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Refining the astronomical unit: Queenstown and the 1874 transit of Venus

Wayne Orchiston
Anglo-Australian Observatory, PO Box 296, Epping, NSW 2121, Australia

Tom Love
Carter Observatory (The National Observatory of New Zealand), PO Box 2909, Wellington, New Zealand

and

Steven J Dick
U.S. Naval Observatory, 3450 Massachusetts Ave, NW, Washington, DC 20392-5420, USA.
E-mail: dick.steve@usno.navy.mil

Abstract
The 1874 transit of Venus was regarded as a major event which promised to produce an improved value for the solar parallax and hence the astronomical unit. As a result, the United States dispatched eight different observing parties to far northern and southern hemisphere locations. This paper documents the activities at the Queenstown transit station in the South Island of New Zealand and examines the scientific outcome of the overall American 1874 and 1882 transit programmes. It also mentions other New Zealand-based observations of the 1874 transit, and traces the early development of astronomical photography in New Zealand at a time when this innovative methodology was emerging internationally as a valid tool of the 'new astronomy', astrophysics.

Keywords: *1874 transit of Venus; solar parallax; astronomical unit; Queenstown; S Newcomb; W Harkness; C H F Peters*

1 INTRODUCTION

One of the fundamental yardsticks in astronomy is the astronomical unit (AU). During the eighteenth century, the opportunity to use transits of Venus to determine the AU prompted a number of nations to dispatch expeditions to the far corners of the globe (see Orchiston, 1998; van Helden, 1995; Woolf, 1959). The 1761 and 1769 transits produced conflicting results, with solar parallax values ranging from 8″. 28 to 10″. 60, and although a smaller spread characterized the latter transit (see Table 1), greater precision was desired. This led to a focus on the next pair of transits, in 1874 and 1882 (e.g. see Dick, Orchiston and Love, 1998; Forbes,1874; Grant, 1874; Janiczek and Houchins, 1974; Meadows, 1974; Proctor, 1874), and "Every country which had a reputation to keep or to gain for scientific zeal was forward to co-operate in the great cosmopolitan enterprise ... " (Clerke, 1893:289).

As a consequence, in 1874 the United States, England, France, Germany, and Russia dispatched observing parties to selected sites widely separated in latitude and longitude. In addition, Italy also funded three observing parties, and Holland one. These expeditions represented one of the first major international scientific collaborations, and occurred at a time when photography was beginning to impact on astronomy (Lankford, 1984, 1987; Norman, 1938), but they were plagued by controversy over instrumentation and methodology.

Table 1: Solar parallax values

Source	Date	Method	Parallax (")
Pingré	1770	1769 transit of Venus	8.88 ± 0.05
Lalande	1771	1769 transit of Venus	8.55 – 8.63
Encke	1835	1761 & 1769 transits of Venus	8.57116 ± 0.0371
Gillis & Gould	1856	Meridian parallax of Mars	8.495
Powalky	1864	1761 & 1769 transits of Venus	8.83
Hall	1865	Meridian parallax of Mars	8.842
Newcomb	1867	Meridian parallax of Mars	8.855
Stone	1868	1761 & 1769 transits of Venus	8.91
Todd	1881	U.S. 1874 transit of Venus	8.883 ± 0.034
Obrecht	1885	French 1874 transit of Venus	8.81 ± 0.06
Harkness	1889	U.S. 1882 transit of Venus	8.842 ± 0.0118
Newcomb	1891	1761 & 1769 transits of Venus	8.79 ± 0.051
Harkness	1894	ystem of constants	8.809 ± 0.0059
Newcomb	1895	System of constants	8.800 ± 0.0038
Spencer Jones	1941	Eros campaign	8.790 ± 0.001
IAU	1976	Radar	8.794148 ± 0.000007

Positional astronomy had long been the research focus of the U.S. Naval Observatory, and it is only natural that it was charged with overseeing the two nineteenth century American transit programmes. The 1874 programme involved eight different stations (Figure 1): Vladivostok in far eastern Russia; Nagasaki in Japan; Peking in China; the Chatham Islands (New Zealand territory to the east of the mainland); Queenstown in the South Island of New Zealand; Hobart and Campbell Town in Tasmania; and Kerguelen Island in the southern Indian Ocean. This paper is about the Queenstown station, its contribution to the overall American programme, and the place of the 1874 transit in the evolution of astronomy in New Zealand.

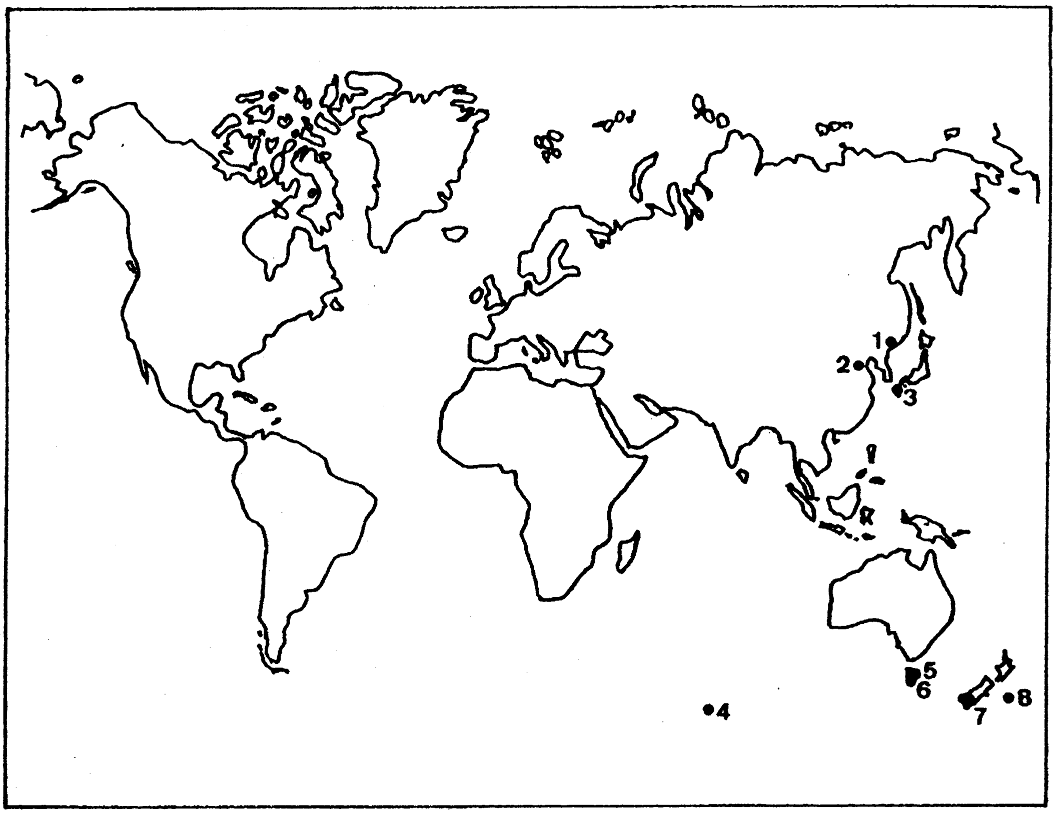

Figure 1. Locations of U.S. 1874 transit of Venus observing stations: 1 Vladivostok; 2 Peking; 3 Nagaski; 4 Kerguelen Island; 5 Campbell Town; 6; Hobart; 7 Queenstown; 8 Chatham Islands.

2 INSTRUMENTATION

The American transit of Venus programme was planned, initiated, and implemented by a special Commission which was created by Congress in 1871. Dominating the Commission were U.S. Naval Observatory personnel, one of the most influential of whom was Simon Newcomb, Professor of Mathematics at the Observatory. Newcomb was destined to become a leading figure in American astronomy (see Archibald, 1924; Newcomb,1903).

The first challenge of the Commission was to decide on the instrumentation, and for this they had to choose between visual and photographic observations. Although they decided to adopt both, photography was to play the leading role. It was then a matter of selecting the type of photographic telescope, and two basic designs were considered: the equatorially-mounted heliograph developed by de la Rue and used by the British transit parties, and the fixed horizontal solar telescope first conceived by Winlock and successfully used at the Harvard College Observatory. The Commission chose the latter, and Newcomb decided that two discrete series of photographs would be taken: of the ingress and egress contacts, and of Venus superimposed on the disk of the Sun during the transit.

The Commission then finalized the instrumentation to be issued to each observing party. It comprised: the photographic telescope, a standard refracting telescope, a transit telescope, a sidereal clock, three box chronometers, a chronograph, five thermometers, a barometer, and equipment for measuring terrestrial magnetism.

The principal research instrument was the photographic telescope, or photoheliograph (see Newcomb, 1880 for details). Vital was the 203-mm square brass photographic plate holder (Figure 2a), which was mounted on a solid metal pier. Permanently cemented into the plate holder was a transparent sheet of plate glass about 7.6 mm thick,

> ... divided into small squares by very fine [etched] lines about one-five-hundredth of an inch thick ... the sensitive plate goes into the other side of the frame, and when in position for taking the photograph, there is a space of about one-eighth of an inch between the ruled lines and the plate. The former are, therefore, photographed on every picture of the sun which is taken, and serve to detect any contraction of the collodion film on the glass plate. (Newcomb, 1887:189).

