Creation and expansion of Vermont's Geodetic Network

Vermont Society of Land Surveyors
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Early History – Few Details

- Earliest work found was in 1836 "Jilson Borden (MZ1913). MAGS
- 1837 "Boundary Bound MA NY VT" (MZ1966) COASUR
- Notice date on mon.
- 1896 report refers to "old" Borden Survey

- Congressional Act of 1843 limited activities to the coast and narrow area associated with the Primary Triangulation
- 1845 US/Canada Boarder (IBC)

- Congress lifted the restriction in 1871, during the superintendency of Benjamin Peirce, when it gave permission for the measurement of the Transcontinental arc. In 1878, the name was changed to U.S. Coast and Geodetic Survey to reflect the bureau's responsibilities for geodetic surveys inland.

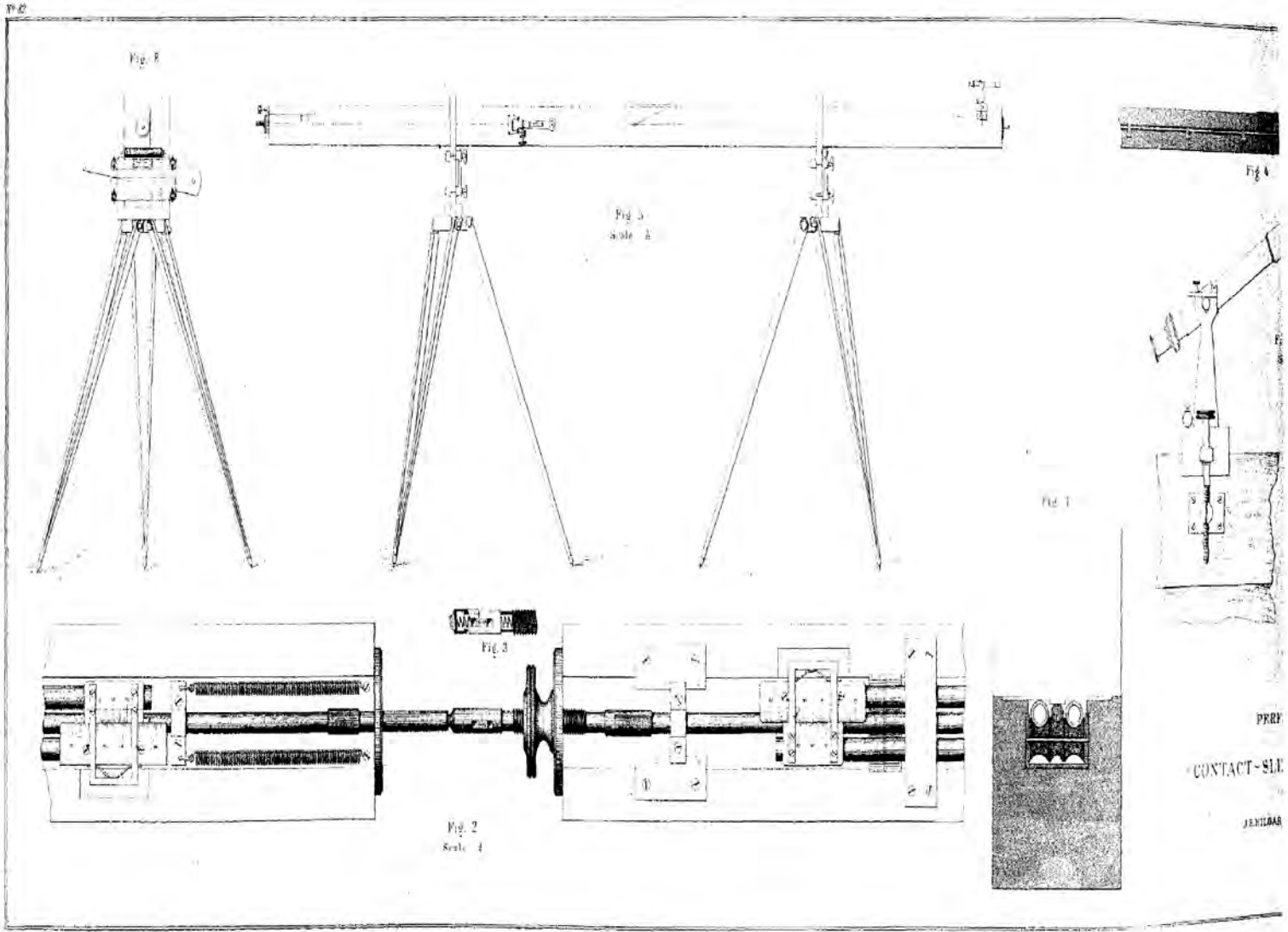
…that the means therein provided for continuing the survey of the Atlantic and Gulf coast should be applied, in part, for a survey of Lake Champlain. The system and methods used in the survey of the coast were, in consequence, with a suitable force, transferred to the lake, and the survey was advanced as far as the limited season and the collateral interests of work on the coast would allow….. On a review of the facts which give *it* special importance, the provision by which it has been included in surveying-operations seems to he fully warranted.

