New Zealand's National CORS Network

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SUMMARY

The PositioNZ CORS network was commissioned in 2002 to monitor the impact of tectonic plate deformation of New Zealand's Geodetic Datum. Over the last 12 years the network has developed to support more than just its original purpose. Land Information New Zealand (LINZ) makes the GNSS data freely available, including its real time streams. This approach supports research and aids the development of the CORS commercial sector.

This paper will discuss the PositioNZ network and its products and services, including the static data archive, the real time service. It also outlines the steps LINZ is taking towards becoming an analysis centre for national GNSS data and how PositioNZ contributes to the international GNSS and positioning communities.

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1. INTRODUCTION

Land Information New Zealand (LINZ) is the government agency responsible for the core land and sea datasets across New Zealand. A core infrastructure that enables LINZ to maintain the national geodetic datum, New Zealand Geodetic Datum 2000 (NZGD2000), is a network of continuously operating reference stations (CORS) that comprise the PositioNZ network.

PositioNZ has been developed over the last decade and contributes to more than just LINZ's own business requirements. Its data is freely available and additional products and services have been created to assist with the utilisation of the GNSS in New Zealand. The network also assists LINZ's contribution to a number of international initiatives to support the wider GNSS community.

2. NEW ZEALAND'S GEODETIC SYSTEM

2.1 New Zealand Geodetic Datum 2000

New Zealand's national datum, New Zealand Geodetic Datum 2000 (NZGD2000) is a semi-dynamic datum nominally referenced to epoch 2000. It is aligned to the International Terrestrial Reference Frame (ITRF1996) and incorporates a deformation model. The datum was defined by a network of 30 - 40 passive control marks and 3 CORS stations (AUCK, WGTN, CHAT). Only two of these sites were International GNSS Service (IGS) stations at the time (Pearse, 2000).

In 2013, the deformation model received its first update. The main driver for the update was the need to account for the post-seismic displacements caused by the Canterbury earthquakes since 2010. The update also included the effects of significant earthquakes prior to 2010 and updated the relationship between NZGD2000, the CORS network and subsequent ITRF realisations since the datum was established in 1998 (Crook and Donnelly, 2013).

2.2 History of the PositioNZ Network

2.2.1 Network Development

New Zealand's national CORS network, PositioNZ (http://www.linz.govt.nz/positionz), was commissioned in 2002 to monitor land deformation in relation to NZGD2000, and to maintain NZGD2000's relationship to the ITRF1996 over time. Over the past 12 years the PositioNZ network has grown from a network of 3 CORS stations to a network of 39 stations (35 on the mainland of New Zealand, 1 on the Chatham Islands and 3 in Antarctica). PositioNZ stations are nominally spaced 100 km apart across the mainland of New Zealand (Figure 1).