Also attached to the plate holder was a plumb line, which was used to indicate vertical on each of the photographs. A simple, prefabricated flat-roofed, wooden 'Photographic House' housed the plate-holder, and contained facilities for preparing and developing the photographic plates.

Twelve metres away from the Photographic House, in the open air, was a second metal pier supporting a 178-mm unsilvered glass heliostat mirror (which captured the rays of the Sun) and a 127-mm objective (which focussed the light on the photographic plate). The heliostat tracked the Sun with the aid of a weight drive (see Figure 2b). If it was deemed necessary, a temporary cover could be erected to shelter the heliostat and drive. Between the heliostat and the plate-holder was a measuring rod which was used to accurately determine the focal length of the telescope, a key element in establishing the plate scale. The measuring rod was supported by a wooden framework, and was protected by a narrow 'roof'. This roof also covered a tube which extended about 4 m from the Photographic House and through which the light from the heliostat passed. An image of the Sun about 108 mm in diameter was formed. Four thermometers and a barometer were generally housed in the Photographic House to monitor variations in environmental conditions. The overall arrangement of the photographic telescope is shown in Figure 3.

In order to visually monitor the transit and obtain precise micrometric measures of Venus on the Sun's disk, each transit party was supplied with a 127-mm (5-inch) *f*/14 refracting telescope manufactured by Alvan Clark, America's leading nineteenth

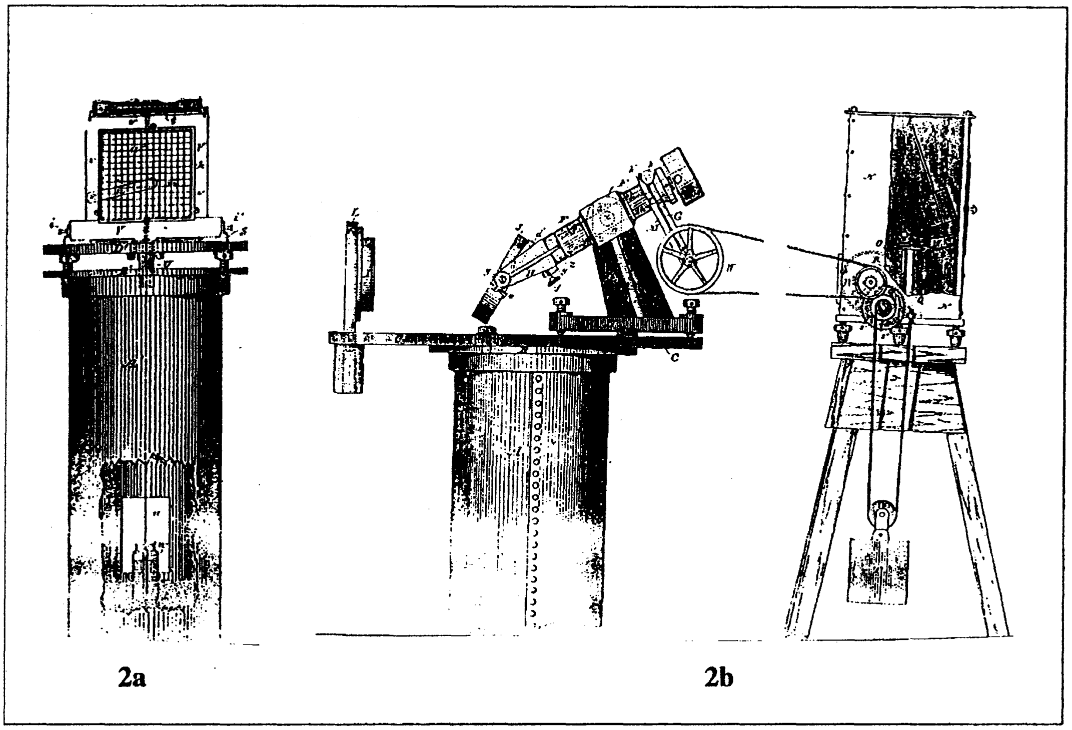

Figure 2. Photographic telescope design (2a: plate-holder; 2b: heliostat and drive)

century telescope-maker (see Warner and Arial, 1996). This instrument (Figure 4) was supported by a solid metal pier rather than a tripod, and was supplied with a German equatorial mounting, circles, a weight drive, slow-motion controls, and the all-important double-image micrometer. Protecting the refractor from wind and inclement weather was a prefabricated, wooden, octagonal observatory of 3 m diameter, with a rotating conical roof containing a single hinged shutter. Those involved in the transit expeditions generally referred to this observatory as the 'Equatorial House'.

Accurate time-keeping was paramount for the success of the venture, and so each transit station was supplied with an astronomical clock. All of the clocks were built by the Howard Clock Company of Boston, and because they were designed for long and difficult journeys to the observing stations they were not particularly elegant (Newcomb, 1880:14-15).

Each station also was provided with a transit instrument, which was used to regulate the clock. These transit telescopes had an aperture of 63.5 mm and were manufactured by Stackpole Brothers. They were of the 'broken tube' construction,

> ... a prism being placed in the center of the tube, by interior reflection from which the pencil rays is [*sic*] thrown along the axis; and the image is thus formed at the end of the latter... This form of instrument has the great advantages of convenience in observing and rapid and easy manipulation, but is still subject to the disadvantages of collimation varying with zenith-distance of the object observed. (Newcomb, 1880:14).

This unusual type of transit telescope is shown in Figure 5, and was mounted on a solid brick foundation capped by a stone slab. Protecting it from the elements was a simple, prefabricated, wooden 'Transit House', with a sloping roof and an observing shutter aligned north-south which could be readily removed to reveal a strip of sky. This building was located near the heliostat so that it could also be used to accurately

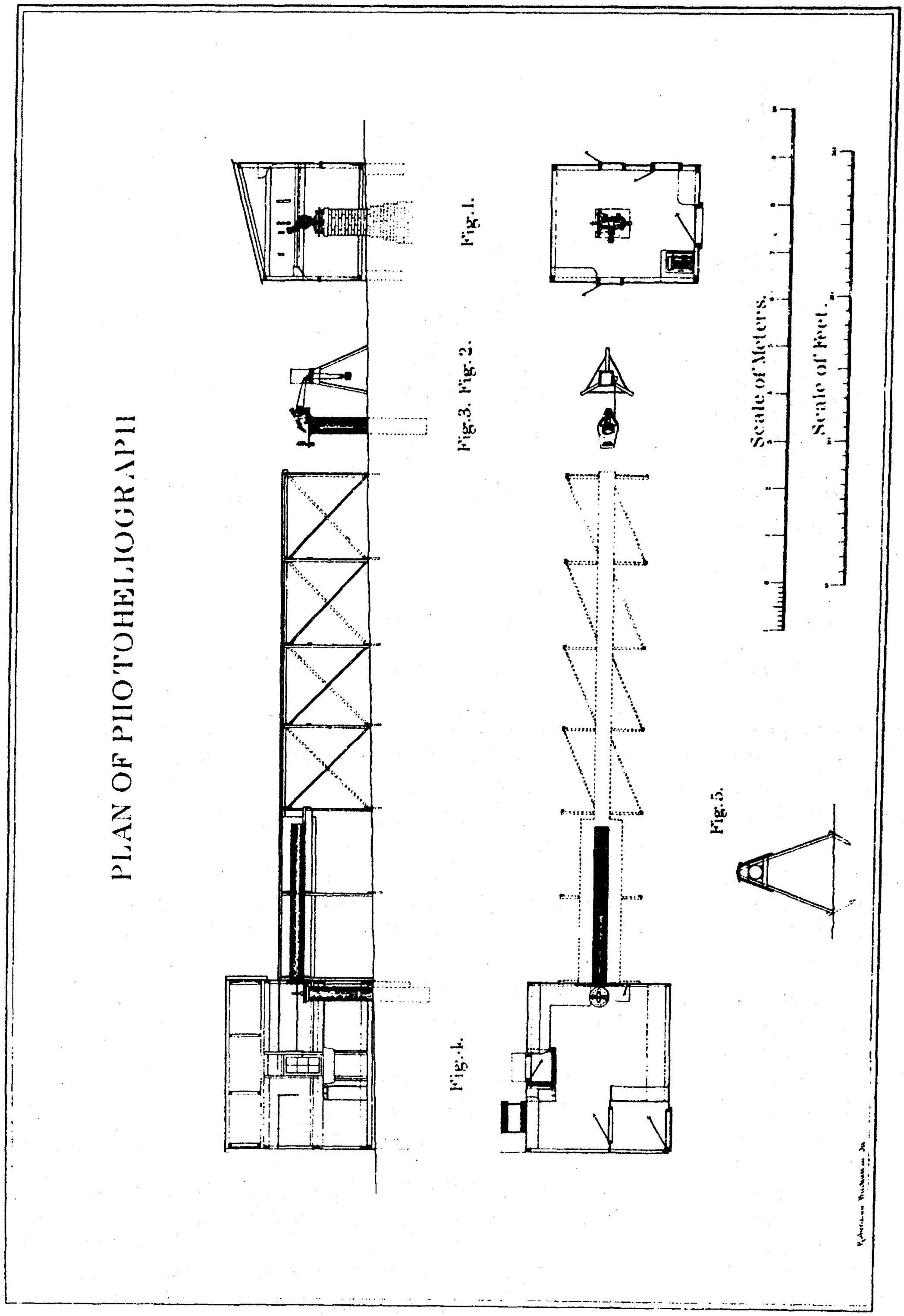

Figure 3. Overall arrangement of the photographic telescope (top: side elevation; bottom: plan)

align the photographic telescope north-south (see Figure 3). One thermometer was normally kept in the Transit House. In addition to its time-keeping role, the transit telescope was used for latitude and longitude determinations.