This narrow lake, about one hundred miles in length, and entirely within the limits of the United States, is connected with Hudson River by the Champlain Canal, and With the Saint Lawrence by its natural outlet, the Richelieu River, the navigation along the latter being improved by the Chambley Canal. Thus there is an almost direct line of water-communication between New York City and Montreal. Further improvements now in progress, and others which are proposed, will shorten this line, and realize, it is expected, all the advantages for domestic intercommunication to be derived from the position, direction, and extent of Lake Champlain, as a natural link between the great lakes and the Atlantic Ocean. It is intended to make the new canal, to connect the navigable waters of the lake with the Saint Lawrence above Montreal, of capacity sufficient to pass vessels of 850 tons. Lake Champlain, when this is accomplished, will be one of the principal routes of trade and commerce between the Northwestern and Eaststern States of the Union.

First Concentrated Effort

- Survey of Lake Champlain Begins in 1870
  - Reconnaissance by G. W. Dean
- Secondary baseline measured at Plattsburgh, NY using 6-Meter Contact Slide Apparatus, the rods of which had been compared with the Coast Survey standard, No.2, before they were forwarded from Washington.(1961.05m)

6 Meter Contact Slide Apparatus



- Another secondary base was measured along Rutland RR at the depot in Burlington using 60 meter wire, whose length was obtained by means of the contact slide apparatus. (1319.76m)

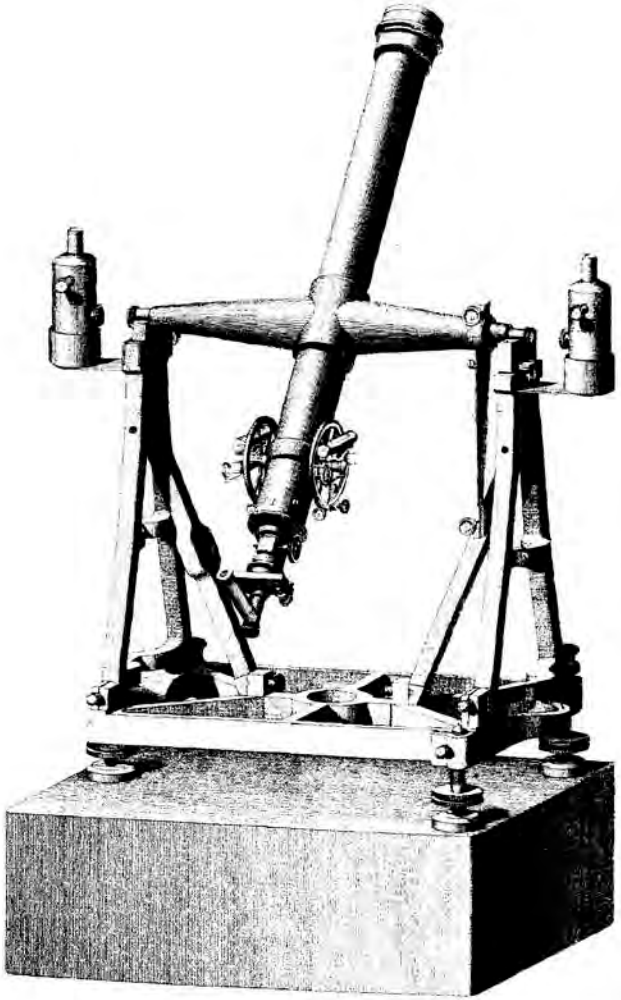
- Location for a Primary Base was found in St. Albans (now gone) and was reported to be 5.5 to 6 miles long.
- Two parties established primary triangulation stations independently.

Triangulation.-The limits of the triangulation to be executed daring the months of September and October were arranged, under the direction of Mr. Cutts, to include the most important harbors and the routes most used by the commerce of the lake. The scheme and its connections were put in the charge of Assistants J. A. Sullivan and S. C. McCorkle. The former commenced work at Barlington, Vermont, and the latter at Plattsburgh, New York, and the junction of the two series of triangles was made on the intermediate and common line, Stave Island-Point Trembleau. The reconnaissance and the organization of his party were commenced by Assistant Sullivan on the 2d, and the erection of signals on the 6th of September. From the latter date until the 23d of October the work was prosecuted without interruption, except during the prevalence of high winds and the thick smoke from burning forests on the Ottawa.