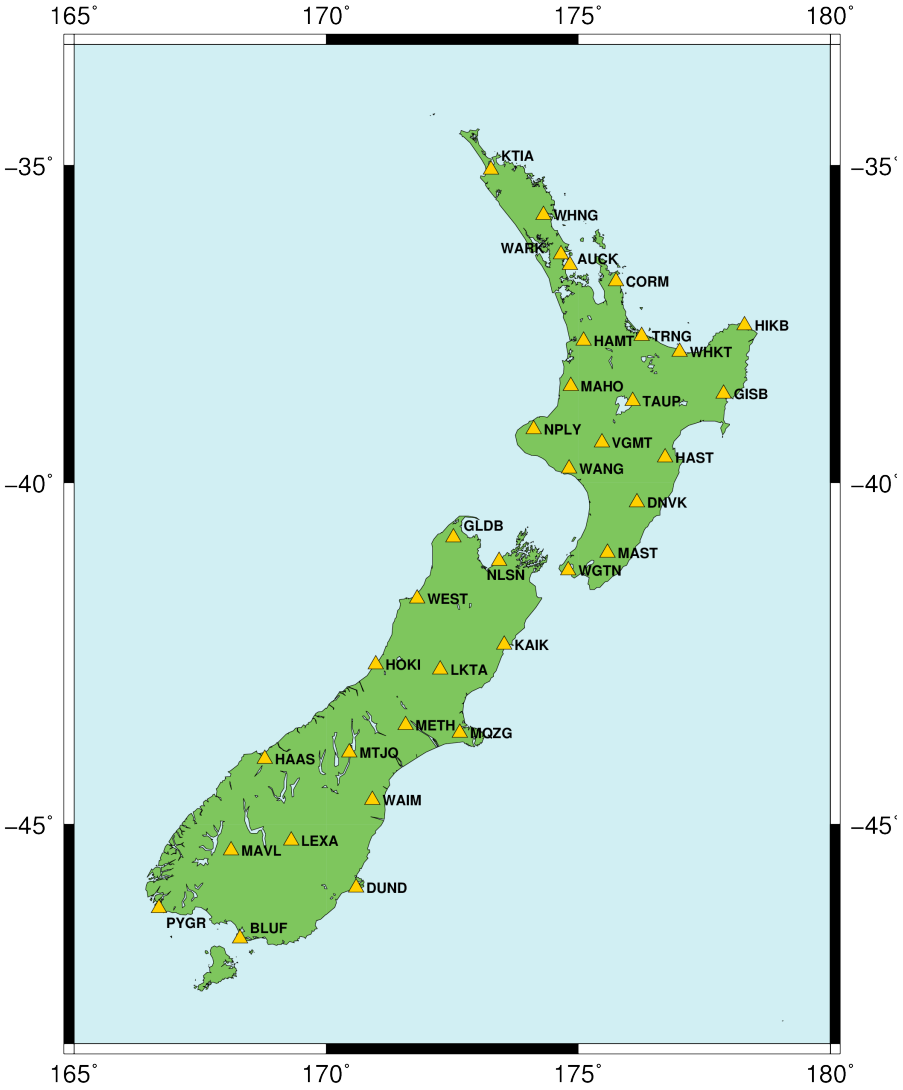

FIGURE 1: PositioNZ Network in 2014

Initially the network only supported GPS, but in 2009, the receivers were upgraded to Trimble NetR9 receivers and the network now supports GPS and GLONASS (Collett, 2010). In May 2013 two stations had their firmware upgraded to support multi-GNSS. Aligned with the

receiver upgrades, LINZ started streaming real time data from the PositioNZ network on the recommendation of a commissioned economic report (Mackenzie Podmore, 2009).

2.2.2 GeoNet Partnership

The GeoNet project (www.geonet.org.nz) operates a network of approximately 190 CORS stations, 30 - 40 seismographs and 17 tsunami monitoring tide gauges across New Zealand for the purpose of hazard monitoring. It is operated by GNS Science and principally funded by the Earthquake Commission (EQC). The PositioNZ network is a subset of the CORS stations operated by GeoNet through a long-standing partnership between LINZ and GNS Science.

FIGURE 2: GeoNet and PositioNZ Networks

2.3 Deformation Monitoring Networks

The PositioNZ network is the foundation of New Zealand's deformation monitoring network. The deformation monitoring network monitors movements at three different levels: tectonic plate movements at a national scale, effects caused by earthquakes at a regional level and

local areas also affected by earthquakes but which also have a high relevance on geodetic infrastructure - generally populated urban areas. The regional and local networks include additional GeoNet stations and a number of passive control marks. These build upon the national PositioNZ active control network to develop the national deformational model and improve its accuracy and resolution over time (Donnelly and Amos, 2010).

Conventionally, accessing the datum would be achieved by physically occupying a number of control marks in a small isolated area. Any deformation in the control marks would have the same relative movement over time so would not impact the network. However, GNSS has made it possible to connect to control marks kilometres to tens of kilometres apart and each control mark could be deforming at a different rate.

The benefit of the deformation model is realised when the density of conventional passive control networks can be reduced and surveyors are able to connect to active control, thus making it more economical for both the government and the survey industry.

3. PRODUCTS AND SERVICES

LINZ has a number of products and services that support and encourage the use of GNSS in New Zealand. This is recognised within the LINZ 2013-2016 Statement of Intent (LINZ, 2013) which supports:

- *"recommendations to improve the current delivery of geodetic services to customers who are increasingly using global systems such as Global Navigation Satellite Systems (GNSS) and datums"*
- *"enhancing the delivery of our GNSS services which enable data to be submitted, automatically processed, and position results returned"*

These products and services continue to be developed to support the industry as it moves away from conventional survey methods and technologies, and starts to develop business models around the use and re-use of LINZ's GNSS data.

