some *verbatim* quotes from Godlonton (1842, pp. 9–15), is given below. "The number of houses are computed at 700, the total amount of population at 5,000, of whom 1,000 are persons of colour [*also called 'native foreigners'*]"; some stores are spacious and handsome edifices, there are two weekly newspapers, a bank, a fire insurance company, a savings bank, a benefit society, a steam navigation company. "A subscription Public Library has been commenced and funds raised for the immediate purchase of 4,000 volumes of standard works", a building was obtained by the government. Access is guaranteed through an annual subscription, but "strangers will have free access to the library". The Episcopalian church is a "heavy clumsy looking building" where is situated the cenotaph to Colonel Graham. The "Wesleyan premises" are described as made up of "a handsome chapel, for 1,000 people, school, and dwelling house for the superintendent", considered by Godlonton to be the handsomest range of buildings in Grahamstown. "The former chapel is now used for the coloured classes, and divine service is held in the [Xhosa] tongue". Grahamstown has its own courthouse, a gaol, and in 1842 sees the presence of a considerable military staff. In addition, "the town is governed by a municipality, composed of six commissioners and eight wardmasters", and "the market is well attended, every morning except Sunday".

From a simple frontier town in 1812, in 30 years Grahamstown rapidly developed into a civil and commercial settlement, vividly described as the "emporium of the Eastern Frontier districts, with incessant commercial activity" (Godlonton 1842).

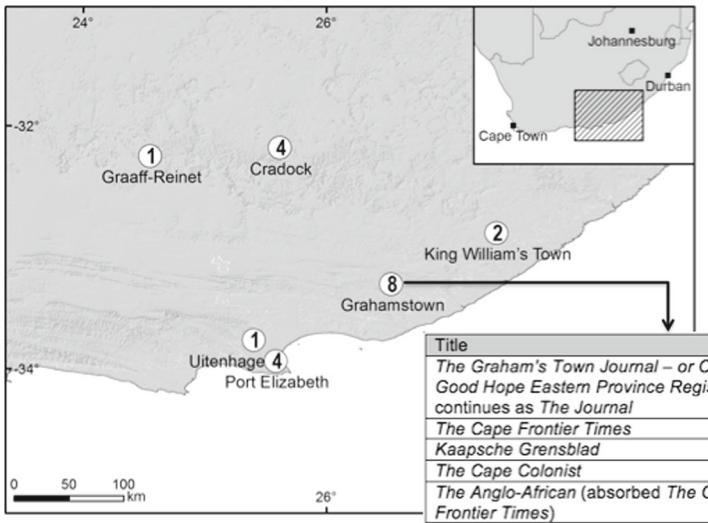
The town changed its appearance even more dramatically between 1850 and 1900, when many "fine buildings were constructed, including the neo-Gothic cathedral, completed in 1879 […] The railway cut its way through what was now a city, providing passengers with new vistas of Grahamstown" (Eve 2003, p.124).

Other important settlements in the Eastern Cape Province, dating back to the nineteenth century, considered in this study (Fig. 1) were Somerset (est. 1825, now Somerset East), Cradock (est. 1837), Graaff-Reinet (the oldest, established in 1786), Uitenhage (1804) and very close to it Port Elizabeth (1820, previously named Fort Frederick). As the easternmost settlement of an eastward expanding frontier, the history of King William's Town (est. 1826 ca) is largely defined by the conflicts between the native Xhosa people and the British military forces during the Xhosa (or Cape Frontier) Wars, but other settlements were also affected to various degrees.

2.3 Sources investigated

What is relevant to our investigation, is that as Grahamstown flourished so did various cultural initiatives by its residents (for details on cultural life in mid-nineteenth century Grahamstown see Letcher 2002 and Eve 2003). Since this is still the case, the Cory Library for Historical Research, at Rhodes University, as well as the Bowker Library, at the Albany Museum, both in Grahamstown were the obvious places to start with the investigation of locally produced sources. In particular, the Cory Library stands out as a fundamental repository for the nineteenth century history of the Eastern Cape Province, especially for its large manuscript holdings.

As pointed out by Godlonton (1842), the idea of establishing a public library was supported by government and potential users, but it was surely encouraged by a lively publishing activity, as the first number of the first newspaper ever issued in the Eastern Districts was the "Graham's Town Journal", published on the 31 of December 1831. In his list of the periodical press of the Cape of Good Hope Colony, two newspapers and a journal published at Grahamstown are included and shortly commented upon by Centilivre Chase (1843):



Title	First issued on
The Graham's Town Journal – or Cape of Good Hope Eastern Province Register, continues as *The Journal*	31 Dec 1831
The Cape Frontier Times	c. 1840
Kaapsche Grensblad	18 Jul 1844
The Cape Colonist	7 Dec 1850
The Anglo-African (absorbed *The Cape Frontier Times*)	1864
The Great Eastern	2 Feb 1864
The Advertiser (continues as *The Grahamstown Advertiser*)	1866
Grocott's Penny Mail, then *Grocott's Daily Mail* (from 1920 to 1964)	1870

Fig. 3 Places of publication of the local press. *Numbers* indicate how many different newspapers where consulted at each place, the table focuses on the eight newspapers published in Grahamstown

1. *The Graham's Town Journal*, published every Thursday, "a well written newspaper"
2. *The Cape Frontier Times*, published every Thursday, "contains much useful intelligence"
3. *The Albany Magazine*, a monthly journal devoted to literature and science.

To assess the period between 1820 and 1936 eight different newspapers were investigated, all published in Grahamstown (Fig. 3). The records supplied by the newspapers shown in Fig. 3 were further supplemented with those of newspapers published either in Cape Town or in Grahamstown's surroundings.

Having set the Eastern Cape Province in its historical context, other types of sources, or networks of information, were identified in addition to that centred on newspaper publishing. One of the most rewarding, in terms of spatial and temporal coverage, was the network made by explorers, travellers and missionaries. As it was a frontier area, many details on the daily life in this territory can be found in the writings of those people who contributed to the establishment of settlements in the eastern part of the Cape Colony. They were explorers (including game hunters), travellers, and missionaries (for mission settlements in South Africa, see Japha et al. 1993; for details on Moravian mission stations, Krüger 1966). Some were, in fact, the founders of settlements and others were visitors on their way to the north or further east. Many of them have left extensive descriptions of their experiences, with lots of details on travel dates, places, people met, weather conditions and the natural phenomena that accompanied them, including earthquakes.

The material is varied, from journals in which they jotted a few words each day, or one page each month, to the compulsory yearly report to the home missionary minister with the list of the expounded Scriptures, to illustrated books complete with maps of their whereabouts. There is an abundance of such accounts relating to the present-day Western and Northern

Table 1 Some accounts of the Eastern Cape Province from 1813 to 1830

Author and activity, full reference	Time-span	Region or places visited	Notes on natural phenomena
John Campbell, missionary and explorer Travels in South Africa undertaken at the request of the Missionary Society, Third edition, 1815. Reprint by C. Struik, Cape Town, 1974, 400 pp.	9 April–20 May 1813	Campbell travelled around Cape Colony: here is considered only his visit to Albany (pp . 95–136)	Yes
William Shaw, missionary (Wesleyan Minister to the 1820–1829 Settlers) The Journal of William Shaw. Edited by W.D. Hammond-Tooke, 1972, Rhodes University, The Graham's Town Series, 2, Balkema, Cape Town, 220 pp.	1820–1829	Albany district	Yes
John Ayliff, missionary The Journal of John Ayliff, I: 1821–1830. Edited by Peter Hinchliff, 1971, Rhodes University, The Graham's Town Series, 1, Balkema, Cape Town, 130 pp.	1821–1830	Albany district	Yes
George Thompson, traveller Travels and adventures in Southern Africa, by George Thompson, eight years resident at the Cape, comprising a view of the present state of the Cape Colony. Edited with notes by Vernon S. Forbes, 1967, The Van Riebeeck Society, Cape Town, Part 1, 187 pp.	Jan 1821–1822	Eastern Cape	Yes
Thomas Pringle, traveller and poet Narrative of a residence in South Africa, by Thomas Pringle, 1835, Edward Moxon, London, 356 pp.	June 1821–Oct 1824	Albany district and Eastern Cape	Yes

Cape Provinces, but much fewer exist on the Eastern Cape Province. Most of the latter have been read, with the specific aim to evaluate their reliability and sensitivity to natural phenomena. Some of these works are listed below, in a far-from-comprehensive synoptic table (Table 1) supplying the time span covered, the region visited, and whether or not they contain notes on natural phenomena.

An indispensable source of information on the Eastern Districts is represented by the "Memoir of the Rev. William Shaw", the Wesleyan Minister to the 1820 Settlers, who spent many years in the Eastern Districts, in particular residing at Grahamstown between 1820 and 1829. Shaw's journals have been edited in full fairly recently (by Hammond-Tooke 1972, see Table 1), but they had been partially edited by Binnington Boyce (1875).

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	total items per year
1820													
Beaufort Vale													(0)
1821													
Beaufort Vale				(4) 6th: thunderstorm 14th: rain	(2)	(1)	(2)						(9)
Grahamstown								(1)	(1)				(2)
1822													
Somerset East	(4) 22nd: thunderstorm									(1) 21st: hail storm		(7)	(12)
1823	(1)					(2)	(3)	(2)	(2)	(1) 13th: severest rain experienced since in the Colony; damage description	(6) 9th: great sufferings of the Settlers because of the rain	(1)	(18)
Somerset East													
1824	(6)	(2)		(3)			(2)	(2)	(3)	(1)	(1)	(1)	(21)
Somerset East				29th: locusts									
1825													
Somerset East	(3)		(2)										(5)
Grahamstown				(1)	(6)	(12)	(5)	(1)		(1)	(9)	(2)	(37)
1826													
Grahamstown	(2) 18th: heavy rains	(1)	(6)	(9)	(11)	(12)	(4)	(1)	(7)	(2)	(2) 7th: to Wesleyville, heavy storms	(10)	(67)
1827													
Grahamstown	(1)	(4)	(2)	(1)			(1)				(1)		(10)
1828													
Salem		(3)	(3)	(4)	(2) 20th: fire at Grahamstown (visit)	(3)	(6)	(2)	(1)	(1)	(1)	(2)	(28)
1829													
Salem		(5)	(3)	(3)	(3)	(3)	4th: most prodigious swarms of locusts	(1)	(2) 3rd: between 11 and 12 o'clock, total eclipse of the moon	(1)		(2)	(22)
1830													
Somerset East		(2)	(8)	(12)				(3)	(8)				(33)

Fig. 4 Analysis of the Journal of John Ayliff, 1821–1830

A specific analysis was carried out and is reported in Fig. 4 on the journals of John Ayliff, missionary of the Wesleyan Methodist Church on the Eastern Frontier of the Cape Colony alongside those of William Shaw. Figure 4 shows the places where Ayliff lived and the corresponding periods (Ayliff's journals cover a time-span longer than that between 1820 and 1830, but the rest of his notes have not been published yet), how many items can be found in his journal for each month and year, and, most importantly, the natural phenomena he described.