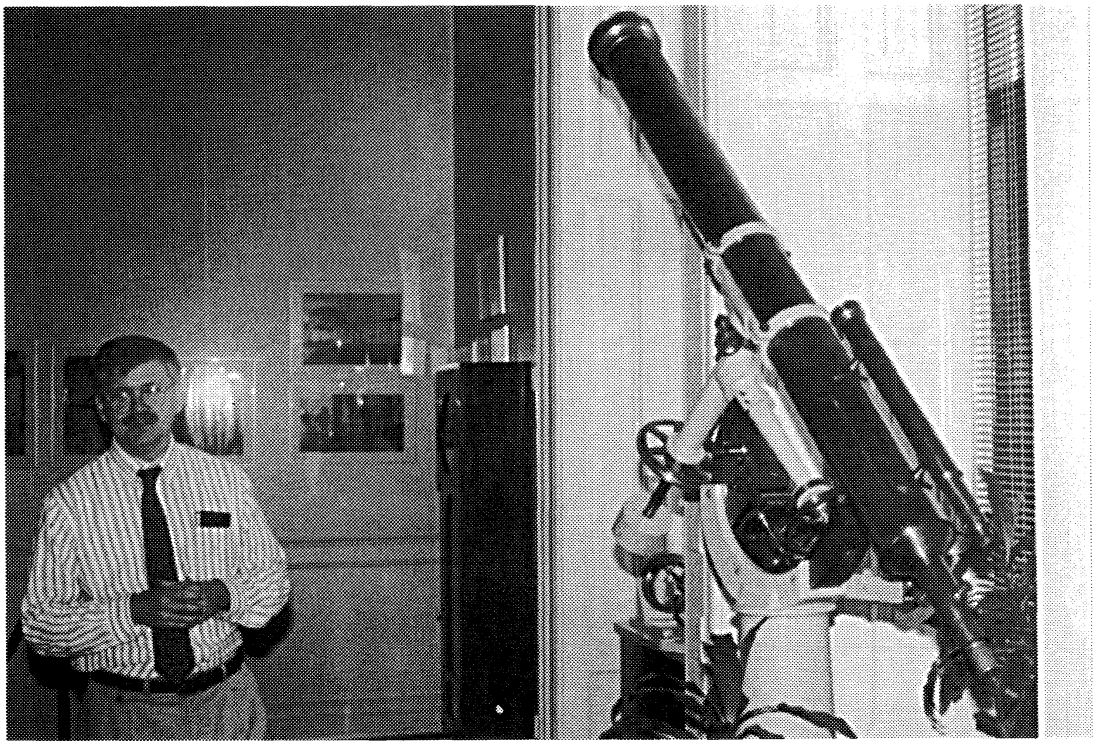

Figure 4. Steven J Dick with one of the 127-mm Alvan Clark refractors.

In order to accommodate these assembled instruments, a transit station required a nearly level north-south site about 25 m in length offering a firm foundation, protection from the winds, and a clear view of the Sun for the entire duration of the transit (Commission ..., 1874).

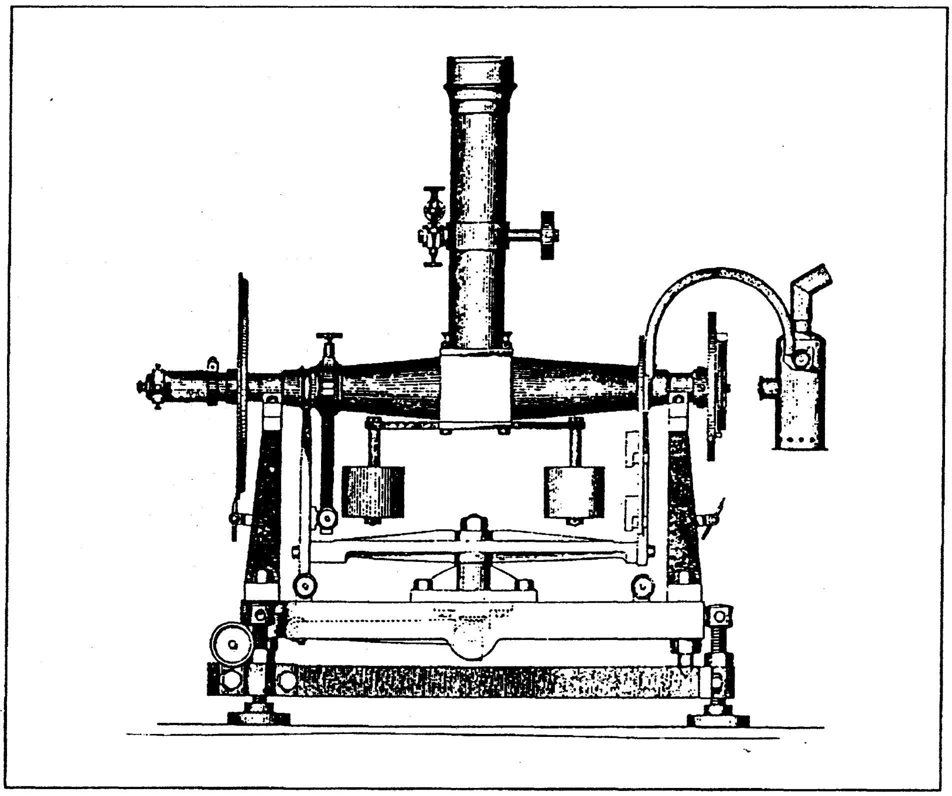

Figure 5. The 'broken tube' transit telescope

3 QUEENSTOWN, AND THE NEW ZEALAND OBSERVING PARTY

Each American transit party normally consisted of a Chief Astronomer and Assistant Astronomer, who were responsible for visual observations and the time-service, respectively, and three or four photographers (Herman, 1984:38). The Chief Photographer was always a professional photographer, while the Assistant Photographers were typically "... young gentlemen of education, recent graduates of different colleages, who had been practised in chemical and photographic manipulation." (Newcomb, 1880:16).

Leading the New Zealand party was C H F Peters (Figure 6), Professor of Astronomy at Hamilton College, New York, and Director of the College's Litchfield Observatory (Sheehan, 1998). Christian Heinrich Friedrich Peters was born at Coldenbüttel, Schleswig, in Denmark (now Germany) on 1813 September 19. He studied mathematics and astronomy at the University of Berlin, completing his Ph.D. in 1836. In 1854 he emigrated to the United States, and after working with the U.S. Coast Survey and at the Dudley Observatory he was appointed to the Hamilton College post in 1858. One of Peters' interests was solar astronomy, and he also searched – with considerable success – for new minor planets (see Ashbrook, 1984; Baum and Sheehan, 1997).

Figure 6. Christian Heinrich Friedrich Peters, 1813-1890
(Photograph courtesy Hamilton College)

The Assistant Astronomer was Lieutenant E W Bass from the U.S Corps of Engineers. After the voyage he was promoted to Lieutenant-Colonel, and became Professor of Mathematics at West Point. Peters was extremely happy with Bass' performance, as the following concluding remarks in his report indicate:

> ... it is my pleasant duty to mention still another circumstance that contributed not a little to the good work that the New Zealand party can show. The companionship of Lieutenant E.W. Bass (now lieutenant-colonel and professor of higher mathematics at West Point) was a most happy one. It is impossible to separate what in the work belonged to each of us, and when in the foregoing pages I have spoken in the plural I include the assistant astronomer. Our judgement agreed almost even in the minute particulars, so that we formed one head with four hands, and, if I may say so, a double brain. (Peters, 1881:548).

Completing the Queenstown party were four photographers: C L Phillippi (Chief Photographer), I Russell (First Assistant Photographer), E B Pierson (Second Assistant Photographer) and L H Aymé (Third Assistant Photographer). Phillippi was a professional photographer (from Philadelphia); Russell and Aymé were college students. Assisting the photographers was a local volunteer named Beckett, who just happened to be from the USA (Peters, 1881). Figure 7 shows members of the Queenstown party (minus Mr Beckett) assembled at the U.S. Naval Observatory prior to their departure for New Zealand.

On 1874 June 8 the U.S. man-of-war *Swatara* sailed from New York with the five southern hemisphere transit parties, and proceeded to the Indian Ocean, via Bahia in Brazil and Cape Town. On September 7 Kerguelen Island was reached, and the first of the observing parties was dropped off. Subsequently, two parties disembarked at Hobart (see Orchiston and Buchanan, 1991 for an account of one of these), and the *Swatara* then headed for New Zealand, anchoring at Bluff Harbour on October 16 (see Figure 8).

There Peters was met by Bass, who had arrived in New Zealand several weeks earlier in order to finalize a suitable site for the transit station. Initially, the Americans had planned to install their South Island transit station at Bluff, a convenient coastal location, but the Hon. J T Thompson (President of the Otago Academy) and James McKerrow (Chief Surveyor of the Province of Otago) counselled Bass against this. Instead, they suggested a site in central Otago, an elevated inland area known in summer for its warm temperatures and clear sunny skies (Peters, 1881:439). After considering various options, Bass selected Queenstown on the shores of Lake Wakatipu, 320 m above sea level (see Figure 9 for New Zealand localities mentioned in the text). In hindsight, this was to prove a particularly astute decision.