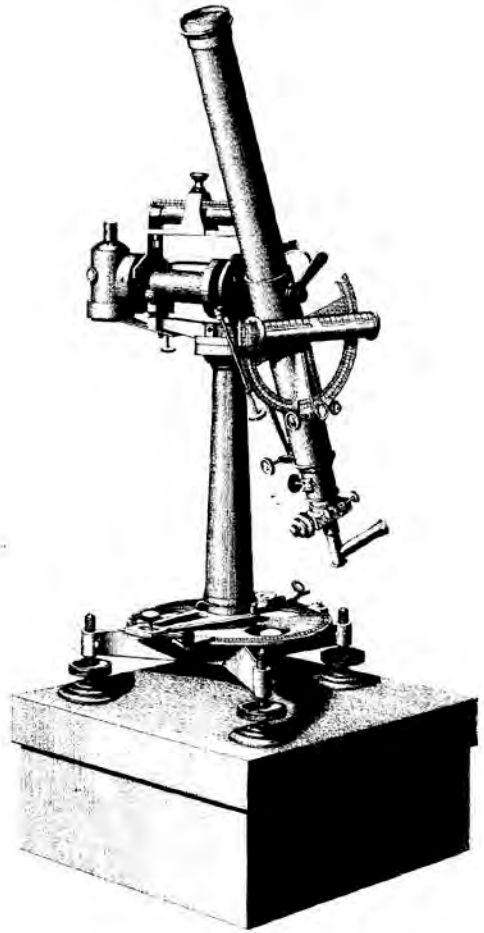
Determination of Latitude at Burlington

Latitude of Burlington, Vermont.-The astronomical station is on high ground within the city limits, and is connectedd with all the principal stations of the lake-triangulation to tlie westward . A temporary observatory was completed on the 12th of September. Transit No. 12 and zenith telescope No. 4 were then mounted, each on a brick pier, sunk two feet below the surface, laid in cement, and capped with marble slabs. After careful attention to these preliminaries, Assistant A. T. Mosman commenced the observations, and by the 16th of October the latitude and azimuth were determined.

Primary azimuth was established between Astronomical Station and Juniper Island



PORTABLE TRANSIT.



ZENITH TELESCOPE.

Determination of Longitude

*Longitude Qf Burlington V*ermont.-The approximate difference of longitude between the astronomical station at Burlington and Cambridge observatory, was determined on the nights of September 26 and 28, and October 2. Assistant G. W. Dean reached Burlington on the 19th of September, and occupied the observatory, using the transit set up by Assistant Mosman, who, in conjunction with his aid, Mr. Smith, furnished all the assistance required for determining the longitude

The local time was ascertained each night by observing eight or ten zenith and circumpolar stars, with transit No. 12, the time being recorded on chronograph No. 2, and by the Frodsham break-circuit chronometer, No. 3451, belonging to Cambridge observatory. As soon as the time had been observed, the break-circuit chronometer was taken to the telegraph-office and there connected in a circuit directly with one of the clocks at the Cambridge observatory. The comparisons of the Burlington chronometer with the Cambridge clock were recorded on the observatory chronograph, during five minutes each night, after which the chronometer was taken back to the astronomical
station, and further comparisons were made with the two chronometers of Assistant Mosman, for the verification of the daily rate of the Frodsham chronometer.