This kind of analysis has a twofold feedback:

1. it confirms that the selected sources were worth investigating as they indeed contain information on natural phenomena; and
2. whenever no information on earthquake effects is found over a certain period (1813–1830 in the case of the source in Fig. 4) this can be used as evidence nonetheless, in the speculative perspective that "should an earthquake—not so weak as not to be felt—have happened, it would have been recorded in written form".

As will be highlighted in the descriptions of the earthquakes in the following section, the contribution given by the absence of records from specific places on the occasion of a particular earthquake, has been carefully taken into account in the investigation of the seismicity of Grahamstown and surroundings in the period 1820–1936.

Some attempts were made to identify documentation written in the Xhosa language, and the starting point was the observation that "Preaching involved learning the [native Xhosa] language, writing it, and printing the gospels, and teaching converts to read these for themselves" (Wilson and Thompson 1969, p. 239). It has also been recognised that "the efforts of the Glasgow Missionary Society and the Wesleyan Methodist Missionary Society were largely responsible for the beginnings of Xhosa-language publishing" (Switzer and Switzer 1979). The missionaries Binnington Boyce (1834) and Ayliff (1846) were the

first to publish a Xhosa grammar, and their work was completed by Appleyard (1850), as such grammars were used at mission schools to create "literate communities […] and, especially after 1850, mission presses gradually produced a literature in the vernacular" (Switzer and Switzer 1979). The Wesleyan missionary Appleyard edited five issues of a monthly English/Xhosa newspaper, "Isitunywa Senyanga" (The Monthly Messenger), at Mount Coke, near King William's Town. A later newspaper in Xhosa, "Indaba" (The News) was published in Lovedale, near Alice, from 1862 to 1865. "The newspaper was written mostly by Africans from Lovedale, among whom was Tiyo Soga (as a Xhosa, the first black South African to be ordained by the United Presbyterian Church), who wrote under the pseudonym "Nonjiba Waseluhlangeni" (Dove of the Nation)" (Switzer and Switzer 1979).

In all, the missionary activity did not result in any written documentation in Xhosa language—that we could find—of the history of the Eastern Cape Province in the nineteenth century and early twentieth century. While we have by no means done an exhaustive research in this respect, we availed ourselves of the valuable work by Bud-M'Belle (1903) (the first black South African to pass the Cape Civil Service examinations), who wrote a very informative essay that supplies a thorough listing of nineteenth century sources regarding the Xhosa language as well as a bi-lingual list of place names. His suggestions led to the discovery of the earliest extant earthquake record in Xhosa language, as will be detailed in the next section.

Other sources investigated are journal and narratives, both manuscript and published, of nineteenth century Grahamstown residents. They are briefly described in Table 2.

The documentation concerning the Eastern Cape Province, produced by the British administration, is stored at the National Archives of South Africa, Cape Town and at the UK National

Table 2 Narrative sources on Grahamstown and surroundings

Author and reference	Time-span	Place	Notes
Sophia Pigot The Journals of Sophia Pigot. Edited by Margaret Rainier, 1974, Rhodes University, The Graham's Town Series, 3, Balkema, Cape Town, 172 pp.	1819–1821	Grahamstown	Daily notes on weather
Thomas Shone Journals, manuscript Partially edited in: The Albany journals of Thomas Shone, Rhodes University, The Graham's Town Series, 12, Balkema, Cape Town, 200 pp.	1 Jan 1850–17 Aug 1851	Grahamstown	Daily notes on weather—earthquake of 1850 (see Sect. 3 of this paper)
James Butler "Jim's Journal"—The diary of James Butler. Edited by Jane Garner, Rhodes University, Grahamstown, 14, Witwatersrand University Press, 330 pp.	1876–1879	Grahamstown Cradock	Daily notes on weather

Archives, Kew Gardens. Some sample investigations were carried out at both locations, but yielded no results in terms of earthquake records for the Eastern Cape Province 1820–1936, apart from those included in very early issues of newspapers (UK National Archives, CO 53 1658–1974).

In general, it should be noted that most of the surviving records are written in European languages (predominantly Dutch and English) used by the colonists of that time. It is important to bear in mind that the perspective of this investigation is therefore unavoidably biased by the fact that the written history of the Eastern Cape Province does heavily, if not solely, rely on British colonial sources for the period (1820–1910) leading up to the establishment of the Union of South Africa.

3 Earthquakes affecting the area of study, from raw data to a full set of parameters

As noted in the introduction, the systematic compilation of a South African earthquake catalogue of historical and early instrumental events was only undertaken fairly recently by Fernández and Guzmán (1979) who presented the first comprehensive listing of source parameters (date, location and magnitude) of events in the southern Africa region up to 1970 (the date of the establishment of the modern South African national seismograph network; Saunders et al. 2008). In addition to early instrumental information, the Fernández and Guzmán (1979) study was based on earlier work by Theron (1974) and Finsen (1950), who provided more qualitative descriptions, including macroseismic information for some events. The Fernández and Guzmán (1979) compilation was updated by Brandt et al. (2005) to incorporate information retrieved from a collection of newspaper reports compiled by De Klerk and Read (1988), as well as the analyses carried out for some larger events by Ambraseys and Adams (1991). For the time period considered here (1820–1936), both the Fernández and Guzmán (1979) study and the Brandt et al. (2005) update relied on macroseismic information, determining the epicentral location and magnitude from the highest intensity (I_{max}) observed among the available data, using the classic relation proposed by Gutenberg and Richter (1956), in the form $M_L = 0.66I_{max} + 1.0$.[1]

In the following paragraphs, individual reports of five events appearing in the seismic history of Grahamstown are presented. The discussion is confined to events that have occurred, or were initially thought to have occurred, in the Grahamstown region, excluding some larger, more distant events which were also felt in Grahamstown, but whose detailed investigation falls outside the scope of the present paper. These five reports are supplemented by a newly identified event that also occurred within the broader Grahamstown region, but for which evidence exists that it was not felt at Grahamstown. This latter event (1864) is included to illustrate how the absence of written records can contribute in developing the seismic history of a locality. This approach only assigns significance to the non-recording of an earthquake, but only within those sources that were investigated and carefully selected as those paying due attention to natural phenomena, both damaging and non-damaging.

Each of the six individual earthquake reports that follow presents the set of resultant IDPs determined during this study, including a summary table of the places at which the earthquake effects are documented and details of the observations on which intensity assignments were based. Each place is identified by a unique pair of geographical coordinates, and the respective observed intensity, assigned according to MMI-56 macroseismic scale using the

[1] Note that the Gutenberg and Richter (1956) relation uses 2/3 as the slope coefficient, and the epicentral intensity, I_0. The approximation to 0.66 and the assumption of equivalence between the maximum observed intensity I_{max} and I_0 are due to Fernández and Guzmán (1979).

methodology recommended by Musson and Cecić (2002), for homogeneity with the intensity values available for later periods (Midzi et al. 2013). The individual reports also include a discussion of the source parameters determined based on these sets of IDPs, contrasted with previous determinations where such exist. The MEEP2 software (Musson 2009) was used to determine epicentral locations and inform magnitude determinations of these events. This software includes implementations of four different methods for source parameter determination (Bakun and Wentworth 1997; MEEP, Musson 2009; centroid method, Gasperini et al. 1999; pairwise method developed by Jumila, described in Musson 2009). The results are listed in Table 3, alongside previous source parameter determinations. The reader is referred to Strasser et al. (2013a,b) for details of the calibration and implementation, as well as a discussion of the relative strengths and weaknesses of the methods. The latter are reflected in the event-specific weights assigned to the results obtained for each of the methods when they are combined to determine the preferred epicentral locations and associated uncertainties, which were obtained using a bootstrapping approach. Estimates of magnitudes are obtained by considering the results from the aforementioned methods, as well as additional constraints such as the extent of the felt area or the presence of instrumental recordings, where available. The resulting source parameters, along with previous determinations, are summarised in Table 3.

3.1 The 21 May 1850 earthquake

On Tuesday 21 May 1850, at about half past 10 of the night, an earthquake was widely felt in the Eastern Cape Province, Free State and Western Cape districts (Table 4; Fig. 5). The event was recorded by all the locally published newspapers, by means of a series of correspondents' reports that kept on being sent to the editor in the three weeks following the earthquake occurrence.

The most severe effects reported by the witnesses are damage to small barns, and rafters of few houses broken (Morley), plaster fallen (Palmerton), a split gable (Aliwal North), and "a large corner stone … split asunder" (Fort Brown) (Grahamstown Journal, 1850a).

From the rest of the settlements, the testimonies refer the following effects:

(a) *on objects:* doors and windows shaking (Grahamstown), bottles, jugs, tin wares, candlesticks moving and rattling, furniture moving, especially beds rocking, a pendulum set in motion (King William's Town)
(b) *on people:* persons that could not stand, people awoken (Sidbury, Whittlesea, Graaff-Reinet, George, Morley), panic and anxiety.

In most of the settlements, a noise was heard, described as that made by passing carriages (e.g. Grahamstown Journal, 1850a).

Some records stressed that there was no memory of earthquakes before this in the history of the area:

> Though we are not aware of any record of previous phenomena of this nature here, still the sound was so unusual as at once to strike the mind with a conviction of its true character (Grahamstown Journal, 1850a)

> As such an occurrence as an earthquake has never before felt here we chronicle a few particulars regarding the shock of Tuesday with more details than the particulars of a more frequent occurrence would seem to require. (Eastern Province Herald, 1850a)

Table 3 Summary of source parameters for the events studied

	21-05-1850	24-02-1864	15-10-1867	09-04-1895	09-08-1932	25-02-1933
Finsen (1950)[a]	–	–	–	–	09-08-1932 02:56 U.O. Seismograph: 610 km? Felt reports from 5 localities	–
Fernández and Guzmán (1979)[b]	25-05-1850 22:30 33.3°S, 26.6°E Grahamstown No M_L, I_{max} 6 (Skead)	–	–	–	09-08-1932 00:56 32.5°S, 27.9°E Komgha M_L (4.0), I_{max} 5 Finsen (1950)	–
Brandt et al. (2005)[c]	21-05-1850 20:30 33.3°S, 26.6°E Grahamstown M_L 5.0, I_{max} 5–6 De Klerk and Read (1988)	–	15-10-1867 10:15 32.9°S, 27.4°E King William's Town M_L 3.7, I_{max} 4 De Klerk and Read (1988)	09-04-1895 tu 33.3°S, 26.6°E Grahamstown M_L 3.7, I_{max} 4 De Klerk and Read (1988)	09-08-1932 00:56 33.3°S, 26.5°E Grahamstown M_L 5.0, I_{max} 5–6 De Klerk and Read (1988)	25-02-1933 16:56 33.3°S, 26.5°E Grahamstown M_L 3.0, I_{max} III De Klerk and Read (1988)