The New Zealand Government supported the US transit project by freighting the boxes of equipment free of charge to Winton. After being off-loaded from the train, they were taken to Kingston by wagon while the transit party travelled by stage coach. The last short leg of the journey from the southern tip of Lake Wakatipu to Queenstown was by steamer, and Peters' party reached its final destination on October 23 (Peters, 1874a), six and a half weeks before the transit. This may appear to be an unreasonably long lead-in period, but a great deal of preparation was necessary before the 'grand event' (see Bass, 1874; Newcomb, 1880; Peters, 1874a, 1881).

On October 24 the astronomers pinpointed a suitable observing site on an old terrace surface 408 m above the lake and about 0.8 km east of the centre of town (Figure 10). There were already a few houses scattered about in the general vicinity, and Peters (1881:516) noted that streets and sections had been laid out, anticipating the future growth of Queenstown. The transit party proceeded to mark out a 24.4 m by 12.2 m enclosure on Melbourne Street, and erect a perimeter fence.

Then began the busy schedule of setting up a functioning transit station. This involved assembling the prefabricated buildings they had brought; installing and adjusting the various scientific instruments; conducting observations for latitude, longitude and time; and practising the photographic procedures to be followed on the day of the transit. Fortunately Newcomb had provided the necessary detailed instructions for all of the observing parties (see Commission ..., 1874). On October

26, the *Otago Daily Times* (1874) reported that the station had been connected to the local telegraph. The first observations with the transit telescope were obtained on October 30, the Alvan Clark telescope came into operation on November 5, and the first experimental plates were exposed with the all-important photographic telescope on November 14. By November 24 the photographers were ready to commence their 'practice drill', in preparation for the December 9 transit. Peters (1881:472) noted that in the course of these preparations daytime temperatures were rather pleasant, but at night "... during observing hours, the air was sometimes very chilly."

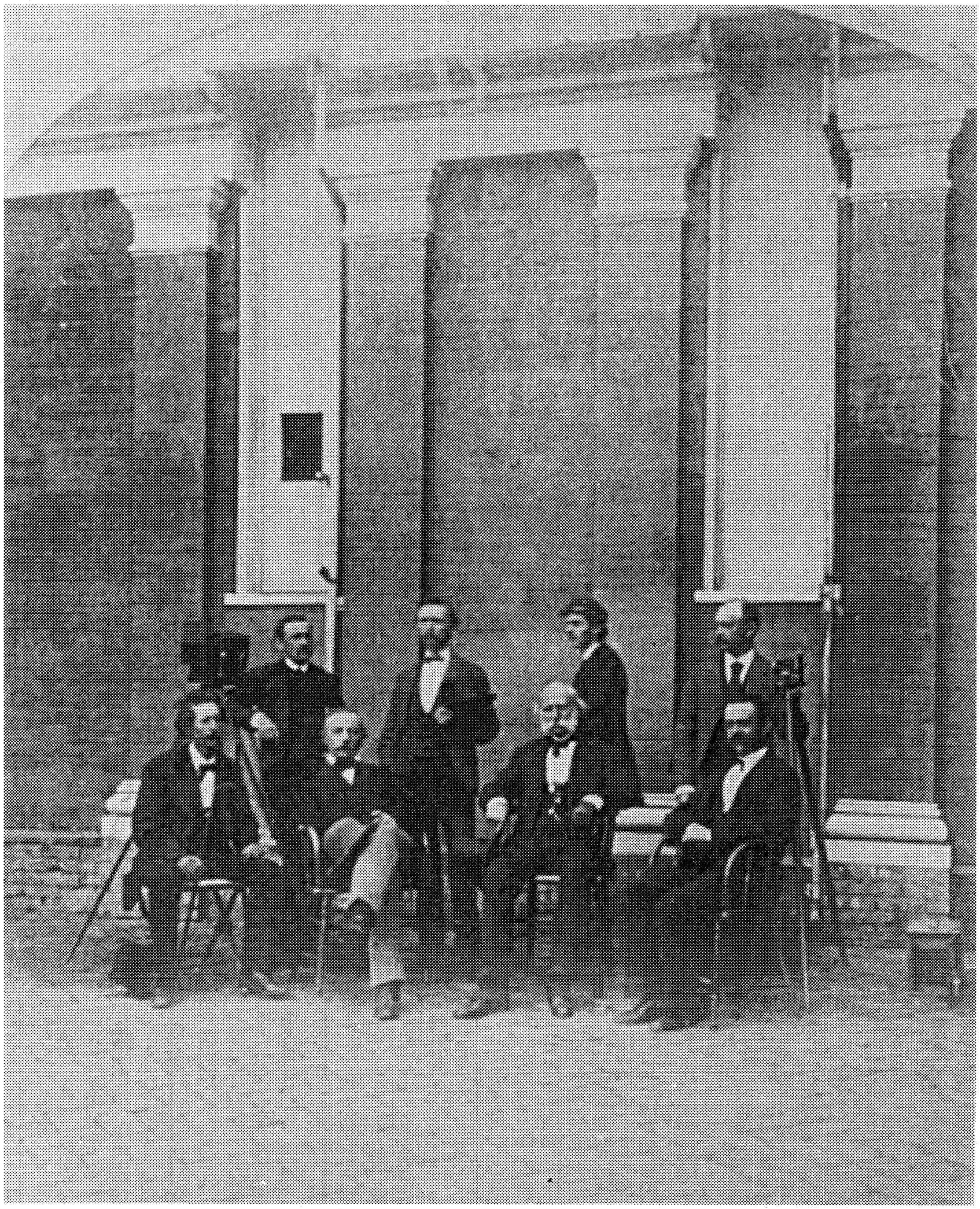

Figure 7. New Zealand transit of Venus observing party and *ex officio* members. Seated (left to right): C.L. Phillippi (Chief Photographer), Professor C.H.F. Peters (Chief Astronomer), Admiral C.H. Davis (President, U.S. Tranit of Venus Commission), Professor H. Draper. Standing (left to right): I. Russell (First Assistant Photographer), E.B. Pierson (Second Assistant Photographer), L.M. Aymé (Third Assistant Photographer), and Lieutenant E.W. Bass (Assistant Astronomer) (Photograph courtesy U.S. Naval Observatory)

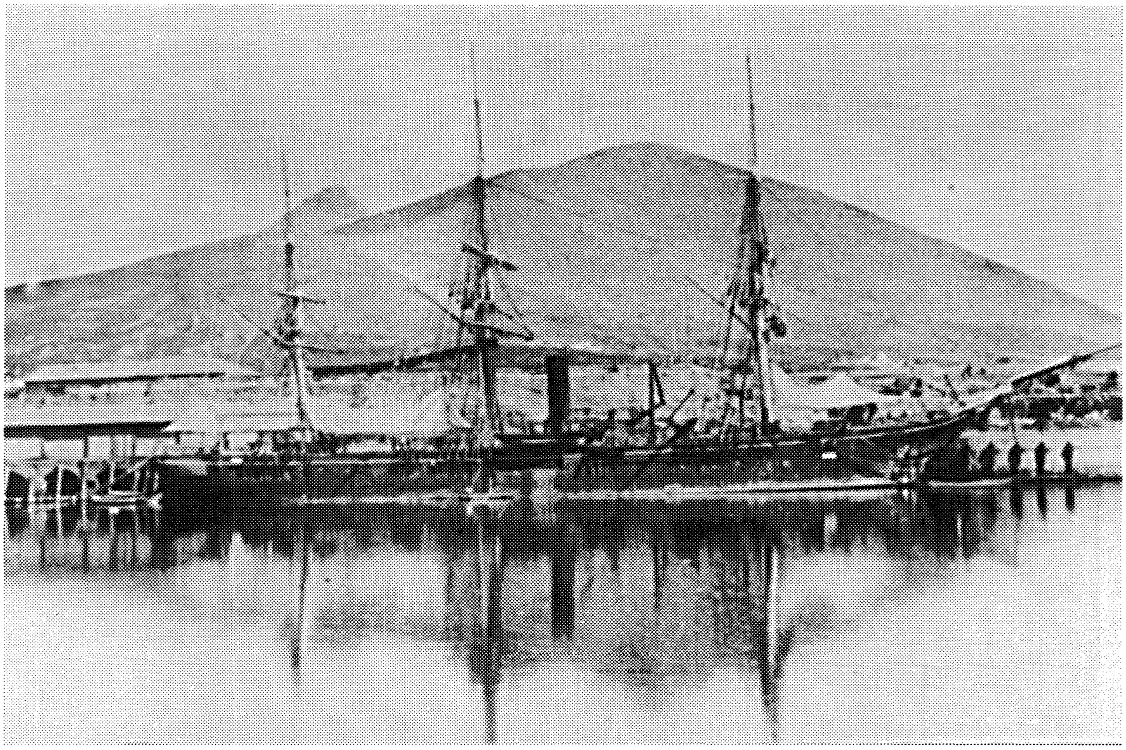

Figure 8. The *Swatara* anchored in Bluff Harbour (Photograph courtesy Hocken Library)