3.1 New Zealand's Open Data Framework

In 2010 the New Zealand Government Open Access and Licensing (NZGOAL) framework was approved, which provides guidance on releasing copyright and non-copyright works for re-use by others. Data released under this framework is licensed under the creative commons. Open data is about providing data that complies with an open standard, that was developed through *"a transparent, collaborative process, fairly accessible for zero or low cost, mature and supported by the market"* (ICT, 2014). There are specific GNSS data formats that fall under this definition and LINZ has been working with GeoNet to make PositioNZ GNSS data available for re-use.

3.2 Static Data Archive

Over the past decade LINZ has collected an archive of static GNSS data for the purposes of time series analyses. Although at the time no official framework for open data was in place, LINZ made it publically available in the ASCII based RINEX format - a non-proprietary

format recognised by the GNSS community. LINZ has been releasing hourly and daily 30 second RINEX data since the PositioNZ network was commissioned.

Providing this data for free also gives surveyors a chance to add control to their GNSS surveys without physically occupying the mark. Figure 3 below shows the number of cadastral plans submitted to LINZ between 2002 and 2012 that have connected to at least one PositioNZ station. As the stations are nominally 100km apart, it is likely that surveyors chose to use primarily local control. Consequently the number of surveys connecting to the network is relatively small. However, it does show a significant increase in the use of active control over the last ten years.

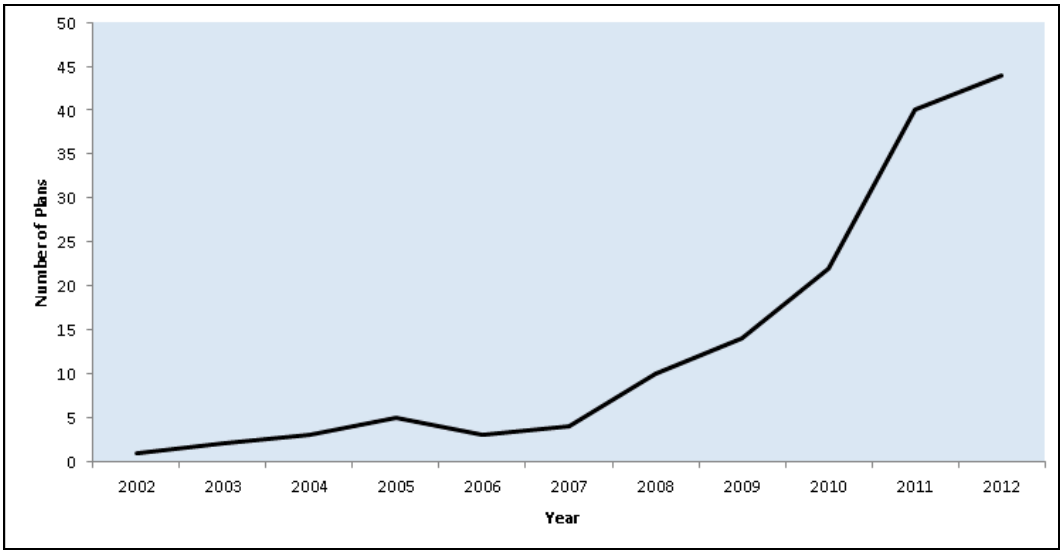

FIGURE 3: Cadastral Surveys using PositioNZ or GeoNet stations

3.3 Real Time Service

The LINZ real time GNSS service (PositioNZ-RT) has been available at no cost to users since 2009. One of the aims of providing this service is to encourage and support the utilisation of GNSS in the private, commercial and research sectors within New Zealand. The service streams real time GPS and GLONASS data through the RTCM (Radio Technical Commission for Maritime Services) format via the NTRIP (Networked Transport of RTCM via Internet Protocol). The data is licensed by Land Information New Zealand for re-use under the CC-By licence.

3.3.1 Commercial CORS Networks

New Zealand's sparse population does not lend itself to a commercial nationwide real time GNSS network and the private sector has chosen to focus its energy in smaller networks in highly populated areas. Over the last five years, the PositioNZ-RT service has made a significant contribution to the commercial networks, and in the beginning, provided the base for which most of these networks have grown. It is reported in the LINZ Statement of Intent that there are over 400 users of these commercial networks in the country (LINZ, 2013).