Table 3 continued

	21-05-1850	24-02-1864	15-10-1867	09-04-1895	09-08-1932	25-02-1933
This study[d]	I_{max} 6–7 at Morley	I_{max} 4 at George	I_{max} 5 at King William's Town	I_{max} 4 at Uitenhage	I_{max} 6 at Grahamstown	I_{max} 3 at Grahamstown
	$N_{OBS} = 32, N_{IDP} = 32$	$N_{OBS} = 4, N_{IDP} = 4$	$N_{OBS} = 11, N_{IDP} = 10$	$N_{OBS} = 7, N_{IDP} = 7$	$N_{OBS} = 40, N_{IDP} = 39$	$N_{OBS} = 3, N_{IDP} = 3$
	B : 31.553°S, 27.874°E	B : 32.847°S, 22.947°E	B : 33.847°S, 27.725°E	B : 33.380°*S*, 25.367°E	B : 34.538°*S*, 26.478°E	B : 34.538°*S*, 26.478°E
	C : 32.545°S, 27.110°E	C : 34.000°S, 22.741°E	C : 32.836°S, 27.687°E	C : 33.063°S, 25.455°E	C : 33.340°S, 26.682°E	C : 33.468°S, 26.754°E
	M : 32.139°S, 28.445°E	M : 34.099°S, 22.579°E	M : 32.997°S, 27.537°E	M : 33.574°S, 25.434°E	M : 33.247°S, 26.352°E	M : 33.452°S, 26.672°E
	P : 31.790°S, 28.022°E	P : 34.000°S, 22.741°E	P : 33.071°S, 27.543°E	P : 33.586°S, 25.464°E	P : 34.143°S, 26.753°E	P : 33.468°S, 26.754°E
	[0.3, 0.1, 0.3, 0.3]	[0.25, 0.25, 0.25, 0.25]	[0.1, 0.3, 0.4, 0.2]	[0.25, 0.25, 0.25, 0.25]	[0.05, 0.45, 0.45, 0.05]	[0.1, 0.3, 0.3, 0.3]
	Near Tsomo, EC	**NE of George, WC**	**SE of King William's Town, EC**	**Kirkwood, EC**	**Grahamstown, EC**	**SE of Grahamstown, EC**
	32 ± 0.75°S	**33.75 ± 0.90°S**	**32.95 ± 0.36°S**	**33.40 ± 0.73°S**	**33.30 ± 0.43°S**	**33.45 ± 0.15°S**
	28 ± 1.28°E	**22.75 ± 0.78°E**	**27.60 ± 0.36°E**	**25.45 ± 0.77°E**	**26.50 ± 0.52°E**	**26.70 ± 0.18°E**
	M_W5.7 ± 0.4	**M_W4.1 ± 0.5**	**M_W5.1 ± 0.5**	**M_W4.1 ± 0.5**	**M_W5.7 ± 0.35**	**M_W3.2 ± 0.8**

[a] Time is given as listed by the original source, namely South African Standard Time (GMT + 2:00)

[b] Time is given as Greenwich Mean Time (GMT), M_L in brackets indicates an uncertain value. Note that the day of the 1850 is erroneously given as 25, which is likely to the date of the "old newspaper" clipping provided by Mr Skead, which is not described more precisely by the authors

[c] Time is given as Greenwich Mean Time (GMT)

[d] The locality given after the maximum intensity I_{max} is that identified as the most affected place. N_{OBS} = number of observations, N_{IDP} = number of IDPs; B = parameters determined using the Bakun and Wentworth (1997) approach; C = parameters determined using the centroid approach; M = parameters determined using the MEEP approach; P = parameters determined using the pairwise approach. The numbers in square brackets are the relative weights assigned to each of the methods, in the same order that they are listed. The last set of parameters (in bold) are the best estimate parameters and associated uncertainties selected considering all the information available

Table 4 Places affected by the 21 May 1850 earthquake and assigned intensity in MMI-56

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
Morley, Umtata River, Kaffraria	10:25 p.m.	Grahamstown Journal, 1850d	−31.900	28.983	EC	6–7
Cotton plantation, near Morley	–	Grahamstown Journal, 1850d	–	–	–	–
Palmerton, about 20 miles beyond the Umzimvooboo, or St. John's River	Between 10 and 11 p.m.	Grahamstown Journal, 1850d	−31.316	29.483	EC	5–6
Aliwal (North)	10:30 p.m.	Grahamstown Journal, 1850e	−30.700	26.700	EC	5
Buntingville	–	Grahamstown Journal, 1850c Cape Frontier Times, 1850d Kaapsche Grensblad, 1850d Zuid Afrikaan, 1850d	−31.633	28.866	EC	5
Fort Brown	10:45 p.m.	Grahamstown Journal, 1850a Cape Town Mail, 1850	−33.116	26.616	EC	5
Grahamstown	10:30 p.m. 10:21 p.m.	Grahamstown Journal, 1850a Cape Frontier Times, 1850a Cape Town Mail, 1850 Friend, 1850 Kaapsche Grensblad, 1850a, 1850c Port Elizabeth Mercury, 1850a Zuid Afrikaan, 1850b Shone, 1850–1851	−33.300	26.533	EC	5
Drostdy House (Grahamstown)	10:20 p.m.	Grahamstown Journal, 1850a	–	–		–
Kamastone	10:30 ca p.m.	Grahamstown Journal, 1850b Zuid Afrikaan, 1850c	−32.066	26.650	EC	5
Schaap Kral	10:30 ca p.m.	Grahamstown Journal, 1850b Zuid Afrikaan, 1850c	−32.033	26.250	EC	5
Sidbury Park	10:30 ca p.m.	Grahamstown Journal, 1850b Zuid Afrikaan, 1850c	−33.433	26.133	EC	5
Places in the neighbourhood of Sidbury	–	Grahamstown Journal, 1850b	–	–		–
Whittlesea	10:30 ca p.m.	Grahamstown Journal, 1850b	−32.166	26.816	EC	5

Table 4 continued

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
		Cape Frontier Times, 1850a Zuid Afrikaan, 1850c				
Fort Peddie (Bathurst)	–	Cape Frontier Times, 1850a	−33.200	27.117	EC	5
Port Elizabeth	10:15 p.m.	Eastern Province Herald, 1850a	−33.936	25.583	EC	4–5
	Between 10 and 11	Cape Frontier Times, 1850a Cape Town Mail, 1850 Friend, 1850 Natal Witness, 1850 Port Elizabeth Mercury, 1850a; 1850b Port Elizabeth Telegraph 1850 Kaapsche Grensblad, 1850c Zuid Afrikaan, 1850b				
King William's Town	10:30 ca p.m.	Grahamstown Journal, 1850b	−32.883	27.400	EC	4–5
	About 11 p.m.	Cape Frontier Times, 1850a Zuid Afrikaan, 1850c				
Burghersdorp	10:30 ca p.m.	Eastern Province Herald, 1850c Cape Frontier Times, 1850c	−30.983	26.316	EC	4
George	10:30 ca p.m.	Eastern Province Herald, 1850b Cape Frontier Times, 1850b	−33.966	22.450	WC	4
	5 min to 10 p.m.	Cape Town Mail, 1850 Grahamstown Journal, 1850c Kaapsche Grensblad, 1850b Zuid Afrikaan, 1850a				
Graaff-Reinet	10:00 ca p.m.	Grahamstown Journal, 1850b Kaapsche Grensblad, 1850c Zuid Afrikaan, 1850c	−32.250	24.550	EC	4
New Castle (near Whittlesea)	Between 10 and 11 p.m.	Cape Frontier Times, 1850a	−32.133	26.866	EC	4
Olifant Hoek	10:10 p.m.	Cape Frontier Times, 1850a Kaapsche Grensblad, 1850a; 1850c Zuid Afrikaan, 1850b	−33.016	26.250	EC	4

Table 4 continued

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
Jelliman's Drift on the Fish River	–	Cape Frontier Times, 1850a	−33.483	27.133	EC	3–4
Somerset East	10:25 p.m.	Cape Town Mail, 1850 Kaapsche Grensblad, 1850c	−32.716	25.583	EC	3–4
Keiskamahoek	Middle of the night	Anonymous, 1861	−32.682	27.150	EC	3–4
Sidumbini Mission		Tyler, 1891	−29.382	31.011	KN	3–4
Pietermaritzburg		Hattersley, 1938	−29.617	30.383	KN	3–4
Cradock	–	Cape Town Mail, 1850 Port Elizabeth Telegraph, 1850	−32.183	25.616	EC	3
Botha's farmhouse in the neighbourhood of Port Elizabeth	–	Cape Town Mail 1850 Port Elizabeth Telegraph, 1850	−33.000	25.583	EC	3
Muller's farmhouse in the neighbourhood of Port Elizabeth	–	Cape Town Mail, 1850 Port Elizabeth Telegraph, 1850	−32.866	25.933	EC	3
New Year's River	–	Cape Frontier Times, 1850a	−33.300	26.083	EC	3
Uitenhage	–	Cape Frontier Times, 1850a Cape Town Mail, 1850 Grahamstown Journal, 1850b Kaapsche Grensblad, 1850c Port Elizabeth Telegraph, 1850 Zuid Afrikaan, 1850c	−33.765	25.402	EC	3
Wynberg	–	Cape Frontier Times, 1850c	−32.333	24.100	EC	3
Zwagershoek	–	Cape Frontier Times, 1850a	−32.500	25.416	EC	3
Zwartkop's River	–	Cape Town Mail, 1850	−33.866	25.600	EC	3
Umzimkulu	–	Grahamstown Journal, 1850d	−30.733	30.450	KN	3

That the occurrence of such a "strong" earthquake was a surprise to many residents, and especially to native people, is fully attested by two records in Xhosa, perhaps the first testimonies of an earthquake in South Africa written in a non-European language:

- a witness account in Xhosa, published in 1861, in prose and verse; these were school-children's essays on varied topics, among which there is one entitled "An earthquake"; the author does not supply the exact date, just a generic indication of time "not long before the War of Mlanjeni started [Dec 1850]", nor the place were he felt the earthquake; his location at the time of the earthquake was fixed according to the editor's preface that the

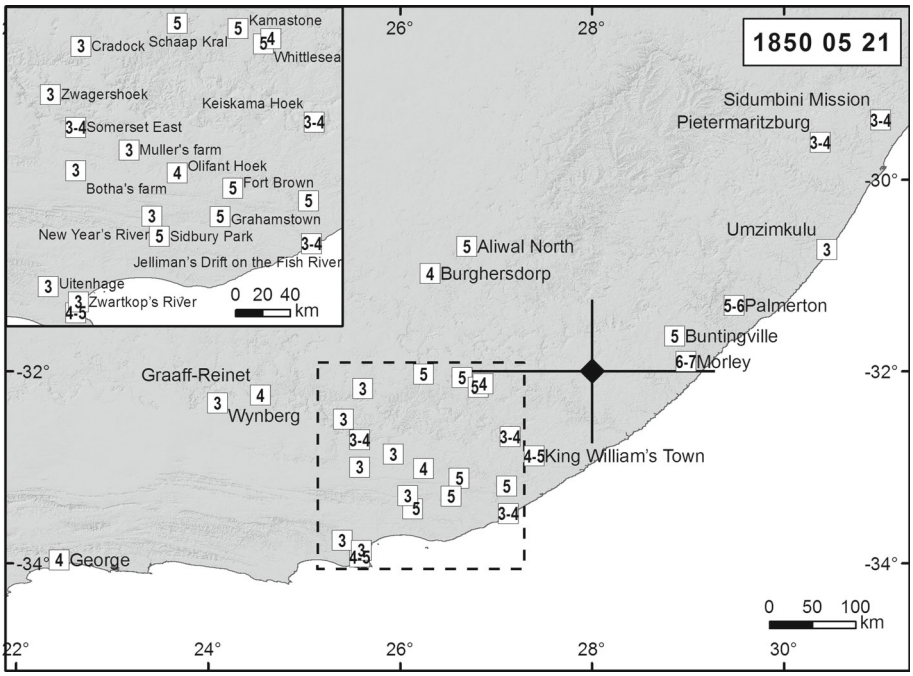


Fig. 5 Distribution of intensity values (MMI-56 scale) for the 21 May 1850 earthquake. The *marker* and *cross* indicate the best estimate epicentral location and associated uncertainties (see Table 3)

essays were written "by some of the more advanced boys in the mission school at St. Matthews, Keiskamma Hoek" (Anonymous, 1861);

- the inclusion in a Xhosa-English dictionary of a specially coined wording "*i-Nyikima*", to indicate "the great earthquake of 1851 [sic, but 1850]" (McLaren, 1984).