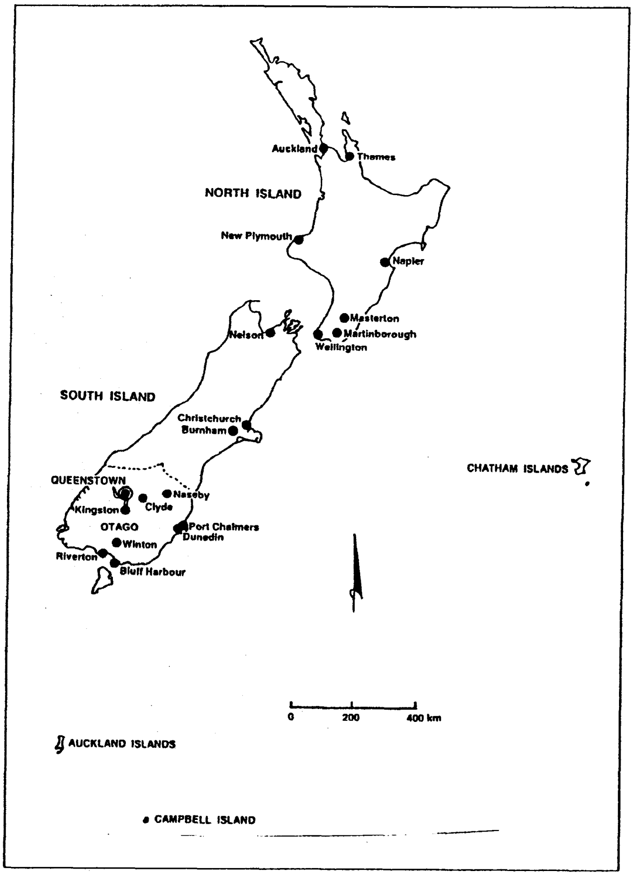

Figure 9. New Zealand localities mentioned in the text

Figure 11 shows part of the completed transit compound, and a plan of the total transit station is reproduced in Figure 12. The specific instruments assigned to the Queenstown transit party are listed in Table 2 (after Newcomb, 1880; Peters, 1881).

Knowledge of the precise location of the transit station was critical, and twenty pairs of stars almost equal distances from the zenith were used to determine the latitude. The first observations were made on November 12, and further observations followed on November 13, 14, 20, 21, 28, 29, and 30 (Peters, 1881:500-509). Meanwhile, the clock had been set up on November 18, and on the 25th time signals were exchanged with the British transit party at Burnham, near Christchurch, in order to establish the longitude of the Queenstown site. Further exchanges with Burnham took place on November 27 and 30, and on December 2. In addition, on December 5, 8 and 28 signals were exchanged with the Rockyside Observatory near Dunedin where McKerrow and Thompson were based; with the *Swatara* on November 2 and December 27, while it was temporarily anchored at Port Chalmers; and with the *Alexandrine* (the German Auckland Islands transit party's vessel) on December 17 and

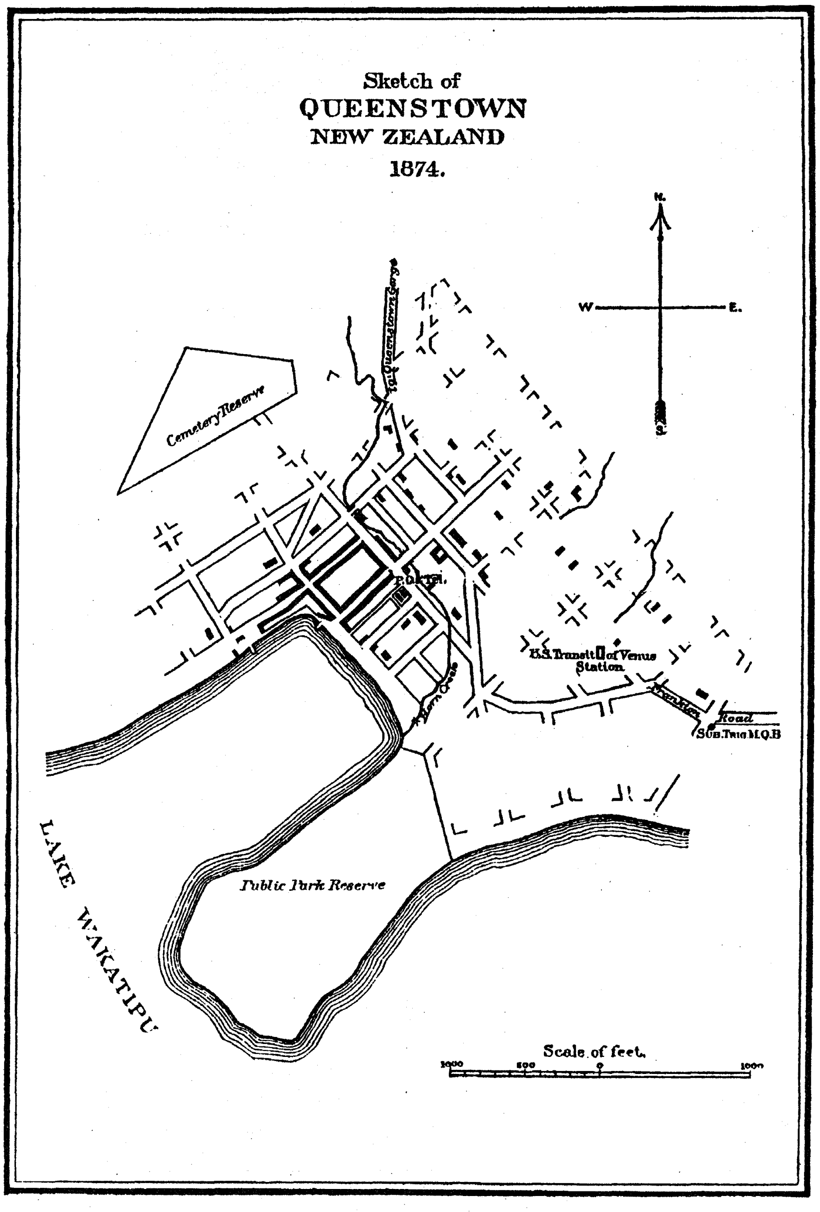

Figure 10. Location of the Queenstown transit station, east of the centre of town

19, while it was in Bluff Harbour (see Peters, 1881:479-499). Apart from the various telegraphic exchanges, Peters (1881:496) lamented that "... we were able to observe only a few occultations and no more than two moon culminations." The derived co-ordinates of the site (after Peters, 1881:499,550) were:

Latitude	45° 02′ 08″.10 ± 0.14 S
Longitude	$11^h\ 14^m\ 40^s.4$ E

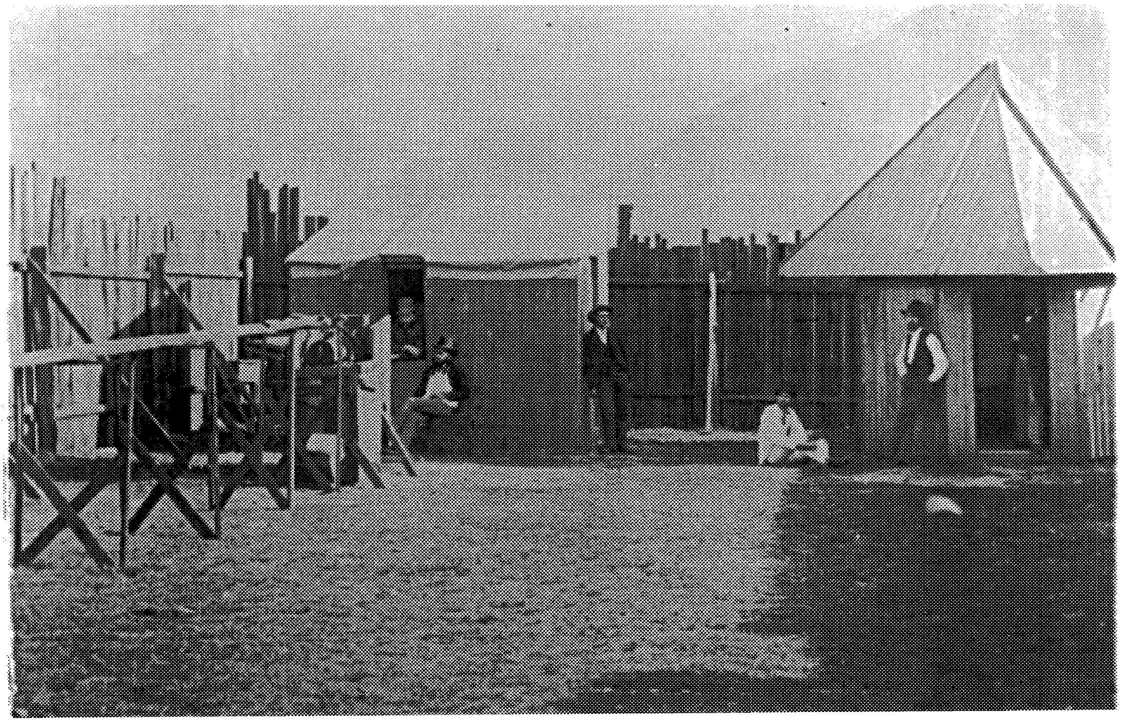

Figure 11. Part of the fenced-in Queenstown transit of Venus compound, showing the Transit House and heliostat (left) and the Equatorial House (right) (Photograph courtesy Hocken Library)