Frodsham Chronometer

Crown Point Baseline

- In 1872, the second primary base was measured. Approximately 3 miles in length

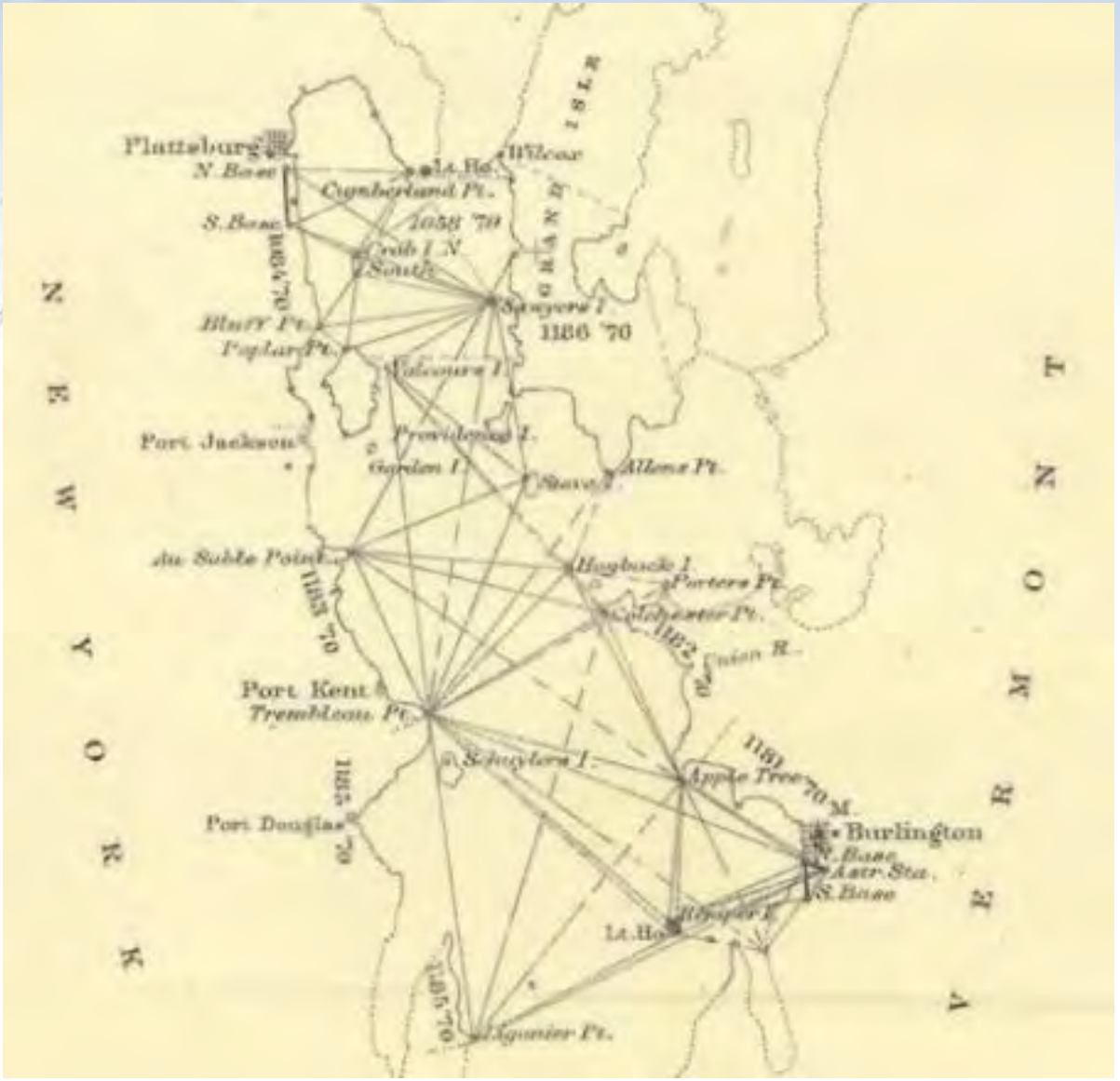

USCS


1883