Also, records of this earthquake have been found in published and unpublished sources, such as:

1. a manuscript journal by Thomas Shone, who at the time of the earthquake was a resident at Grahamstown (Shone, 1850–1851);
2. the narrative of his "Forty years among the Zulus" by the missionary Josiah Tyler, covering the years 1849–1888; and
3. an early local history of Pietermaritzburg (Hattersley, 1938).

Considering that at the time of the event there were just scattered settlements in the area, this should be considered an earthquake of which the effects are well described, and certainly the earliest fully documented earthquake in the Eastern Cape Province at present.

A macroseismic intensity value in MMI-56 scale was assessed at 32 places (Fig. 5). For the sake of completeness, Table 5 includes all the 35 places mentioned by the sources, including individual buildings and areas, though in the latter cases (shown in italics) a macroseismic intensity value was not assessed (and no co-ordinates are provided).

As illustrated in Fig. 5, the distribution of IDPs stretches from George in the west to the Pietermaritzburg area in the east, and as far inland as Aliwal North, with observations concentrated in the area delimited by Cradock, King William's Town and Port Elizabeth, shown in the inset of Fig. 5. The lack of observations in the region between Graaff-Reinet and

George can be related to the very sparse population of this region (still seen today), combined with the relatively low levels of intensity that would be expected, based on neighbouring observations, ranging from 3 to 4 MMI-56. More conspicuous is the gap in the eastern part of the felt area, including in particular the Lesotho highlands, observations in the area delimited by Aliwal North, KingWilliam's Town and Pietermaritzburg being essentially confined to the coastal region, where the highest intensities observed in this earthquake were recorded (6–7 at Morley and 5–6 at Palmerton). This data gap can be explained by the geographical pattern of settlement, in particular the eastward expansion of the Cape Colony. In 1850, the Eastern Cape Frontier ran along the Kei River, with only isolated outposts beyond the border. This bias in the spatial distribution of IDPs needs to be considered when assessing the quality of the epicentral locations given by the various analysis methods (Table 3), and explains the low weight given to the centroid method, which is the most strongly affected by this data-related bias. The preferred epicentre for this event is located some 200 km from the Grahamstown location previously adopted by Fernández and Guzmán (1979). The latter was maintained by Brandt et al. (2005) following their review of the materials included in De Klerk and Read (1988), but with a slightly reduced I_{max} (5–6 instead of 6). The reduction of the intensity at Grahamstown is supported by our analysis, which assigns a value of 5 MMI-56 to this locality. However, the more comprehensive information available in the present study brings with it an increase in the magnitude assigned to the event (from 5.0 M_L to 5.7 M_w).

3.2 The 24 February 1864 earthquake

At about 1:30 a.m. in the morning of Wednesday 24 February 1864, an earthquake was distinctly felt at Graaff-Reinet, as well as in Mossel Bay, George and Knysna.

Effects described are people awakened, furniture vibrating, and shutters shaking. The only two available records are variously repeated by eight different newspapers (Cape and Natal News, 1864; Cape Argus, 1864a; 1864b; Eastern Province Herald, 1864; Graaff-Reinet Herald, 1864; Great Eastern, 1864; King William's Town Gazette and Kaffrarian Banner, 1864; South African Advertiser and Mail, 1864; Zuid Afrikaan, 1864a; 1864b; 1864c) out of the 15 investigated (no information was found in: Cape Frontier Times, 1864; Cape Mercantile Advertiser, 1864; Journal, 1864; Natal Courier and Pietermaritzburg Advertiser, 1864; Natal Mercury, 1864; Natal Witness, 1864; Volksblad, 1864). Though the records are short, they are of good quality and reliability as they are the original observations of two eyewitnesses, located respectively at Graaff-Reinet (Graaff-Reinet Herald, 1864) and Knysna (Cape Argus, 1864b).

Press accounts in the days immediately before and after the earthquake concern mainly the weather. Heavy rains were experienced at Fort Beaufort two weeks earlier, and on 20 February at Cradock and Grahamstown (Fig. 6), in the latter causing some damage (Journal, 1864). This lack of earthquake reports seems to strongly suggest that this earthquake was not felt to the east of Graaff-Reinet (more specifically at Grahamstown and Port Elizabeth).

As a result, the IDPs for this earthquake, for which there are no prior determinations, are limited to four in number, all with the same intensity (4 MMI-56); three of these are clustered in the coastal region between Knysna and Mossel Bay, with the fourth IDP being located at Graaff-Reinet. The lack of observations in the intermediate region can be related to the sparse population in this mountainous area. This IDP distribution is far from ideal for the application of the methods, and the uncertainty in location is consequently very high. As would be expected, the preferred epicentre is located within the area delimited by the IDPs, slightly to the northeast of the coastal cluster. The magnitude uncertainty is also very high;

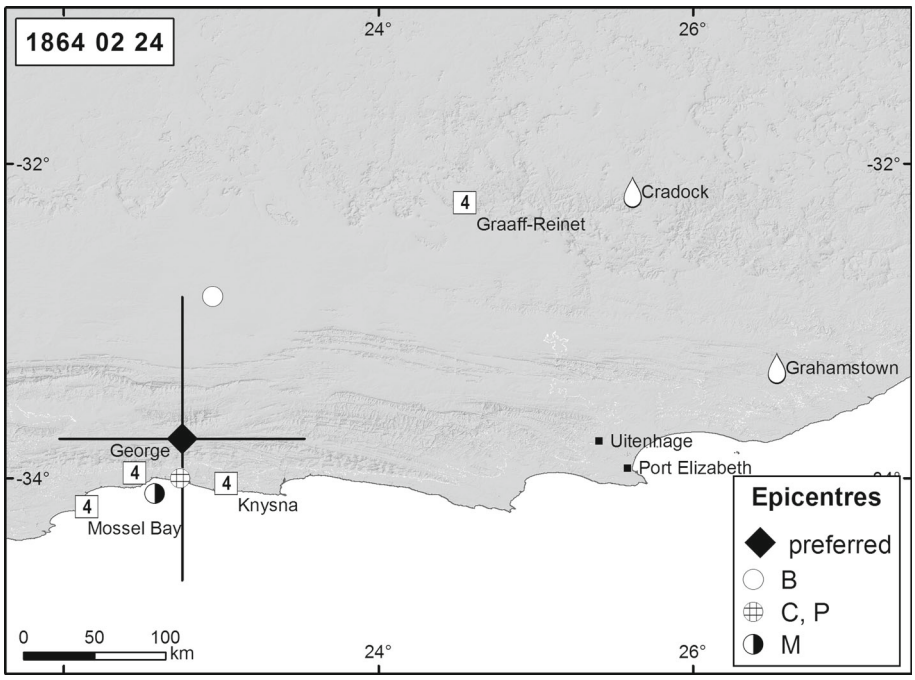


Fig. 6 The 24 February 1864 earthquake effects distribution (MMI-56 scale). The "*drops*" show the places affected by heavy rains on 20 February, causing damage at Cradock and Grahamstown. The *marker* and *cross* indicate the best estimate epicentral location and associated uncertainties, while the other *symbols* show the alternative locations (see Table 3)

the preferred magnitude is set tentatively at M_w 4.1, with an uncertainty of 0.5 magnitude units around this value.

3.3 The 15 October 1867 earthquake

The earthquake occurred about midday on Tuesday 15 October 1867. Records were found in 13 out of 18 newspapers investigated, though the really original observations are but a few, those shown in Fig. 7, within a thick frame. Most of the records are in fact an exact copy of the correspondence published in the "King William's Town Gazette" the day after the earthquake, 16 October 1867 (with a dotted frame and linked by means of dotted arrows, Fig. 7).

Its severest effects are documented at East London and King William's Town (Table 5), and they were described as a rumbling noise, objects falling from shelves and the "rattling of crockeryware and cooking utensils". The earthquake caused panic, and there is evidence supplied to some newspapers from small settlements to the north and west of East London and King William's Town. The intensity distribution is shown in Fig. 8, together with the indication of the places (crossed squares) at which the local press did not report any account of earthquake effects.