Table 2: Instruments used at the Queenstown 1874 Transit of Venus Station

Instrument/Component	Manufacturer	Number
Sidereal clock	Howard Clock Company	626
Mean time chronometer	T.S. & J.D. Negus	994
Sidereal chronometer	T.S. & J.D. Negus	1470
Sidereal chronometer	Bond	335
Transit telescope	Stackpole Bros.	1504
Refracting telescope	Alvan Clark & Sons	858
Heliostat mirror	Alvan Clark & Sons	II
Photographic objective	Alvan Clark & Sons	IV
Measuring rod	Alvan Clark & Sons	VIII
Plate holder	Alvan Clark & Sons	8
Engineer level	Alvan Clark & Sons	1489

4 OBSERVATIONS AND RESULTS

On December 9, the long-awaited morning of the transit, Peters (1874a) wrote in his journal: "The eventful day at 5 o'clock in the morning looked very ugly and black. The forenoon was cloudy and inclined to be stormy." Despite this far from promising situation, all the final adjustments were made to the instruments, and

> About 2 minutes before computed time of 1st contact the Sun came out, permitting observations of Equatorial and photographs to be made without interuption for 1¾

> hours about. After that only at intervals, up to within 16 minutes before computed time of 3^{d} contact. The Sun then remained invisible until 30^{s} to 40^{s} after 4th contact. Attempts were made for reversed photographs at 6^{h}p.m. but invain [*sic*]. (ibid.).

During the transit, Bass was in charge of the Photographic House. Phillippi exposed the different plates, Russell and Pierson developed them, and Aymé entered information on each plate in the photographic journal (see Bass, 1874). Becker took care of the heliostat and its drive (Peters, 1881:530).

In all, 237 photographs of the transit were obtained, 178 of the first and second contacts and 59 of Venus superimposed on the disk of the Sun (Peters, 1874b). The final photograph was taken 16 minutes before the commencement of egress (Peters, 1881). Regrettably, none of the Queenstown photographs has survived, but one of the images obtained at the Campbell Town transit station in Tasmania is shown in Figure 13 for reference purposes.

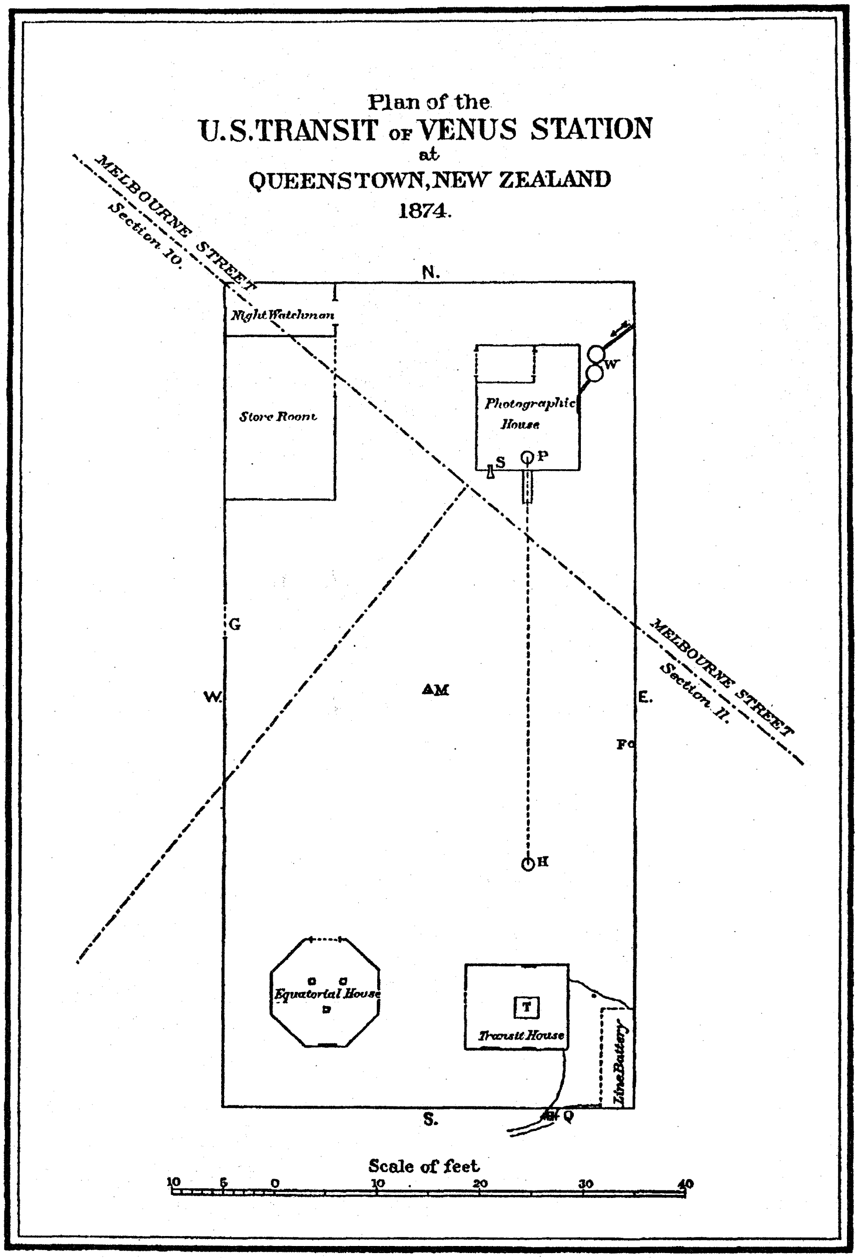

Figure 12. Plan of the Queenstown transit of Venus station (T = transit telescope; H = heliostat; P = photographic plate)

While Bass and the photographers were busy in the Photographic House, Peters was observing the first and second contacts with the 127-mm refractor, and he specifically noted the absence of the notorious 'black drop effect' (Peters, 1874a). He succeeded in obtaining fourteen measures of chords and cusps while Venus was on the Sun's limb (see Newcomb, 1880:135), and twenty-one measures of the distance of the planet from the limb while the transit was in progress. He also made ten determinations of the diameter of Venus. He remarked that during the transit

> ... perfect silence reigned in and around the station. Though my door [of the Equatorial House] was shut, whenever a picture registered itself in the photographic house the distant click was audible, and gave encouraging satisfaction and delight. (Peters, 1881:543)

All in all, Peters was pleased with the outcome of the programme and that "The instruments and appliances worked admirably, and everything passed off well." (*Lake Wakatip Mail*, 1874c). Despite the intermittent cloud cover, Queenstown proved to be one of the few 'successes' of the American transit programme. Global weather conditions were generally poor at the time (Janiczek, 1983) and although they were far from ideal in Queenstown, Peters' party did succeed in observing two of the four transit contacts and obtaining more photographs than at any of the other southern transit stations (see Dick, Orchiston and Love, 1998:Table 2). Peters (1881:548) was quick to acknowledge that their success at Queenstown was in part due to following the advice proffered by Thompson and McKerrow and selecting "... an inland station". Most other regions of New Zealand were clouded out at the critical time.

After the transit, Peters and his party dismantled the transit station and journeyed to Bluff Harbour where the *Swatara* was waiting at anchor. After loading the boxes of equipment, they sailed for the United States on 1875 January 20. Their route took them first to Hobart and Melbourne (Newcomb, 1880:19). Soon after their return Peters continued his regular research, and on 1875 June 3 he discovered two new minor planets which he promptly named after the Roman goddesses of journeyings and homecomings to commemorate his Queenstown successes (see Ashbrook, 1984).

For the Commission, the challenge now was to analyse the entire suite of observations from the expedition and produce a meaningful result. Newcomb believed that the visual observations from all the different transit parties (not just those of the Americans) would, when combined, "... give a value of the solar parallax of which the probable error will lie between 0″.02 and 0″.03." (*Annual Report*, 1875). He also felt that the American photographs alone would produce a result of comparable, if not better, accuracy.

In 1875 June the task of measuring these plates was assigned to William Harkness, and he subsequently reported that these yielded "excellent results" for the period when the planet was visible on the Sun's disk but that those taken during the four limb contacts were of "no value" because of the black drop effect (Harkness, 1883). Forty-five of the 59 disk photographs obtained at Queenstown were used in the final anlaysis.

Although all measurements on the photographs were completed by the end of 1877, the laborious task remained of determining the longitudes of the various transit stations. When this was accomplished, the official report of the American 1874 transit of Venus programme was to have been published in several volumes, but funding restrictions only allowed the appearance of the first volume (Newcomb, 1880). This comprised 157 quarto pages; the first 117 discussed the photographic work (without providing any conclusions) and the final 40 pages related to the visual observations. The planned Part II, in two volumes, reached the proof stage in 1881 and today exists as only a single copy in the Library of the U.S. Naval Observatory in Washington, DC. In the course of 564 pages, Part II provides detailed accounts of the eight different transit stations, including Queenstown (Peters, 1881), but does not report any results. Parts III and IV were supposed to contain the results, but did not even reach the proof stage.

Because of this unfortunate situation, D P Todd, an assistant at the Nautical Almanac Office, analysed some of the successful 1874 photographs, and obtained a provisional value of 8″.883 ± 0. 034 for the solar parallax. This result was published in 1881 (Todd, 1881), and although it differed significantly from some of the earlier values obtained (see Table 1), there was continuing concern about the quality of the photographic images – which showed some limb-darkening – and the difficulty of establishing plate scales (see Lankford, 1984). As a result, some astronomers then decided to turn to other methods in order to calculate the AU (including the night-time observations of minor planets, which appeared as point-sources).