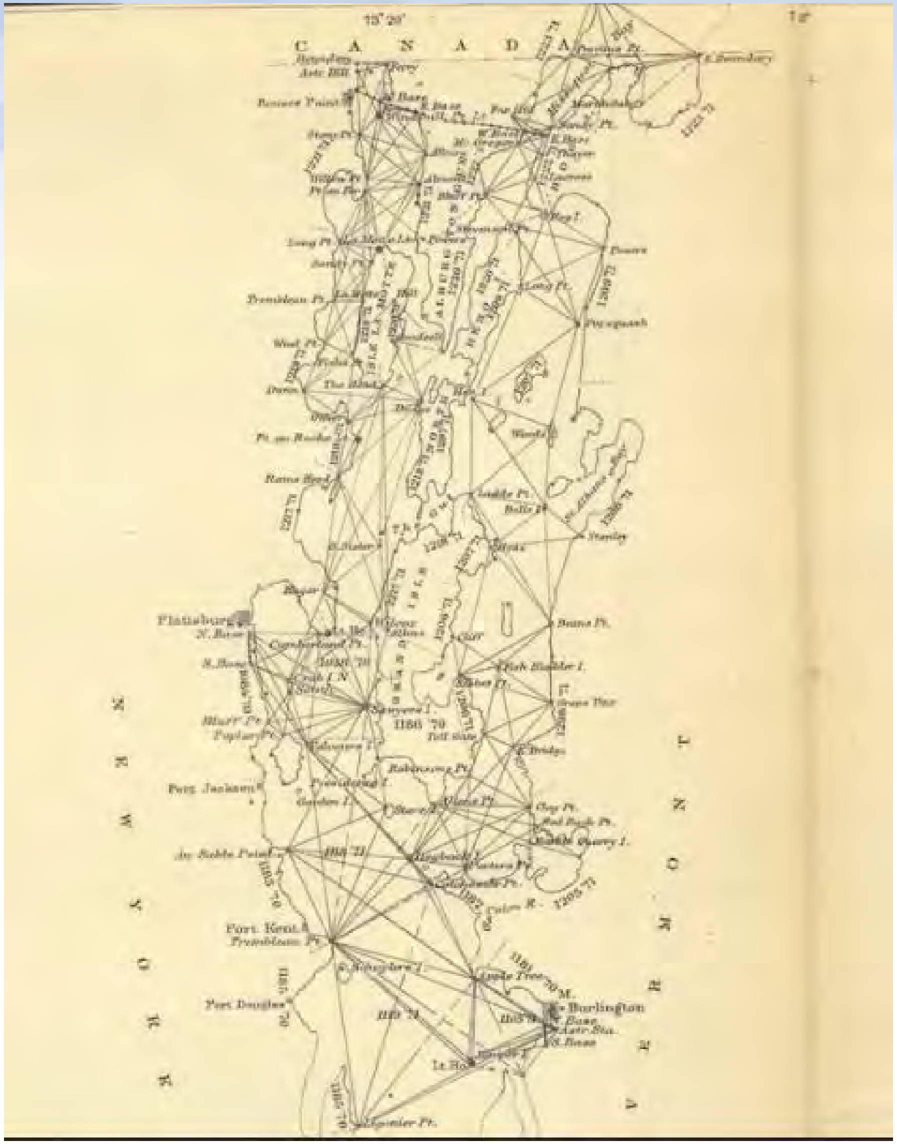
All this to support

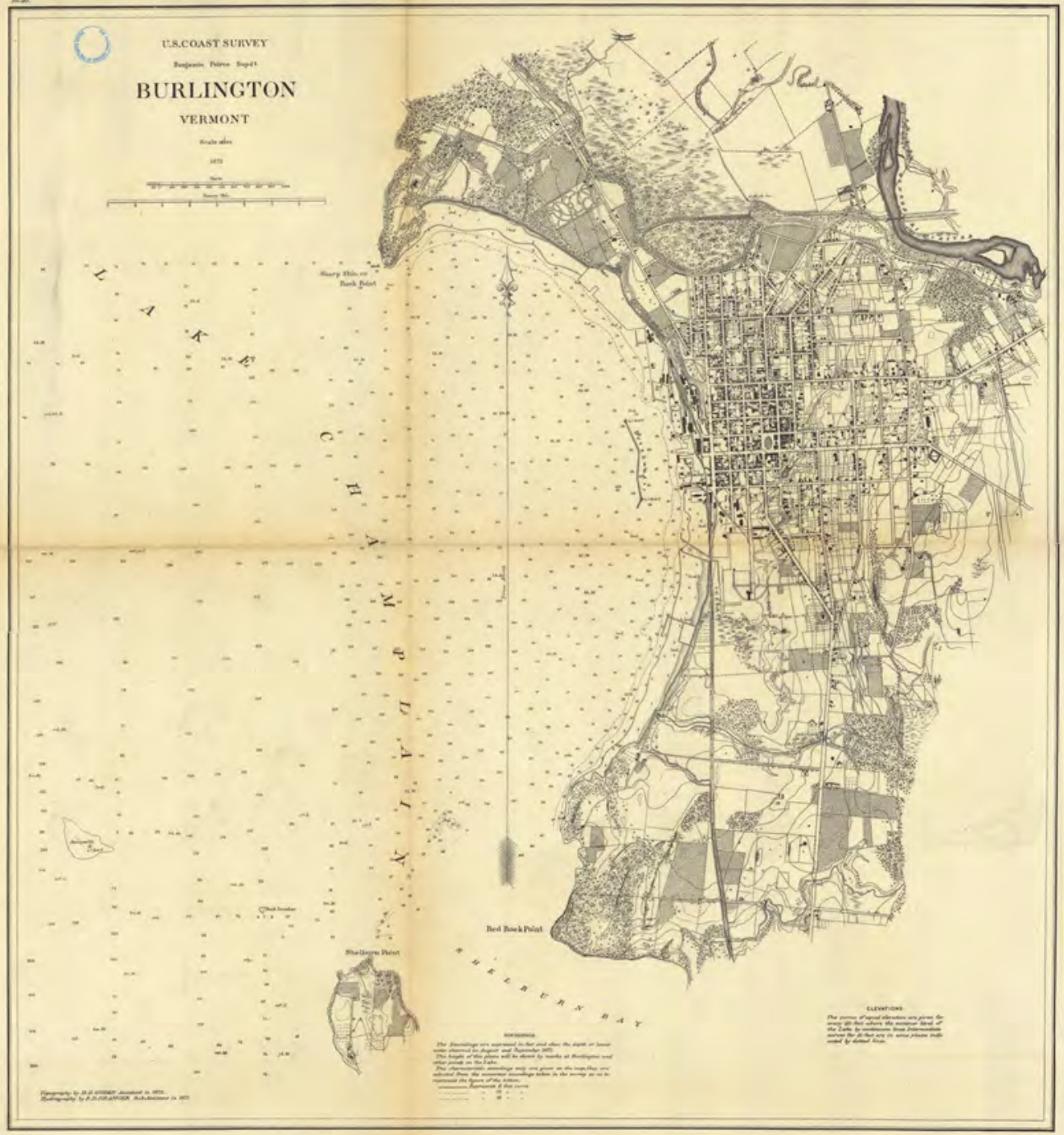
- Topography – Plane table surveys of shoreline
- Hydrography – Lead line hydrographic survey