A limitation of the PositioNZ network is that the stations locations were selected for their geophysical qualities. As a result, many stations are in remote locations not readily accessible for urgent repairs, or in areas where there is no reliable communications network. Consequently, it has been difficult to set reliable service levels. This year LINZ, in consultation with GeoNet, is aiming to publish service levels so users have a better idea of the expected data latency at each station.

3.3.2 Other users of the real time service

The real time service was originally open to anonymous access. Since October 2013 users have needed to register with the network in order to access the data. Registration may be perceived as a barrier to access but it will result in a better overall service. Previously, anonymous users could not be notified of scheduled maintenance or general outages of the network. It is important that GNSS usage is correctly reported against the LINZ Statement of Intent, and having accurate usage statistics aids in appropriate decision making in regards to station support, service levels and maintenance requirements.

After brief analysis of the access logs since mandatory registration was implemented, some interesting results have been discovered (Table 1). AUCK is the closest station to New Zealand's largest city, Auckland, and due to its proximity to a large population was expected to be one of the most used stations. However, it has only ranked fifth and was significantly behind MQZG (near Christchurch) in terms of number of connections made and total connection time (4600 hours total connection time at MQZG compared to 840 hours at AUCK in February 2014). The Auckland region is also supported by commercial GNSS networks so users may be opting to subscribe to a network solution instead of the single base RTCM stream PositioNZ-RT provides. It is assumed that MQZG is being used by surveyors to support the rebuild after the Canterbury earthquakes.

	Nov-13		Dec-13		Jan-14		Feb-14	
	Connections	Users	Connections	Users	Connections	Users	Connections	Users
MQZG	91	7	121	9	105	7	85	8
HOKI	40	3	50	4	70	4	59	4
HAMT	44	7	48	7	40	8	46	3
NPLY	43	3	42	4	45	4	45	3
AUCK	19	8	41	7	56	8	44	7
WHNG	42	3	46	4	28	3	31	4
WGTN	20	5	30	6	36	5	48	3
MAVL	12	1	21	2	35	2	50	3
KTIA	12	1	20	4	36	3	25	2
BLUF	17	4	19	5	0	0	38	4

TABLE 1: Top ten most used PositioNZ streams and number of users (excluding private network operator connections)

Also, a station in a relatively remote part of New Zealand (HOKI - Hokitika), has been found to be one of the most popular. HOKI currently has four active users and has had the second most connections within the last four months. Further investigation is required to understand how this station is being used and whether better service levels can be given to the station. For example, if the communications went down, how urgently would they need to be restored before these companies were severely affected? Prior to this analysis the station would have been given a low priority due to its remote location.

4. DEVELOPMENTS

4.1 Post Processing Service

New Zealand's post processing service (PositioNZ-PP) has been in development for a number of years. The service will allow static GNSS data to be submitted via the internet and NZGD2000 and ITRF2008/IGB08 coordinates will be received by the submitter. PositioNZ-PP will include the updated deformation model that was incorporated into NZGD2000 after the Canterbury (2010/2011) earthquakes. A pilot version of this service is due for release in the latter half of 2014.

4.2 Daily Network Processing

In May 2012 GNS Science started processing daily solutions for all PositioNZ stations as well as a selection of private CORS stations on behalf of LINZ. In mid-2014 this service will cease and LINZ will take over this routine processing. Previously the network was processed as part of the GeoNet project but this did not fully meet LINZ's business requirements due to their research focus and not being able to use their resources to directly support the commercial sector. LINZ will be using Bernese v5.2 to produce its station coordinate solutions.

4.3 Supporting the New Zealand CORS Community

Once routine processing is operational, CORS operators will have the opportunity to submit continuous GNSS data to LINZ to obtain official NZGD2000 and ITRF2008 coordinates for their stations. This service will also monitor the stations for site stability through analysis of their time series. Many commercial companies have stations mounted onto rooftops and on the sides of buildings so this processing service will provide another level of confidence for users on the stability of these stations. The time series, under agreement with these companies, will be beneficial in the event of another earthquake as shown in the Canterbury earthquakes where a number of companies donated their data to LINZ and GNS Science to aid in the earthquake recovery (Donnelly et al, 2011).