Following what appeared to be a far from satisfactory outcome of the 1874 transit observations, scientists from 14 nations met in Paris in 1881 October to plan for the 1882 transit, and after some debate most nations decided to reject the use of photography. The United States was one of the few countries which determined to persevere with a photographic investigation, but for a time there was even doubt as to whether an international programme would be mounted. In the end it was agreed that eight different stations would be established, four in the United States itself and four at overseas localities. Parties were subsequently dispatched to South Africa, South America and New Zealand. The single New Zealand station was located in Auckland, and the leader of that party was Edwin Smith, Chief Astronomer of the United States Coast and Geodetic Survey. During the previous transit, Smith had led the Chatham Islands party.

This time it was William Harkness, another U.S. Naval Observatory astronomer, who was responsible for the overall U.S. programme:

> Although Newcomb had initiated American interest [in the nineteenth century transits], it was Harkness who had designed much of the equipment and personally led one of the parties, and it was Harkness who after Newcomb's abdication in 1882 would not only be the driving force behind the 1882 expeditions but also (in sharp

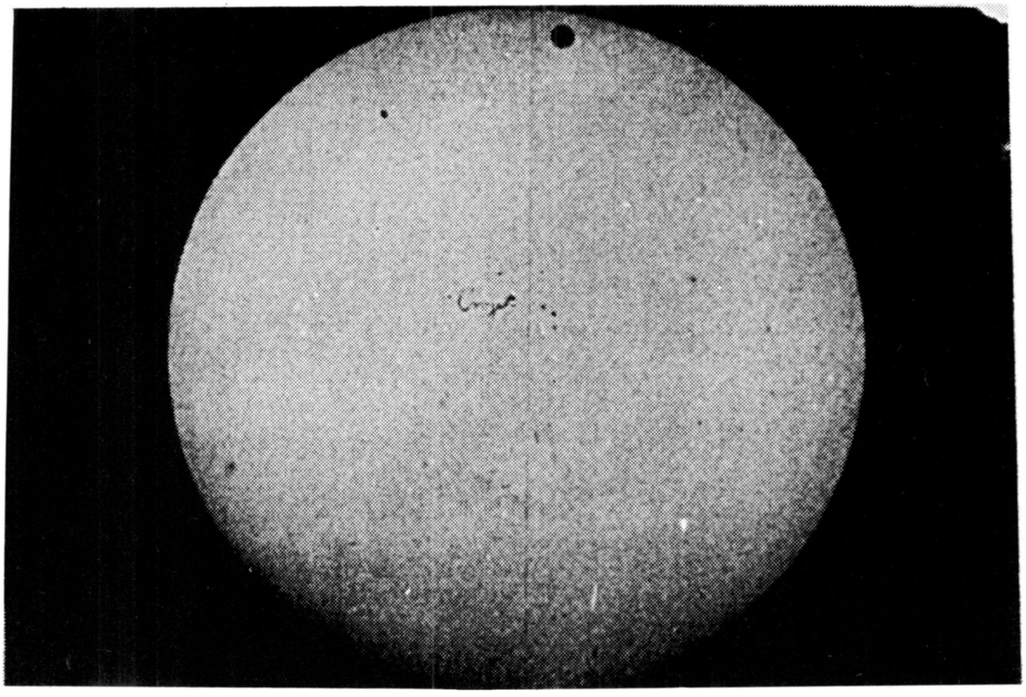

Figure 13. Photograph of the 1874 transit of Venus obtained at Campbell Town, Tasmania. (Photograph courtesy Queen Victoria Museum and Art Gallery, Launceston)

> contrast to Newcomb) produce a final result. Bringing the transit of Venus observations to fruition became a major goal of Harkness and a landmark in his career. (Dick, Orchiston and Love, 1998:242).

Six years after the 1882 transit Harkness reported a value of 8″.847 ± 0. 012 for the solar parallax based on his analysis of 1,475 photographs of the event (*Annual Report*, 1888:17-18), and just four months later he revised this to 8″.842 ± 0. 0118 (*Annual Report*, 1889:424-425).

5 DISCUSSION

Investigation of the astronomical unit did not end with the publication of the 1882 transit results. Harkness insisted that the solar parallax was intricately entwined with lunar parallax, the constants of precession and nutation, and parallactic inequality of the Moon, the masses of Earth and Moon, and the velocity of light, among others. By treating these constants as a system, he was able to produce what has been described as "... the crowning achievement of a lifetime of work ..." (Dick, Orchiston and Love, 1998:247), a monograph tilted *The solar parallax and its related constants* (Harkness, 1891). Three years later, Harkness (1894) published a 'best estimate' for the solar parallax of 8″.809 ± 0.0059, and Newcomb (1895) then produced a value of 8″.800 ± 0.0038, which was adopted as the international standard at the Conference Internationale des Étoiles Fondamentales in 1896. By way of comparison, the current value of the solar parallax (ratified by the IAU in 1976) is 8″.794148 ± 0.000007, equating to a mean solar distance of 149,597,870 km.

As one of the most visually-appealling of all sciences, astronomy has long enjoyed a high public profile, and the importance of the transit of Venus certainly was not lost on the good citizens of Queenstown back in 1874. Throughout their stay, amiable relations persisted between the Americans and the townsfolk, and when Peters gave a public lecture about the transit programme on November 26 this was well attended and was reported in the local newspaper, the *Lake Wakatip Mail* (1874b). The account ran to two and a half columns of detail, and summarized the history of astronomical distance measurement from antiquity through to the nineteenth century transits of Venus. Given Cook's intimate association with New Zealand, Peters made a point of labouring his exploits, to the obvious delight of the audience:

> To this astronomer, who had fought his way up, the highest credit was due, considering the instruments he had to work with. He had no time-piece that would exceed an ordinary American clock ... yet his efforts were, to this day, appreciable (Applause). He did not intend to flatter, but these were facts well known, and they were much indebted to Captain Cook (Renewed applause). He took his observations at Cape Venus, Otaheite. The observations of this memorable explorer were made in the year 1769. They should be proud of him who afterwards met his death in the South Seas Islands he loved so well (Applause). And to him, more than anyone else, was due the presence of the present expedition (Cheers).

On December 17, after the 1874 transit, there was a dinner in the Queen's Arms Hotel to farewell the visiting scientists, and the coverage in column inches assigned to this event in the *Lake Wakatip Mail* (1874d) outstrips by far the account of the transit itself! Yet the speeches, which were reported in detail, hardly touched on the transit or on science. Instead, they focussed on the glories of New Zealand in general and Queenstown in particular (to the frequent accompaniment of enthusiastic applause). In a diplomatic yet prophetic moment, Peters saw

> ... in the stars a large city here [at Queenstown] in the future; railways converging upon it; people coming from many other parts of the earth to enjoy its beautiful climate, and behold its grand scenery (Loud Cheers).

Finally, on 1874, Boxing Day, the transit party attended a picnic and dance given in their honour by the Masonic fraternity. All in all, the Americans were made to feel very welcome during their two month stay in Queenstown.

Nor did the Americans restrict their non-astronomical activities to socializing. On December 2 and 3 the photographers went on 'an excursion', in order to photograph Queenstown and the magnificent scenery offered by Lake Wakatipu and the surrounding countryside. Pierson and Phillipi subsequently published an album of New Zealand photographs which presents a unique record of Otago in the 1870s and is currently the subject of research by staff at the Hocken Library in Dunedin. Janiczek (1983:66) has reproduced some of the photographs from this album in one of his papers.

The transit party also extended its scientific interest beyond astronomy. In an interesting seismological diversion, Peters (1881:469,474) wondered whether some of the problems associated with the sidereal clock and the chronometers were caused by minor earthquakes – not that members of the transit party noticed any during their sojourn at Queenstown. Meanwhile, Russell (one of the photographic team) was always on the look-out for local 'curiosities', and in the course of their stay he succeeded in collecting seven Maori adzes, together with native birds, plants, insects, crustaceans, small vertebrates and moa bones. This collection found its way into the Smithsonian Institution, and the adzes, together with ethnographic specimens sourced from Riverton and the Chatham Islands, are documented by Keyes (1967). It is of interest to note that the adzes are stylistically and petrologically typical of those found in early prehistoric southern South Island New Zealand (Orchiston, 1974), and they reflect the important role that Central Otago (and the Queenstown area) played in early Maori life.

One of those living in Queenstown during the transit was a 10-year old girl, Sarah Cockburn, who had a passion for astronomy. In later years (under her married name of Salmond) she lobbied relentlessly for a monument to be erected on the site of the transit station, to mark what is arguably the most important venture in international science ever carried out at Queenstown. Her endeavours were finally rewarded in 1953 when at the age of 88 she had the honour of unveiling the monument (see Salmond, 1993). The plaque (Figure 14) reads:

> From this site a transit of the planet Venus across the solar disc was observed on 1874 December 9 by an American scientific expedition which came to Otago in the ship "Swatara".

In 1995 the monument was incorporated into the new multi-storey international Millennium Hotel which was constructed on the site of the transit station.