The IDPs for this event include three MMI-56 points delineating a triangular cluster bounded by East London, King William's Town and Chalumna. Other IDPs with slightly lower intensities (3 and 4) surround this triangle, again with a bias towards the west in

Table 5 Places affected by the 15 October 1867 earthquake and assigned intensity in MMI-56

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
King William's Town	Midday	Anglo-African, 1867a, 1867b	−32.883	27.400	EC	5
		Cape and Natal News, 1867a				
		Cape Argus, 1867				
		Cape Standard, 1867a;1867b;1867c				
		Eastern Province Herald, 1867				
		George Advertiser, 1867				
		Graaff-Reinet Herald, 1867				
		Journal, 1867a; 1867b				
		Great Eastern, 1867a; 1867b				
		South African Adv. and Mail, 1867				
		Volksblad, 1867				
		Zuid Afrikaan, 1867				
East London	Midday	Anglo-African, 1867a	−33.033	27.917	EC	5
		Cape and Natal News, 1867a				
		Cape Argus, 1867				
		Cape Standard, 1867a;1867b;1867c				
		Eastern Province Herald, 1867				
	12.20 p.m	George Advertiser, 1867				
		Graaff-Reinet Herald, 1867				
		Journal, 1867a; 1867b				
		Great Eastern, 1867a; 1867b				
		South African Adv. and Mail, 1867				
		Volksblad, 1867				
		Zuid Afrikaan, 1867				
Chalumna (and other places in the district)	–	Journal, 1867b	−33.137	27.538	EC	5
		Great Eastern, 1867b				

Table 5 continued

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
Cobungo / Cobongo Park	13 min past 12 (noon)	Anglo-African, 1867b	−32.733	27.600	EC	4–5
		Cape and Natal News, 1867b				
		Great Eastern, 1867b				
Mr. Roach's farm	–	Anglo-African, 1867b	–	–	EC	4–5
Komgha	10 min past 12 o'clock	Anglo-African, 1867b	−32.577	27.892	EC	4
		Cape and Natal News, 1867b				
Kwelgha /Kwelegha	About one o'clock	Anglo-African, 1867b	−32.849	28.006	EC	4
		Great Eastern, 1867b				
Colesberg (and district)	–	Great Eastern, 1867c	−30.720	25.097	NC	4
Somerset East (and district)	–	Great Eastern, 1867c	−32.716	25.583	EC	4
Bedford	Midday	King Williamstown Gazette, 1867	−32.679	26.087	EC	4
Grahamstown	About noon	Cape Standard, 1867a	−33.300	26.533	EC	3

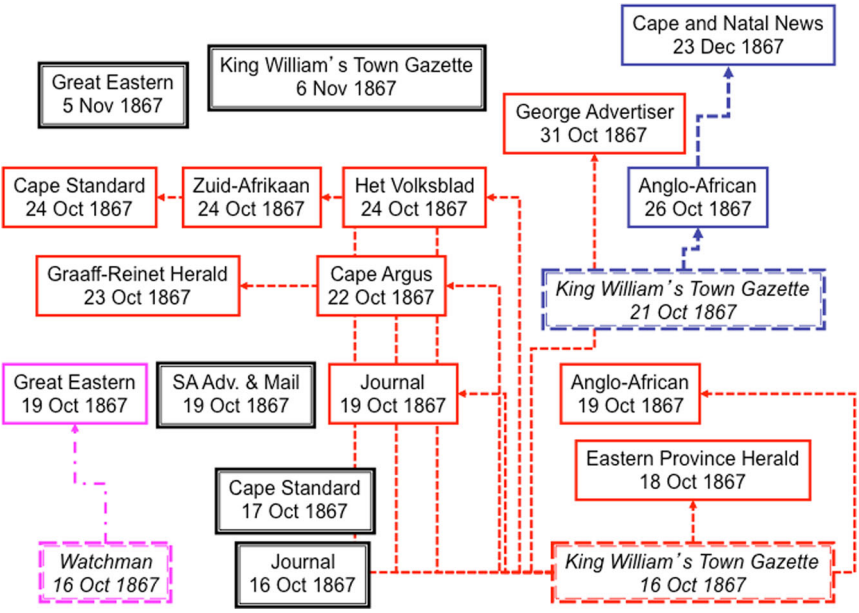


Fig. 7 Scheme of relationships among records as in the studied newspapers for the 15 October 1867 earthquake. The newspaper issues in a *dotted* frame could not be consulted directly, but are referred to by those issues to which they are linked with a *dotted line*

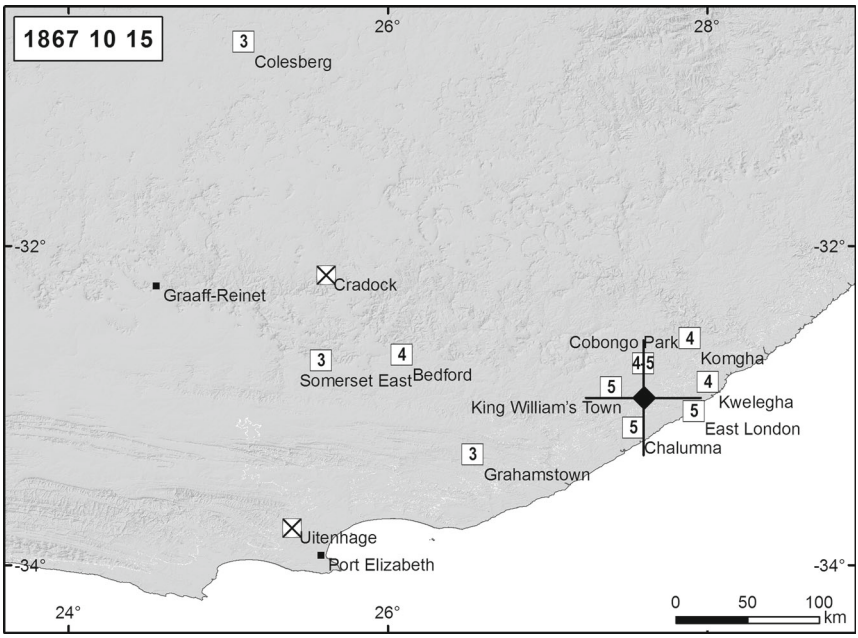


Fig. 8 Distribution of intensity values (MMI-56 scale) for the 15 October 1867 earthquake. *Crossed squares* indicate places at which the local press did not account for any effect. The *marker* and *cross* indicate the best estimate epicentral location and associated uncertainties (see Table 3)

the spatial distribution, reflecting colonial settlement patterns. Overall, the distribution indicates an epicentre in the King William's Town area, confirming the previous determination of Brandt et al. (2005). The magnitude assigned, however, is somewhat greater ($M_w 5.1 \pm 0.5$), reflecting in particular the upward reappraisal of I_{max} (from 4 to 5 MMI-56).

3.4 The 9 April 1895 earthquake

"Queer sensations and noises" were distinctly felt on Tuesday 9 April 1895, around 10 o'clock in the evening in some places of the Graaff-Reinet and Uitenhage districts (as they were in 1895) (Fig. 9). They mostly consisted of rattling of windows and doors.

Records were found in the issues of five out of the nine newspapers investigated in connection with this earthquake. It is worthwhile to note that neither the newspaper published at George ("George and Knysna Herald") nor the one published at Port Elizabeth ("Port Elizabeth Telegraph") reported any effect felt at these two places (to the west, Fig. 9).

A macroseismic intensity was assigned at seven places (Table 6). There is a vague indication that the earthquake was felt at "many farm-houses" in the Uitenhage district, but these farms are not mentioned explicitly, and thus such information could not be used further.

The IDPs for this event consist of a set of six IDPs with intensity 3 MMI-56 describing an arc from Grahamstown to Graaff-Reinet, with one IDP of intensity 4 MMI-56 at Uitenhage to the southwest of this arc. Again, the lack of data to the west is likely to be linked to the sparse population of that region. While the dataset is limited, it nevertheless points to an epicentre near Uitenhage, the location finally selected being near the town of Kirkwood. The magnitude determined for this event is 4.1 ± 0.5, the same as determined for the 1864 event.

Table 6 Places affected by the 9 April 1895 earthquake and assigned intensity in MMI-56

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
Uitenhage	About 10 p.m.	Cape Mercury, 1895 Grocott's P. Mail, 1895 Journal, 1895b Midland News, 1895	−33.765	25.402	EC	4
"Many farm-houses" in the Uitenhage district	–	Port Elizabeth Tel., 1895	–	–		–
Grahamstown	Night	Grocott's P. Mail, 1895 Journal, 1895a	−33.304	26.533	EC	3
West Hill		Grocott's P. Mail, 1895 Journal, 1895a	−33.300	26.500	EC	3
Jansenville	Evening, about 10 o'clock	Grocott's P. Mail, 1895 Port Elizabeth Tel., 1895	−32.933	24.667	EC	3
Graaff-Reinet	Evening	Grocott's P. Mail, 1895 Midland News, 1895	−32.250	24.550	EC	3
Pearston	10:15 p.m.	Grocott's P. Mail, 1895 Midland News, 1895	−32.583	25.133	EC	3
Somerset East		Grocott's P. Mail, 1895	−32.716	25.583	EC	3

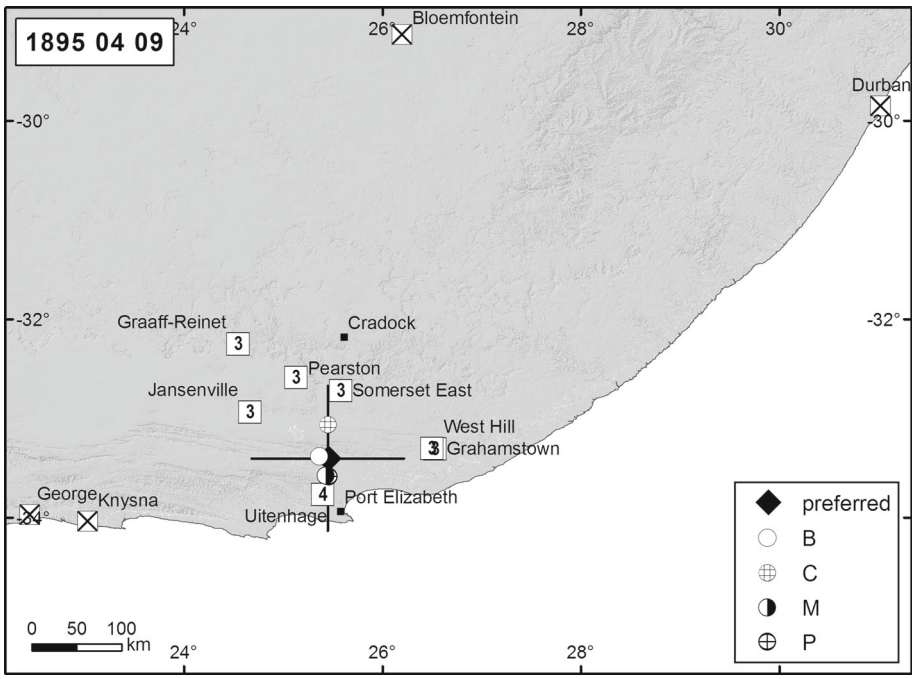


Fig. 9 Distribution of intensity values (MMI-56 scale) for the 9 April 1895 earthquake. *Crossed squares* indicate places at which the local press did not account for any effect. The *marker* and *cross* indicate the best estimate epicentral location and associated uncertainties, while the other *symbols* show the alternative locations (see Table 3)

3.5 The 9 August 1932 earthquake

At 3 a.m. of Tuesday 9 August 1932, the Eastern Cape Province was affected by an earthquake, which was felt on the coast from East London to the east, Knysna to the west, and as far north as Tarkstad (Table 7; Fig. 10).

In summary, the earthquake caused the following (maximum) effects in the area most affected:

- damage to a chimney of the Training College, Grahamstown
- cracks in some buildings at Fort Brown
- plaster falling (e.g. at Uitenhage and Graaff-Reinet)
- houses shaking (e.g. Port Elizabeth)
- windows rattling
- crockery thrown to the floor
- many inhabitants who woke up because their beds were rocking (e.g. Alexandria, Grahamstown, Cradock), and panic made many run in the open.