This service will have added benefits to the CORS and survey industries, by providing official NZGD2000 coordinates, surveyors who have subscribed to these commercial networks will be able to utilised these stations more effectively in their cadastral and geodetic surveys.

4.4 Multi-GNSS Updates

LINZ is investigating the possibility of upgrading the firmware of all of its stations to collect and archive multi-GNSS observations from the new GNSS constellations, especially Galileo, QZSS and Beidou.

The firmware of stations WARK and LEXA has already been upgraded to support the multi-GNSS experiment (MGEX, www.igs.org/mgex), which is a project set up by IGS to track and analyse all GNSS signals. The data from those stations are actively contributing to better orbit determinations over New Zealand.

5. INTERNATIONAL CONTRIBUTIONS

5.1 Asia Pacific Reference Frame

The Asia Pacific Reference Frame (APREF) project will provide a regional reference frame in the Asia-Pacific area. In 2010 LINZ responded to a call for participation indicating that it is intending to contribute its CORS data and network solutions to the project, thus becoming an APREF data and analysis centre. LINZ has been contributing data for the last 4 years and is planning to become an operational analysis centre by the end of 2014 after its daily routine processes are established. Currently the New Zealand CORS data is being processed for the APREF project by the Central Bureau housed within Geoscience Australia.

5.2 International GNSS Service

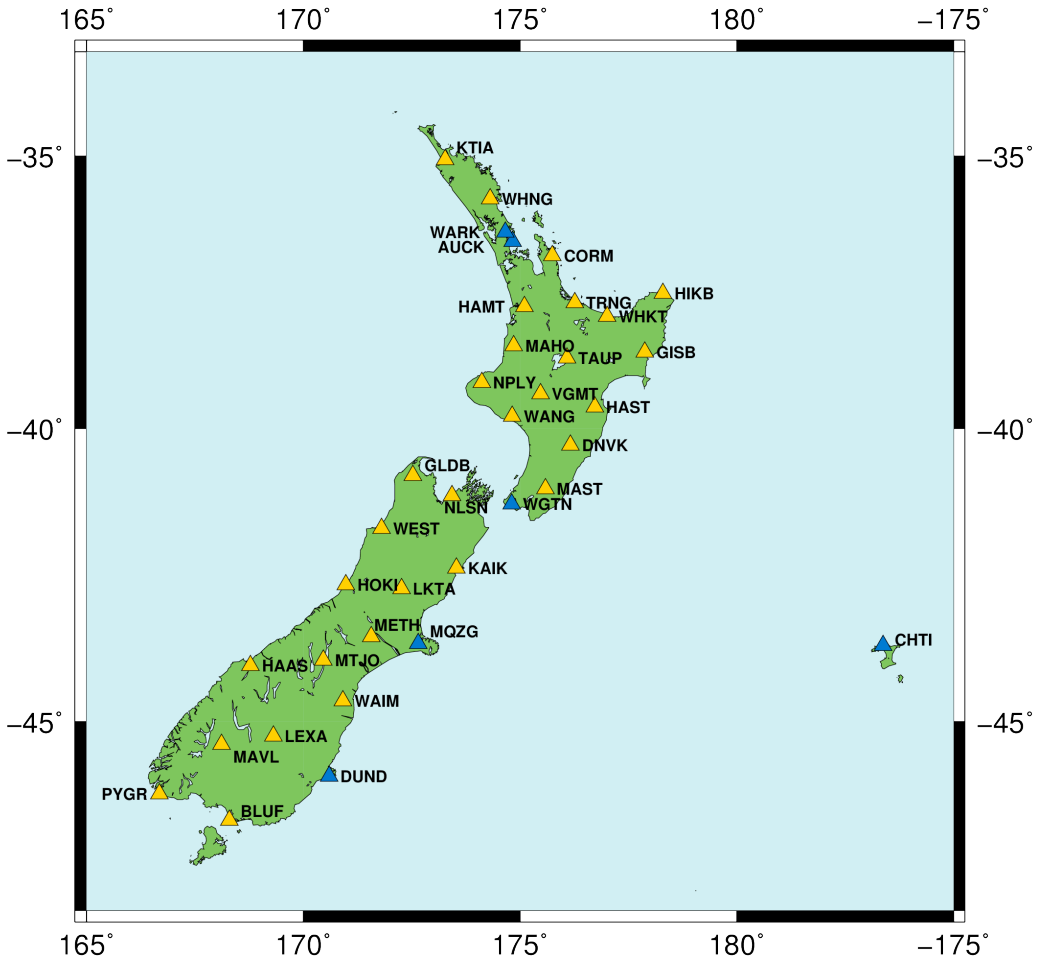

FIGURE 4: Current PositioNZ stations (yellow) and IGS stations (blue)