From an astronomical point of view, the 1874 transit was important because it also attracted British, French and German parties to New Zealand and its outlying islands, Campbell Island and the Auckland Islands, respectively (see Airy, 1881; Auwers, 1898; Bouquet de la Grye, 1882; Filhol, 1885), and Major Palmer at Burnham even had one of his party set up a 'satellite station' at Naseby, 300 km to the southwest (see Figure 9). As in Australia (see Orchiston and Buchanan, 1993), the transit served as a catalyst for the development of local astronomy as it was the first opportunity for local astronomers to become involved in a project of international importance. Observers in Auckland, Thames, Wellington, Nelson and Dunedin, among other centres, prepared for the event (see *Lake Wakatip Mail*, 1874a; The transit of Venus, 1874(a), 1874(b); Tomorrow's transit of Venus, 1882), and one of the Wellington astronomers, Archdeacon Arthur Stock, produced a small popular book about the transit (Stock, 1874). Unfortunately, cloudy skies prevented most observers from viewing the transit.

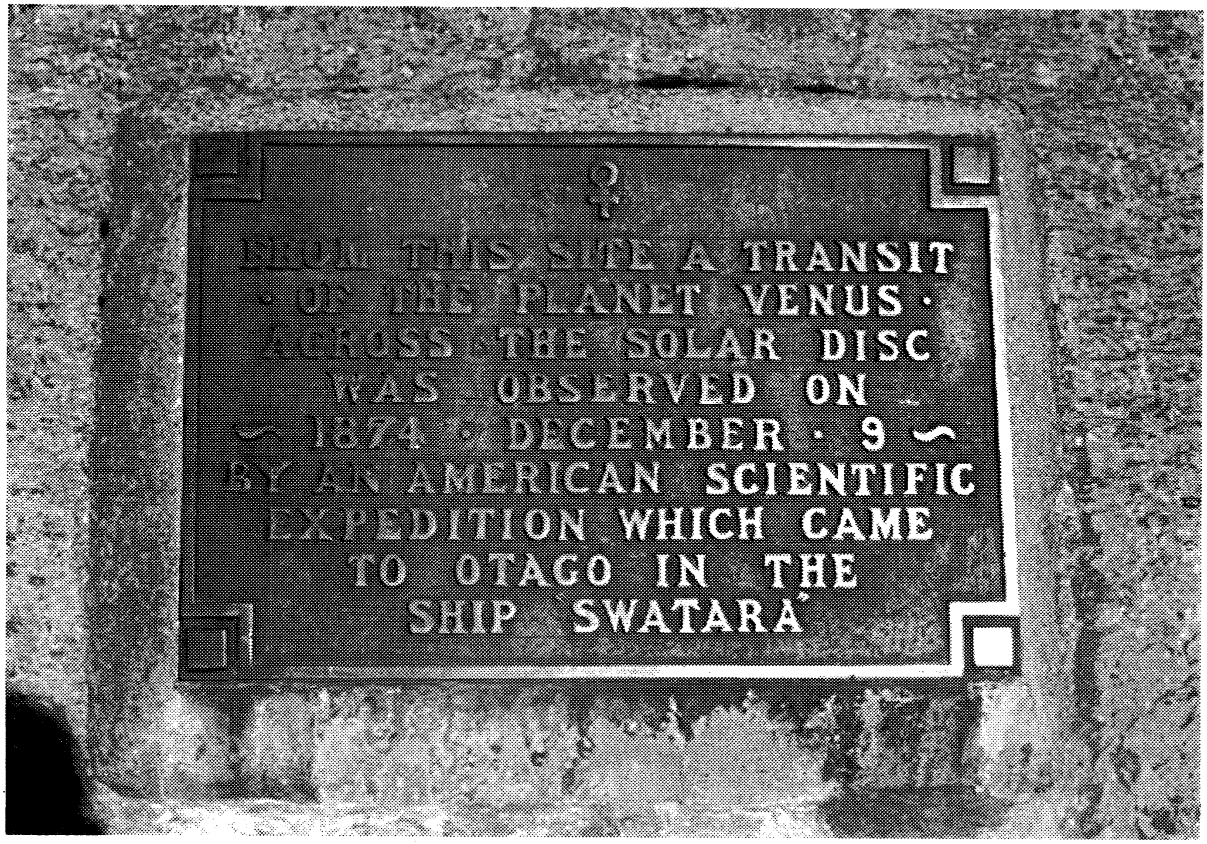

Figure 14. The Queenstown transit of Venus monument

This transit also was a milestone because it precipated the first attempts to apply photography to astronomy in New Zealand. However, the Americans in Queenstown were not the only ones to experiment successfully with this new technology, as a team from Auckland comprising Professor S J Lambert, FRAS, and Messrs Martin, Pond and Redfern obtained "A good many photographs of the first and second contact stages ..." of the transit (McIntosh, 1958a). Their pioneering spirit is to be applauded, even though the 'black spot' phenomenon prevented their images from having any appreciable research value.

There was even more New Zealand interest in the 1882 transit (e.g. see Hector, 1882; Stone, n.d.; Tomorrow's transit of Venus, 1882; Transit of Venus, 1882), with observers located in Auckland, Thames, New Plymouth, Martinborough, Wellington, Nelson, Christchurch, Dunedin and Clyde. A party under Professor Lambert was again successful, photographing the event through both 63.5-mm and 76-mm refractors (McIntosh, 1959), and Mr Foy, in Thames, obtained two photographs of the transit (McIntosh, 1958b). Meanwhile, the American transit party – situated in Auckland – was happy with its efforts, a total of 74 photographs (McIntosh, 1958a).

The year 1882 also appears to mark the start of non-transit astronomical photography in New Zealand. Just two weeks before the transit, an Auckland professional photographer and astronomy enthusiast, Josiah Martin (see Maitland, 1993), exhibited "... a very successful photograph of the sun ..." at a meeting of the Auckland Institute (McIntosh, 1959).

The 1885 September 9 total solar eclipse, provided yet another incentive for New Zealand astronomers to develop their photographic skills. At Masterton, within the band of totality, a Mr Humphries obtained good photographs of the event, recording Bailey's Beads, prominences and the corona (ibid.). In Auckland, where the eclipse was only 95% total, a Mr Cranwell "... climbed Mt Eden and secured a few photographs through gaps in a cloudy sky ..." (ibid.).

John Grigg of Thames was also active at about the same time, obtaining photographs of the Moon and of the partial solar eclipse of 1890 December 12. During the first decade of the twentieth century, he photographed the Moon, sunspots, star fields, and two comet: the Great Comet of 1901 (C/1901 G1) and Halley's Comet (1P/Halley) in 1910. Grigg's name is well-known today through his cometary discoveries, and he was New Zealand's leading amateur astronomer at the start of the twentieth century (see Orchiston, 1993, 1999). He was the first New Zealander to carry out astronomical photography systematically and over an extended period of time, and his pioneering efforts in this emerging field of astronomy have been reviewed by Orchiston (1995).

Early in the twentieth century, cometary photography also was pursued successfully by the Reverend Dr David Kennedy and his assistants Cullen and von Gottfried at the Meeanee Observatory near Napier in 1907 (Orchiston, 1996), and Grigg, Cullen and von Gottfried and C.J. Westland all obtained photographs of Halley's Comet in 1910 (some of which are reproduced in Mackrell, 1985). Westland (of Christchurch) went on to independently discover Comet C/1914 S1 (Campbell) in 1914, and he also took a number of successful photographs of this object (see Orchiston, 1983).

6 CONCLUSIONS

The 1874 U.S. transit of Venus programme was a expensive venture designed to refine that fundamental yardstick of solar system astronomy, the astronomical unit. It was a major logistical exercise, involving the transportation of extensive equipment (including prefabricated buildings) to eight different transit stations, five of which were in the southern hemisphere. One of these was situated at Queenstown, in the South Island of New Zealand.

While most other New Zealand sites were clouded out during the transit, those at the Queenstown station succeeded in observing both ingress contacts and obtaining a succession of photographs of these contacts and of Venus while it was visible on the disk of the Sun. Todd used the latter photographs and those from other U.S. transit stations to produce a value for the solar parallax that differs only 0″.089 from the currently-accepted figure, but because the reliability of photography was called into question at the time this result was not seen as improving on the value of the astronomical unit.

Despite this disappointing outcome, from a national perspective the 1874 transit did serve to introduce astronomical photography to New Zealand, and it provided an important impetus for the development of local astronomy.

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Wayne Orchiston recently retired as Executive Director of Carter Observatory (the National Observatory of New Zealand) and moved to Sydnet, Australia. He is on the Organizing Committee of Commission 41 (History of Astronomy) of the International Astronomical Union, and author of *Nautical Astronomy in New Zealand: The Voyages of James Cook* (1998).

Tom Love is a graduate in Classics from the University of Canterbury (New Zealand) where he developed an interest in the history and philosophy of science. He is a Research Associate of Carter Observatory.

Steven J Dick is an astronomer and historian at the U.S. Naval Observatory in Washington, DC, and President of IAU Commission 41. He is editor of the forthcoming volume *Mnay Worlds: Extraterrestrial Life, the New Universe and the Theological Implications*, co-editor of the *Proceedings of the Sesquicentennial Symposium of the American Nautical Almanac Office* (1999), and author of *The Biological Universe* (1996), *Life on Other Worlds* (1998), and *Plurality of Worlds* (1982).