The event was widely felt, with only one of the nine newspapers investigated not mentioning it. An intensity value was assessed at 40 different places, but not at Brownlee Mission Station, at that time already part of King William's Town. The assessed intensities for Port Elizabeth, Grahamstown, Graaff-Reinet and Uitenhage resulted to be the highest experienced in Eastern Cape Province between 1820 and 1936.

Table 7 Places affected by the 9 August 1932 earthquake and assigned intensity in MMI-56

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
Grahamstown	3 a.m.	Burger, 1932 Cape Mercury, 1932a; 1932c Cape Times, 1932 Eastern Province Herald, 1932 Grocott's Daily Mail, 1932a; 1932c Midland News, 1932	−33.300	26.533	EC	6
East London	2.57 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932 Eastern Province Herald, 1932	−33.033	27.917	EC	5-6
	2.55 a.m.	Finsen, 1950				
Fort Brown	Few min to 3 a.m.	Eastern Province Herald, 1932 Grocott's Daily Mail, 1932a	−33.116	26.616	EC	5-6
Port Alfred	2.57 a.m.	Burger, 1932 Cape Times, 1932 Eastern Province Herald, 1932 Grocott's Daily Mail, 1932a; 1932b	−33.600	26.900	EC	5–6
Uitenhage	Few min to 3 a.m.	Eastern Province Herald, 1932	−33.765	25.402	EC	5–6
Alexandria	2.55 a.m.	Eastern Province Herald, 1932	−33.650	26.417	EC	5
Alicedale	5 min to 3 a.m.	Cape Mercury, 1932c Eastern Province Herald, 1932 Grocott's Daily Mail, 1932a	−33.317	26.083	EC	5
Bedford	2.55 a.m.	Burger, 1932 Cape Times, 1932 Eastern Province Herald, 1932	−32.683	26.083	EC	5
Cradock	3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932 Eastern Province Herald, 1932	−32.183	25.616	EC	5
Halesowen	3 a.m.	Eastern Province Herald, 1932	−32.250	25.633	EC	5
King William's Town	3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932	−32.883	27.400	EC	5

Table 7 continued

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
		Eastern Province Herald, 1932 Midland News, 1932 Finsen, 1950				
Komgha	3 a.m.	Cape Times, 1932 Finsen, 1950	−32.583	27.900	EC	5
Port Elizabeth	Few min to 3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932 Eastern Province Herald, 1932 Grocott's Daily Mail, 1932a; 1932b Midland News, 1932	−33.936	25.583	EC	5
Queenstown	3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932 Eastern Province Herald, 1932	−31.900	26.883	EC	5
Balfour	2.50 a.m.	Finsen, 1950	−32.533	26.683	EC	4–5
Graaff-Reinet	3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932 Eastern Province Herald, 1932 Midland News, 1932	−32.250	24.550	EC	4–5
Adelaide	3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932 Eastern Province Herald, 1932 Midland News, 1932	−32.700	26.300	EC	4
Alice		Burger, 1932 Cape Times, 1932	−32.787	26.834	EC	4
Aliwal North		Cape Times, 1932	−30.700	26.700	EC	4
Barkly East		Cape Times, 1932 Burger, 1932	−30.968	27.596	EC	4
Berlin	–	Cape Mercury, 1932a	−32.883	27.581	EC	4
Brownlee Station (see King William's Town)	–	Cape Mercury, 1932c	–	–	–	–
Cathcart	3 a.m.	Burger, 1932 Cape Mercury, 1932a Cape Times, 1932	−32.300	27.133	EC	4

Table 7 continued

Place	Time (local)	Source	Lat	Lon	Prov (today)	Int. MMI-56
		Eastern Province Herald, 1932				
		Midland News, 1932				
Durban	Few min to 3 a.m.	Burger, 1932	−29.850	31.017	KN	4
		Cape Mercury, 1932a, 1932b				
		Cape Times, 1932				
		Eastern Province Herald, 1932				
		Grocott's Daily Mail, 1932b				
Fort Beaufort	–	Burger, 1932	−32.774	26.634	EC	4
		Cape Mercury, 1932a				
		Cape Times, 1932				
Indwe		Burger, 1932	−31.466	27.333	EC	4
		Cape Times, 1932				
Jansenville	3 a.m.	Cape Times, 1932	−32.933	24.667	EC	4
		Eastern Province Herald, 1932				
Kei Road	–	Cape Mercury, 1932a	−32.705	27.547	EC	4
Keiskama Hoek	–	Cape Mercury, 1932a	−32.682	27.150	EC	4
Kirkwood		Burger, 1932	−33.398	25.443	EC	4
Knysna	3 a.m.	Burger, 1932	−34.033	23.033	WC	4
		Cape Mercury, 1932a				
		Cape Times, 1932				
		Eastern Province Herald, 1932				
		Midland News, 1932				
Pearston	3 a.m.	Burger, 1932	−28.733	24.767	EC	4
Peddie	2:55 a.m.	Burger, 1932	−33.200	27.114	EC	4
		Cape Times, 1932				
Somerset East		Burger, 1932	−32.716	25.583	EC	4
		Cape Times, 1932				
Sterkstroom		Burger, 1932	−31.557	26.554	EC	4
Stutterheim	–	Cape Mercury, 1932a	−32.570	27.423	EC	4
Tarkastad	3 a.m.	Burger, 1932	−30.017	26.267	EC	4
		Cape Mercury, 1932a				
		Cape Times, 1932				
		Eastern Province Herald, 1932				
		Midland News, 1932				
Isidenge		Cape Mercury, 1932a	−32.673	27.283	EC	3–4
Wepener	2.55 a.m.	Finsen, 1950	−29.733	27.033	FS	3–4
Kimberley		Cape Mercury, 1932a	−28.733	24.767	NC	3

This earthquake is the first examined here which was instrumentally recorded. It was recorded on the Wiechert seismograph at the Union Observatory in Johannesburg, where it registered a double-amplitude of 7 mm. The highest intensity (6 MMI-56) amongst the IDPs developed is observed at Grahamstown, with three intensity 5–6 IDPs distributed along the coast at Uitenhage, Port Alfred and East London. The remainder of the IDPs in the

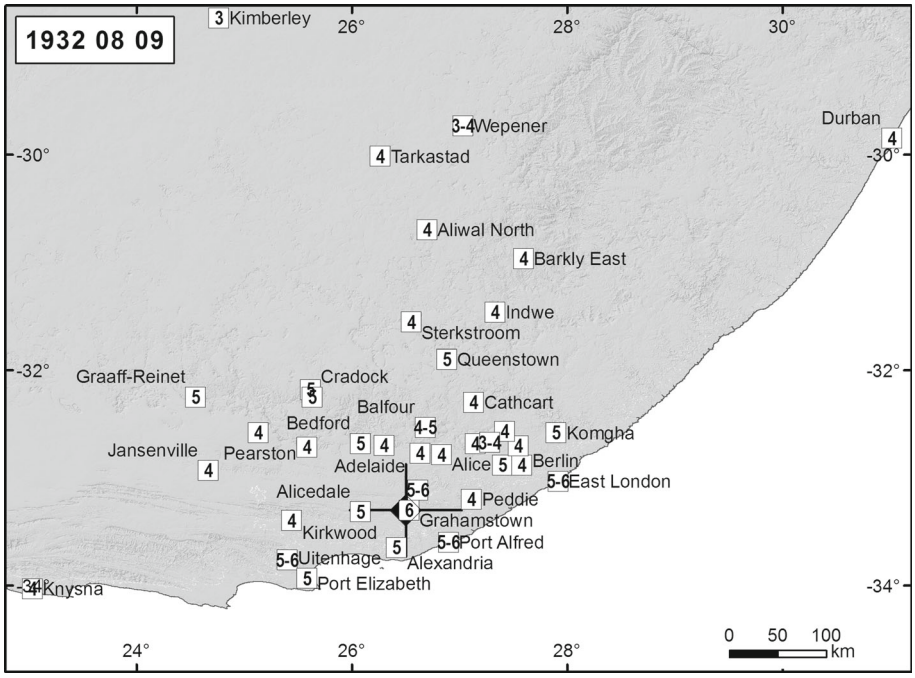


Fig. 10 Distribution of intensity values (MMI-56 scale) for the 9 August 1932 earthquake. The *marker* and *cross* indicate the best estimate epicentral location and associated uncertainties (see Table 3)

region surrounding Grahamstown have intensities of 4–5 MMI-56, and overall tend to be slightly higher to the west and northwest of Grahamstown than to the east and northeast. The presence of the coastline brings with it some censuring of the data, and once again the gap in population between the Port Elizabeth and Knysna areas is clearly visible. Despite the relative completeness of the dataset, the MEEP and pairwise methods tend to favour an offshore epicentre, in all likelihood as a result of spatial overlap of different intensity levels; this possibility, however, requires a larger magnitude, which is not borne out by the instrumental recording. The outlying intensity 4 MMI-56 IDP at Durban, which would fit with the assumption of a larger magnitude, is most likely related to site effects. Such effects have been frequently observed in that location due to the presence of tall buildings on soft coastal deposits (e.g. Midzi et al. 2013). The preferred location for this event, therefore, remains in the Grahamstown region, confirming the previous location of Brandt et al. (2005). Similarly to the 1850 event, the magnitude is revised upwards (from M_L 5.0 to $M_w 5.7 \pm 0.35$), reflecting the increase in assessed I_{max} (from 5–6 to 6), more modest than in the 1850 case, but also the fact that the magnitude was assessed from the full set of IDPs, considering the extent and spacing of the implied isoseismals, rather than from a single point.

3.6 The 25 February 1933 earthquake

"At 4 min to 7 on Saturday morning there was an Earth tremor here which will assuredly be described as an earthquake" (Eastern Province Herald, 1933). The item is not signed, and it is included in the column of the news concerning Grahamstown, Bathurst and Port Alfred. Out of the four investigated newspapers only the one quoted above reported the information about the earthquake. Therefore, this small earthquake appears to only have been reported locally

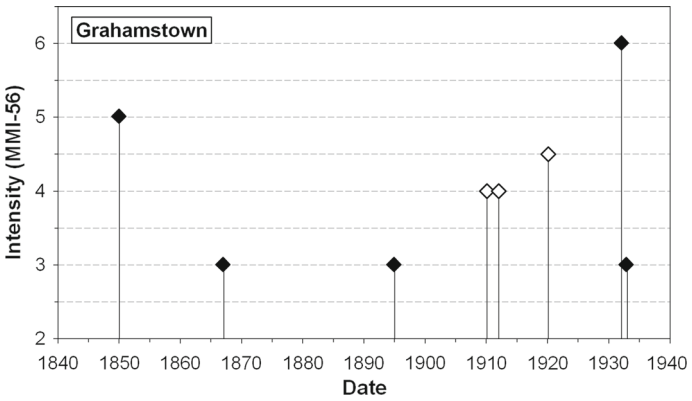


Fig. 11 Intensity assigned at Grahamstown related to earthquake effects 1820–1936; *open diamond shapes* are effects due to earthquakes not described in this paper and originating outside the study area

in the Grahamstown region. The limited observations available place it slightly to the SE of Grahamstown, with the smallest magnitude in the dataset considered herein (3.2 ± 0.8).