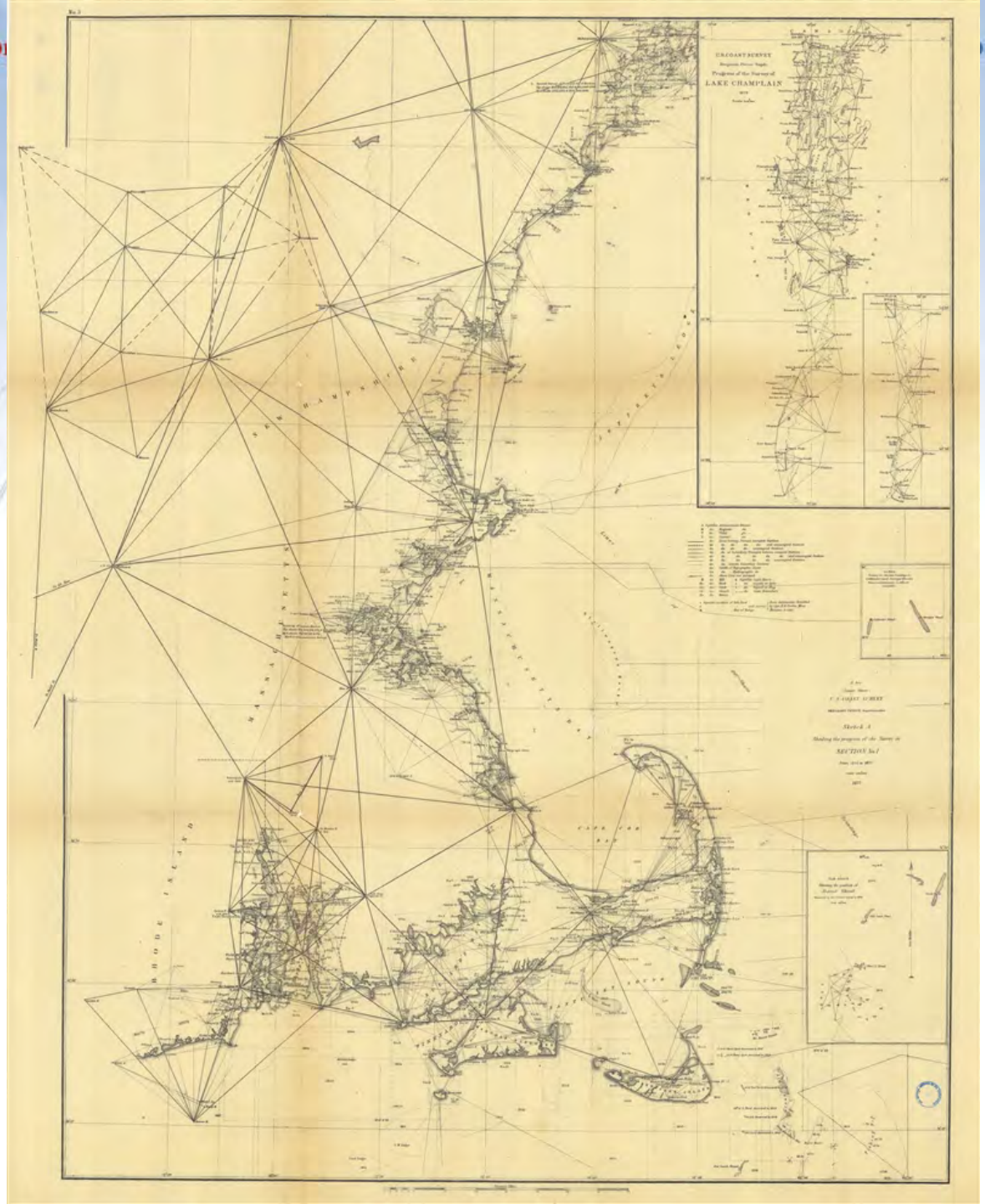
Progress of the Survey 1870



Progress 1872






COAST SURVEY
Progress of the Survey of
LAKE CHAMPLAIN
NEW HAMPSHIRE
MASSACHUSETTS
RHODE ISLAND
CAPE COD BAY
U.S. COAST SURVEY
Sketch A
Shewing the progress of the Survey in
SECTION No I