There are 6 official IGS stations in New Zealand: AUCK, WGTN, MQZG, CHTI, DUND and WARK. CHTI was run alongside CHAT, a historical IGS station on Chatham Island, for approximately three years before CHAT was decommissioned in 2012. The IGS also receives real time information for IGS stations on New Zealand's mainland.

WARK was installed to support geodetic infrastructure in New Zealand. It is now co-located with the only Very Long Baseline Interferometry (VLBI) radio telescope in the country. The local tie between these two stations was completed by LINZ with the support from Geoscience Australia in 2012. It is the hope that GNSS data and the VLBI observations from the Warkworth Observatory will be included in the next realisation of the International Terrestrial Reference Frame (ITRF2013).

5.3 POLNET Project

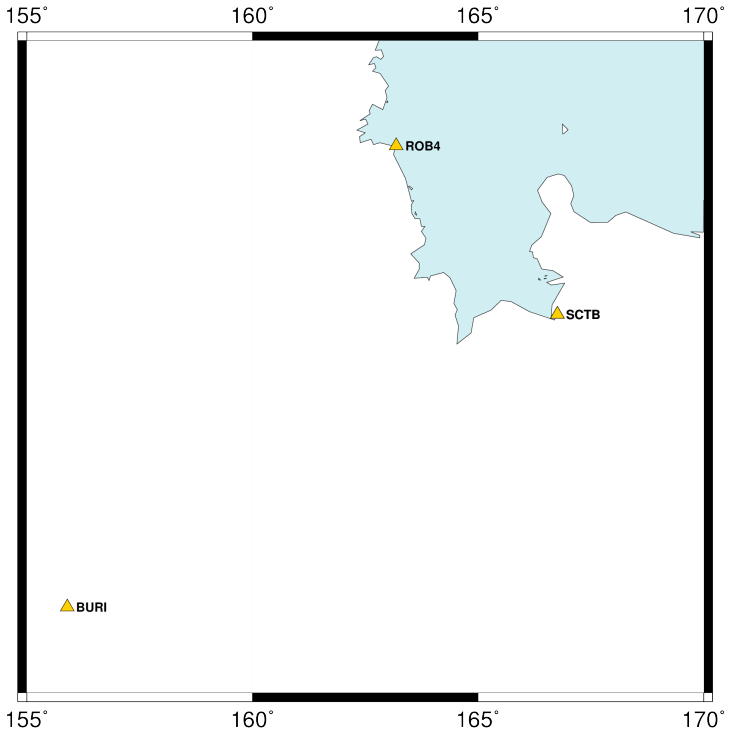

FIGURE 5: The CORS stations supported by LINZ in the Ross Sea Region (Antarctica)

LINZ supports 3 CORS stations in Antarctica with the data contributing to the POLNET project (Polar Earth Observing Network, http://polenet.org/). Its purpose is to study the effects of ice mass changes on crustal deformation, changes in sea level and other geophysical activity in Antarctica.

The station located at Scott Base (SCTB), New Zealand's Antarctic Base, is operated by GeoNet on behalf of LINZ. LINZ contributed to the hardware for ROB4 and BURI but unlike SCTB these stations are managed and operated by UNAVCO.

These stations also support the Ross Sea Region Geodetic Datum 2000 (RSRGD2000) that LINZ maintains as part of their mandate to support land and seabed information in Ross Sea Region.

6. CONCLUDING REMARKS

This multipurpose PositioNZ network has a vital role to play in maintaining and utilising New Zealand's geodetic system. LINZ has, and continues to develop, a range of CORS related products and services that support the spatial industry. The network has progressed a long way from its inception a decade ago and continues to be utilised as the industry adapts to the new and innovative ways of working.

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BIOGRAPHICAL NOTES

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