4 The seismic history of Grahamstown

A seismic history is presented here as the series of earthquake effects experienced at one place within a certain time-window. With eight macroseismic intensity values expressed in MMI-56 scale, quite evenly distributed in the time-window 1820–1936 (Fig. 11), the seismic history of Grahamstown resulted to be well attested and regular, especially with respect to the other observation points considered (Fig. 1).

As reported in Sect. 2 of this paper, for Grahamstown, the time-window of "complete" observations might be extended back in time as far as 1820, that is 30 years before the first earthquake effect was recorded in town, due to several, local and reliable sources that provide a continuous accounting of the events in this place during that time period (see Sect. 2).

Three earthquakes originating outside the region of study did have effects at Grahamstown. These are the 21 October 1910 Hanover (NC) and the 20 February 1912 Koffiefontein (FS) earthquakes, as well as the 4 December 1920 earthquake offshore of South Africa. They have been included in the seismic history (Fig. 11), where they are represented with an open diamond shape.

What is worthwhile to note is that the strongest effects observed are to be attributed to the 9 August 1932 earthquake, with an intensity 6 MMI-56, which has not been exceeded since. In 1932 Grahamstown was a much larger settlement than when the 1850 earthquake was experienced, and the town's sensitivity and "exposure" to earthquakes had certainly increased. Therefore the overall pattern of intensities observed for this locality does not appear to be anomalous.

5 Discussion and conclusions

This paper presents the first detailed study of primary sources documenting earthquakes in Grahamstown and surroundings between 1820 and 1936. Comprehensive processing of the data has made it possible to pass from the documented earthquake records to a full

set of macroseismic IDPs assigned at 68 different places in the region of study. These, in turn, were used to determine source parameters using state-of-the-art analysis methods that consider all of the IDPs, rather than basing them solely on the maximum observed intensity, I_{max}. Comparisons of these newly obtained results with previous determinations provides a fresh look at the seismicity of the Grahamstown region, highlighting, in particular, the value of gathering new information and the potential value of including records from different language groups.

Out of the six events investigated, only two (1850 and 1932) were included in the first historical earthquake catalogue for South Africa by Fernández and Guzmán (1979). Brandt et al. (2005) added the 1867, 1895 and 1933 events, and reappraised the parameters for the 1850 and 1932 events, based on the De Klerk and Read (1988) compilation. The 1864 event is a new addition to the catalogue, and no detailed macroseismic studies were previously undertaken for any of the six events discussed here.

Altogether, the results confirm the low level of seismicity that can be observed from the instrumental record. The intensity of 6 MMI-56 observed at Grahamstown for the 1932 event remains the highest in this location since 1820. The seismic history is considered to be complete at the intensity 5–6 MMI-56 level for the period 1820–1936, following the examination of a corpus of quasi-continuous observations of the natural events of the territory. Added to this examination is included a thorough consideration of the retrieved written records on earthquakes, as compared with (possible) reasons for their absence in the examined sources, as described previously (see the introduction to Sect. 3).

A comparison of the seismic history of Grahamstown with that of neighbouring locations (Port Elizabeth, King William's Town and Graaff-Reinett) confirms the salient nature of the 1850 and 1932 events, which were observed and recorded in multiple locations, contrasted with the other, more local events (1864, 1867, 1895 and 1933).

The overall picture that emerges from the present reappraisal is essentially a tale of two "Grahamstown" earthquakes: one that was relocated (1850), and one that was not (1932). Interestingly, both of these were listed in Brandt et al. (2005) as having a magnitude M_L5.0, based on an I_{max} value of 5–6 MMI-56. In both cases, consideration of the full set of reappraised IDPs resulted in a significant, and identical, increase in magnitude, with new best estimates of M_w 5.7 for these events.

Notwithstanding these significant differences in source parameters, our analysis validates most of the revisions made by Brandt et al. (2005) to the Fernández and Guzmán (1979) catalogue. This apparent paradox can be explained by the inclusion of additional data (stemming from the assessment of a greater number of original contemporary documents in various languages), and by the use of interpretative methods considering the overall pattern of intensities, rather than singling out the highest value. We thus have attempted to avoid the pitfall of "slavish repetition of previous lists" Nicholas Ambraseys warned against in the introductory quote to this paper, in our striving to continuously improve the South African earthquake catalogue.

Acknowledgments The work presented in this paper was conducted as a part of the PSHA project for the Thyspunt site conducted by the Council for Geoscience under contract from Eskom, the South African state-owned energy utility. The contributions of individuals from both CGS and Eskom in supporting this work are too numerous for mention herein, but we note particular thanks to Erna Hattingh, Project Manager from the CGS Nuclear Geo-hazard Group, and André P Nel from Eskom Nuclear Sites for their support for the work and their appreciation of the value of extending the earthquake record for this region of South Africa. Sincere thanks are also due to the project PTI, Julian Bommer, and the SSC TI Lead, Kevin Coppersmith, for their continued guidance and support. Moreover, the authors are extremely grateful to Vindina Mitha, who accompanied P.A. in Eastern Cape repositories and shared the labours of historical field-work in a frozen

Karoo; the staff of the Cory Library for Historical Research, at Rhodes University, Grahamstown, for their warm welcome and valuable support; Linda Akromah, for her translation of the Xhosa documents, and valuable feedback on terminology issues; Refilwe Shelembe, for additional thoughtful feedback on these issues, and a thorough check of the draft manuscript; Andrea Rovida for the painstaking effort to prepare all the maps in this paper; and Céline Beauval, for guidance in the determination of the source parameters. The work presented herein also greatly benefited from lively discussions with, and thoughtful comments from, various participants of the Thyspunt PSHA project.

References

Sources

Anglo-African, The (1867a) Grahamstown. Saturday, October 19, 1867, XXVI, no.853
Anglo-African, The (1867b) Grahamstown. Saturday, October 26, 1867, XXVI, no.845 [sic]
Anonymous (1861) Kafir essays and other pieces with an English Translation. Printed at the office of "The Anglo-African", Grahamstown, 80 pp
Appleyard JW (1850) The Kafir language: comprising a sketch of its history: which includes a general classification of South African dialects, ethnographical & geographical remarks upon its nature and a grammar. Wesleyan Missionary Society, King William's Town, 390 pp
Ayliff J (1821–1830) The Journal of John Ayliff, I: 1821–1830. Edited by Peter Hinchliff, 1971, Rhodes University, The Graham's Town Series, 1. Balkema, Cape Town, 130 pp
Binnington Boyce W (1875) Memoir of the Rev. William Shaw. Edited by his oldest surviving friend W.B.B., Wesleyan Conference Office, London, 463 pp
Burger, De (1932) Cape Town. Wednesday, August 10, 1932
Butler J (1876–1879) "Jim's Journal": the diary of James Butler. Edited by Jane Garner, 1996, Rhodes University, Grahamstown, 14, Witwatersrand University Press, 330 pp
Campbell J (1815) Travels in South Africa undertaken at the request of the Missionary Society, Third edition, reprint by C. Struik, Cape Town, 1974, 400 pp
Cape and Natal News, The (1864) London. 25 April 1864, p 131
Cape and Natal News, The (1867a) London. 23 November 1867, IX, 181, p 340
Cape and Natal News, The (1867b) London. 23 December 1867, IX, 182, 372–373
Cape Argus, The (1864a) Cape Town. Saturday, February 27, 1864
Cape Argus, The (1864b) Cape Town. Tuesday, March 8, 1864
Cape Argus, The (1867) Cape Town. Tuesday, October 22, 1867, XI, no.1659
Cape Frontier Times, The (1850a) Grahamstown. Tuesday, May 28, 1850, no.522
Cape Frontier Times, The (1850b) Grahamstown. Tuesday, June 4, 1850, no.523
Cape Frontier Times, The (1850c) Grahamstown. Tuesday, June 18, 1850, no.525
Cape Frontier Times, The (1850d) Grahamstown. Tuesday, June 25, 1850, no.526
Cape Frontier Times, The (1864) Grahamstown. 19 February to 18 March 1864 (no information on the 24 February 1864 earthquake)
Cape Mercantile Advertiser, The (1864) Cape Town. 24 February to 14 March 1864 (no information on the 24 February 1864 earthquake)
Cape Mercury, The (1895) King William's Town. Saturday, April 27, 1895, XXXIII, no.2697
Cape Mercury, The (1932a) King William's Town. Tuesday, August 9, 1932, LXIX, no.11834
Cape Mercury, The (1932b) King William's Town. Wednesday, August 10, 1932, LXIX, no.11835
Cape Mercury, The (1932c) King William's Town. Thursday, August 11, 1932, LXIX, no.11836
Cape Standard, The (1867a) Cape Town. Thursday, October 17, 1867, II, no.283
Cape Standard, The (1867b) Cape Town. Saturday, October 19, 1867, II, no.284
Cape Standard, The (1867c) Cape Town. Thursday, October 24, 1867, II, no.286
Cape Times, The (1932) Cape Town. Wednesday, August 10, 1932
Cape Town Mail, The (1850) Cape Town. Saturday, June 1, 1850, no.484
Centilivres Chase J (1843) The Cape of Good Hope and the Eastern Province of Algoa Bay etc. etc. with statistics of the colony. London, 338 pp
Eastern Province Herald and Port Elizabeth Commercial News, The (1932) Port Elizabeth. Wednesday, August 10, 1932, no.191
Eastern Province Herald and Port Elizabeth Commercial News, The (1933) Port Elizabeth. Tuesday, February 28, 1933
Eastern Province Herald, The (1850a) Port Elizabeth. Saturday, May 25, 1850, no.263
Eastern Province Herald, The (1850b) Port Elizabeth. Saturday, June 1, 1850, no.264