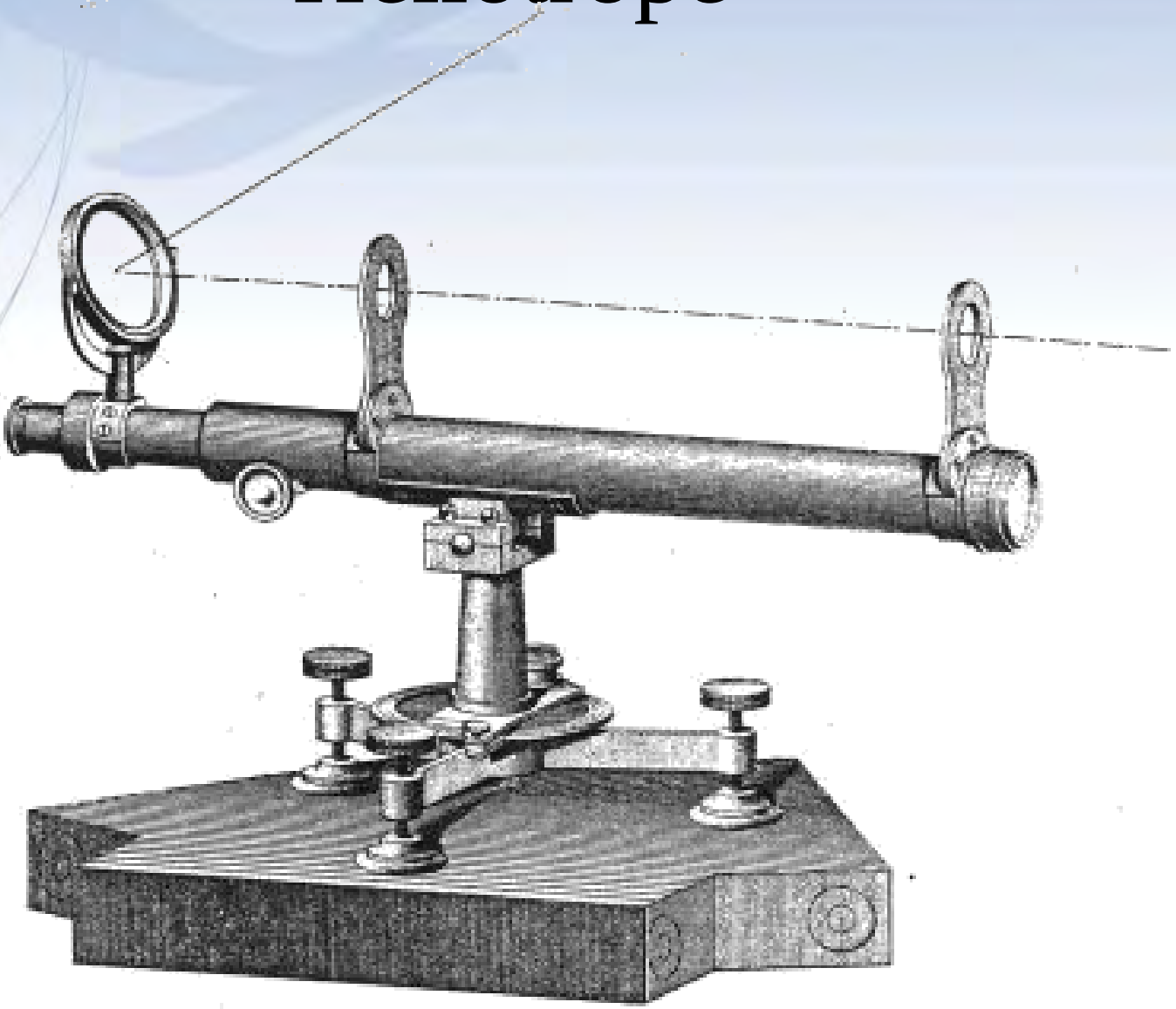
1879-1880

Primary triangulation.—In the scheme of geodetic operations for connecting the survey of Lake Champlain with the primary triangulation of the coast of New England, Killington Peak, near Rutland, Vt., was indicated, and at the opening of the fiscal year that station was occupied by Assistant Richard D. Cutts. It connects directly with several primary points of the Coast and Geodetic Survey, and with numerous positions which will be used by Prof. V. G. Barbour for triangulation on account of the geological survey of Vermont. Assistant Cutts left Washington late in June, 1879, and in the course of a few days traced out a sled road for transporting instruments and equipage to the summit of Killington. At the same time he suggested the desirability for public uses of a wagon road to enable citizens and sojourners at Rutland to enjoy the magnificent view from Killington Peak. The citizens responded promptly, subscribed a sum sufficient for the work, and, although hands were scarce and the ground very rough, the road to the summit was practicable for wheeled vehicles on the 14th of July.

Meanwhile, Mr. *C. H.* Sinclair, aid in the party, had adjusted the signal on Mount Equinox to the southward and westward of Killington, and stationed heliotropers at Prospect Mountain and Blueberry Hill to the northward and westward. Northeast of Killington the summit of Mount Washington was seen on favorable days at a distance of about eighty-eight, miles.

The plan of work, as laid out in advance, was to connect with and verify the New Hampshire triangulation; to commence observations for the Vermont series, assisted by Professor Barbour, and to take measures for connecting Lake Champlain with the main triangulation. In pursuance of the general scheme, heliotropers were stationed at Mount Mansfield, Mount Washington, and Gunstock Mountain. When arrangements were complete for the measurement of horizontal angles at Killington, the triangles meeting there as a septagon cover an area of ten thousand six hundred square miles.

Heliotrope



As triangulation advanced in the State of New Hampshire, Professor Quimby selected and observed upon stations in the Green Mountains, and these are included in the scheme laid out by Assistant Cutts. Intermediate points in Vermont, selected by the observer in New Hampshire, will be embraced in the series of triangles laid out by Professor Barbour.