Eastern Province Herald, The (1850c) Port Elizabeth. Saturday, June 8, 1850, no.265
Eastern Province Herald, The (1864) Port Elizabeth. Friday, February 26, 1864, XIII, no.997
Eastern Province Herald, The (1867) Port Elizabeth. Friday, October 18, 1867, no.1335
Friend of the Sovereignity and Bloemfontein Gazette (1850) Bloemfontein. Monday, June 10, 1850
George Advertiser, The (1867) George. Thursday, 31 October, 1867
Godlonton R (1842) Sketches of the Eastern Districts of the Cape of Good Hope as they are in 1842. Compiled by the Editor of the "Graham's Town Journal", with a view to assist the emigrant and to serve as a Hand Book for Travellers. Graham's Town, printed and published at the office of the "Graham's Town Journal" 128 pp
Graaff-Reinet Herald, The (1864) Graaff-Reinet. Wednesday, February 24, 1864, XII, no.818
Graaff-Reinet Herald, The (1867) Graaff-Reinet. Wednesday, October 23, 1867, no.1200
Grahamstown Journal, The (1850a) Grahamstown. Saturday, May 25, 1850, no.963
Grahamstown Journal, The (1850b) Grahamstown. Saturday, June 1, 1850, no.964
Grahamstown Journal, The (1850c) Grahamstown. Saturday, June 15, 1850, no.966
Grahamstown Journal, The (1850d) Grahamstown. Saturday, June 22, 1850, no.967
Grahamstown Journal, The (1850e) Grahamstown. Saturday, July 6, 1850, no.969
Great Eastern, The (1864) Grahamstown. Saturday, February 27, 1864, I, no.12
Great Eastern, The (1867a) Grahamstown. Thursday, October 17, 1867, VIII, no.579
Great Eastern, The (1867b) Grahamstown. Saturday, October 19, 1867, VIII, no.580
Great Eastern, The (1867c) Grahamstown. Thursday, November 5, 1867, VIII, no.587
Grocott's Daily Mail (1932a) Grahamstown. Tuesday, August 9, 1932, no.11,656
Grocott's Daily Mail (1932b) Grahamstown. Wednesday, August 10, 1932, no.11,657
Grocott's Daily Mail (1932c) Grahamstown. Thursday, August 11, 1932, no.11,658
Grocott's Penny Mail (1895) Grahamstown. Friday, April 19, 1895
Hattersley AF (1938) Pietermaritzburg panorama: a survey of one hundred years of an African city. Pietermaritzburg, 126 pp
Journal, The (1864) Grahamstown. 23 February to 11 March 1864 (no information on the 24 February 1864 earthquake)
Journal, The (1867a) Grahamstown. Wednesday, October 16, 1867, no.2304
Journal, The (1867b) Grahamstown. Friday, October 18, 1867, no.2305
Journal, The (1895a) Grahamstown. Monday, April 15, 1895
Journal, The (1895b) Grahamstown. Monday, April 22, 1895
Kaapsche Grensblad (1850a) Grahamstown. Saturday, May 25, 1850
Kaapsche Grensblad (1850b) Grahamstown. Saturday, June 1, 1850
Kaapsche Grensblad (1850c) Grahamstown. Saturday, June 8, 1850
Kaapsche Grensblad (1850d) Grahamstown. Saturday, July 6, 1850
King William's Town Gazette and Kaffrarian Banner (1864) King William's Town. Thursday, March 3, 1864, VII, no.533
King William's Town Gazette and Kaffrarian Banner (1867) King William's Town. Wednesday, November 6, 1867, X, no.1125
McLaren J (1984) A new concise Xhosa-English dictionary [revised by Bennie WG and Jolobe JJR]. Maskew-Miller Longman, Cape Town. 194 pp
Midland News and Karroo Farmer, The (1895) Cradock. Tuesday, April 16, 1895, VIII, no.462
Midland News and Karroo Farmer, The (1932) Cradock. Thursday, August 11, 1932, 41st year
Natal Courier and Pietermaritzburg Advertiser, The (1864) Pietermaritzburg. 24 February to 11 March 1864 (no information on the 24 February 1864 earthquake)
Natal Mercury, The (1864) Durban. 26 February to 15 March 1864 (no information on the 24 February 1864 earthquake)
Natal Witness, The (1850) Pietermaritzburg. Friday, June 28, 1850
Natal Witness, The (1864) Pietermaritzburg. 24 February to 15 March 1864 (no information on the 24 February 1864 earthquake)
Pigot S (1819–1821) The Journals of Sophia Pigot. Edited by Margaret Rainier, 1974, Rhodes University, The Graham's Town Series, 3. Balkema, Cape Town, 172 pp
Port Elizabeth Mercury, The (1850a) Port Elizabeth. Tuesday, May 28, 1850, no.13
Port Elizabeth Mercury, The (1850b) Port Elizabeth. Tuesday, June 4, 1850, no.14
Port Elizabeth Telegraph and Eastern Province Standard (1895) Port Elizabeth. Thursday, April 18, 1895, Supplement
Port Elizabeth Telegraph (1850) Port Elizabeth. Thursday, May 23, 1850, II, no.90
Pringle T (1835) Narrative of a residence in South Africa. Edward Moxon, London, 356 pp

Shaw W (1820–1829) The Journal of William Shaw. Edited by W.D. Hammond-Tooke, 1972, Rhodes University, The Graham's Town Series, 2. Balkema, Cape Town, 220 pp
Shone T (1850–1851) Journals. Manuscript 10,763(1), Cory Library, Grahamstown. Partially edited in: The Albany journals of Thomas Shone, Rhodes University, The Graham's Town Series, 12, Balkema, Cape Town, 200 pp
South African Advertiser and Mail, The (1864) Cape Town. Saturday, February 27, 1864
South African Advertiser and Mail, The (1867) Cape Town. Saturday, October 19, 1867, XLV, no.5930
Thompson G (1822) Travels and adventures in Southern Africa, by George Thompson, eight years resident at the Cape, comprising a view of the present state of the Cape Colony. Edited with notes by Vernon S. Forbes, 1967, The Van Riebeeck Society. Cape Town, Part 1, 187 pp
Tyler J (1891) Forty Years among the Zulus. Boston and Chicago, 300 pp
UK National Archives (1658–1974) Record of local bodies and other colonial miscellanea, Cape Colony, CO 53 [1658-1974], including newspapers printed in South Africa. Kew Gardens
Volksblad, Het (1864) Cape Town, 25 February to 10 March 1864 (no information on the 24 February 1864 earthquake)
Volksblad, Het (1867) Cape Town. Thursday, October 24, 1867
Zuid Afrikaan, De (1850a) Cape Town. Monday, May 27, 1850
Zuid Afrikaan, De (1850b) Cape Town. Thursday, May 30, 1850
Zuid Afrikaan, De (1850c) Cape Town. Monday, June 10, 1850
Zuid Afrikaan, De (1850d) Cape Town. Monday, June 24, 1850
Zuid Afrikaan, De (1864a) Cape Town. Monday, February 29, 1864
Zuid Afrikaan, De (1864b) Cape Town. Thursday, March 3, 1864
Zuid Afrikaan, De (1864c) Cape Town. Monday, March 7, 1864
Zuid Afrikaan, De (1867) Cape Town. Thursday, October 24, 1867

Modern studies

Ambraseys NN (2004) Three little known early earthquakes in India. Curr Sci 86(4):506–508
Ambraseys NN, Adams RD (1991) Reappraisal of major African Earthquakes, South of 20°N, 1900–1930. Nat Hazards 4:389–419
Bakun WH, Wentworth CM (1997) Estimating earthquake location and magnitude from seismic intensity data. Bull Seismol Soc Am 87(6):1502–1521
Bergh JS, Visagie JC (1985) The Eastern Cape Frontier Zone, 1660–1980: a cartographic guide for historical research. Butterworths, Durban, 84 pp
Bommer JJ, Coppersmith KJ, Coppersmith RT, Hanson KL, Mangongolo A, Neveling J, Rathje EM, Rodriguez-Marek A, Scherbaum F, Stafford PJ, Strasser FO (2013a) A SSHAC Level 3 Probabilistic Seismic Hazard Analysis for a New-Build Nuclear Site in South Africa. Earthq Spectra. doi:10.1193/060913EQS145M
Bommer JJ, Coppermsith KJ, Hattingh E, Nel AP (2013b) An application of the SSHAC Level 3 process to the probabilistic seismic hazard assessment for the Thyspunt nuclear site in South Africa. In: Proceedings of the 22nd international conference on structural mechanics in reactor technology (SMiRT22). San Francisco, August 18–23
Brandt MBC, Bejaichund M, Kgaswane EM, Hattingh E, Roblin DLR (2005) Seismic history of Southern Africa. Seismological Series of the Council for Geosciences no.37, Pretoria, 32 pp
Bud-M'Belle I (1903) Kafir scholar's companion. Lovedale Missionary Press, South Africa, 181 pp
De Klerk WJ, du Read JS (1988) An account of historical seismic activity in southern Africa with emphasis on the southern and eastern Cape. Report, Albany Museum, Grahamstown, 82 pp
Eve J (2003) A literary guide to the Eastern Cape. Double Storey Books, Cape Town, 402 pp
Fernández LM, Guzmán JA (1979) Seismic history of Southern Africa. Seismological Series, 9, Geological Survey of South Africa, 22 pp
Finsen WS (1950) The geographical distribution of some South African earthquakes. Circular No. 110, Union Observatory, Johannesburg, pp 457–472
Gasperini P, Bernardini F, Valensise G, Boschi E (1999) Defining seismogenic sources from historical earthquake felt reports. Bull Seismol Soc Am 89(1):94–110
Gutenberg B, Richter CF (1956) Seismicity of the earth and associated phenomena. Princeton University Press, Princeton, NJ

Japha D, Japha V, Le Grange L, Todeschini F (1993) Mission settlements in South Africa: a report on their historical background and prospects for conservation. South Africa Department of Environment Affairs, University of Cape Town, Cape Town, 97 pp +ill

Krüger B (1966) The pear tree blossoms. A history of the Moravian Mission Stations in South Africa 1737–1869. Genadendal, 335 pp

Letcher V (2002) "Five Years in Kaffirland": Harriet Ward, Frederick I'Ons and nineteenth century Ways of Looking at South Africa. English in Africa, n. 1, May 2002, pp 5–25

Midzi V, Bommer JJ, Strasser FO, Albini P, Zulu BS, Prasad K, Flint NS (2013) An intensity database for earthquakes in South Africa from 1912 to 2011. J Seismol 17:1183–1205. doi:10.1007/s10950-013-9387-y

Musson RMW, Cecić I (2002) Macroseismology. In: Lee WHK, Kanamori H, Jennings PC, Kisslinger C (eds) International handbook of earthquake and engineering seismology. Int Geophys 81: Part A 49: 807–822

Musson RMW (2009) MEEP 2.0 User Guide. Earth Hazards and Systems Programme Open Report OR/09/045, British Geological Survey, 16 pp

Richter CF (1958) Elementary seismology. W.H Freeman, San Francisco

Saunders I, Brandt M, Steyn J, Roblin D, Kijko A (2008) The South African National Seismograph Network. Seismol Res Lett 79(2):203–210

Strasser FO, Albini P, Flint NS, Beauval C (2013a) 20th century seismicity of the Koffiefontein region (Free State, South Africa): Consistent determination of earthquake catalogue parameters from mixed data types. Geophys J Int, submitted

Strasser FO, Beauval C, Albini P (2013b) Comparative study of third-generation macroseismic analysis techniques. Bull Seismol Soc Am, submitted

Switzer L, Switzer D (1979) The Black Press in South Africa and Lesotho. A descriptive bibliographic guide to African, Coloured and Indian newspapers, newsletters and magazines 1836–1976. G. K. Hall & Co., Boston

Theron JN (1974) The seismic history of the south-western Cape Province. In: The earthquake of 29 September 1969 in the south-western Cape Province, South Africa, Seism. Ser. Geol. Survey S. Africa, 14, 53 pp

Wilson M, Thompson L (1969) The Oxford History of South Africa: South Africa to 1870, vol I. Oxford, xxiii pp, Clarendon, 500 pp