At Killington observations with the theodolite were commenced on the 24th of July, and were completed on the 27th of September. The journal shows that on twenty-four mornings and eighteen afternoons no observations could be recorded. Amongst other obstacles to progress the field report mentions the fog or low clouds present at the high summit generally in the morning. Assistant Cutts remarks: "They frequently hang on during the day, while fifteen hundred or two thousand feet below the summit it is all sunshine."

An unusual number of stations were observed on from Killington Peak. Of these, eleven were primary points at distances varying between fifty and seventy miles, the longest line (88.54 miles) being that to Mount Washington. Eleven signals of the Vermont series were also observed on, and seven subsidiary directions were measured on objects in Rutland and in the Adirondacks.

STYLES

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OD1328                              STATION DESCRIPTION
OD1328
OD1328'DESCRIBED BY COAST AND GEODETIC SURVEY 1881 (VGB)
OD1328'STYLES PEAK IS ONE OF THOSE OF TABER MOUNTAIN, IN THE TOWN OF
OD1328'PERU, AND IS THE ONE LYING ABOUT 1-1/2 MILES N OF THE NOTCH
OD1328'ROAD RUNNING FROM PERU VILLAGE TO EAST DORSET, AND ABOUT 2
OD1328'MILES W OF THE RESIDENCE OF SAM STYLES.  THE STATION IS AT
OD1328'THE NE EXTREMITY OF THIS PEAK AND AT ITS HIGHEST POINT, ABOUT
OD1328'10 FEET FROM THE EASTERN FACE OF THE ROCK, WHICH HERE DROPS OFF
OD1328'ABRUPTLY ABOUT 10 FEET.
OD1328'
OD1328'STATION IS MARKED BY AN IRON BOLT IN THE ROCK WHICH IS PARTIALLY
OD1328'BARE.  THERE IS ALSO AN IRON BOLT ABOUT 10 FEET TO THE W USED FOR
OD1328'SUPPORTING THE FOOT OF ONE OF THE BRACES.  THE STATION BOLT IS
OD1328'IN A TRIANGLE CUT IN THE ROCK.
OD1328'
OD1328'TO REACH THE STATION, GO BY RAIL TO MANCHESTER, VERMONT, THENCE
OD1328'BY STAGE TO PERU VILLAGE, THENCE N TO RESIDENCE OF SAM STYLES,
OD1328'THENCE CLIMB TO STATION.
OD1328
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Magnetic Declination

Name of station.	Lat.	Long.	Date.	D.	Δ D.	D_{1900}	Observer or authority.	Reference.
				VERMONT.				
Group I.								
Rutland, city park.	43 36	72 55	1890·75	+11·54	....	+12·4	J. B. Baylor.	
Burlington, University grounds.	44 28	73 12	1890·74	+12·02	....	+12·5		
Group II.								
Pownal.	42 46	72 59	1786·5	+5·87	+5·6	+11·5	— Williams.	
Bellows Falls.	43 09	72 28	1876·58	11·11	1·3	12·4	F. E. Hilgard.	
White River Junction.	43 40	72 18	1876·59	11·09	1·6	12·7		
West Hartford.	43 42	72 22	1860·21	11·15	2·9	14·0	J. M. Clark.	
Wells River.	44 09	72 05	1876·60	11·91	1·4	13·3	F. E. Hilgard.	
Ryegate.	44 10	72 10	1801·5	7·00	6·2	13·2	J. Whitelaw.	
Montpelier.	44 17	72 36	1829·5	12·42	4·9	17·3?		
Saint Johnsbury.	44 26	71 55	1837·5	9·27	4·3	13·6	A. C. Twining.	
Essex Junction.	44 31	73 06	1849·65	9·40	2·9	12·3	J. M. Clark.	
Barton.	44 44	72 03	1837·5	10·85	3·8	14·6	A. C. Twining.	
Swanton Falls.	44 56	73 09	1850·29	11·47	3·4	14·9	J. M. Clark.	
Derby.	45 00	72 12	1876·61	+13·30	+1·1	+14·4	F. E. Hilgard.	

Early USGS

- 1890's USGS begins leveling and mapping activities to support development of topographical maps
- 1904 First mention of "Montpelier datum", e.g., "358 MONTPELIER"
- Local datums often based on leveling done by the RR, or early USC&GS leveling

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1        National Geodetic Survey,   Retrieval Date = AUGUST 30, 2019
 PG0882 ***********************************************************************
 PG0882  DESIGNATION -  358 MONTPELIER
 PG0882  PID         -  PG0882
 PG0882  STATE/COUNTY-  VT/CHITTENDEN
 PG0882  COUNTRY     -  US
 PG0882  USGS QUAD   -  ESSEX JUNCTION (1987)
 PG0882
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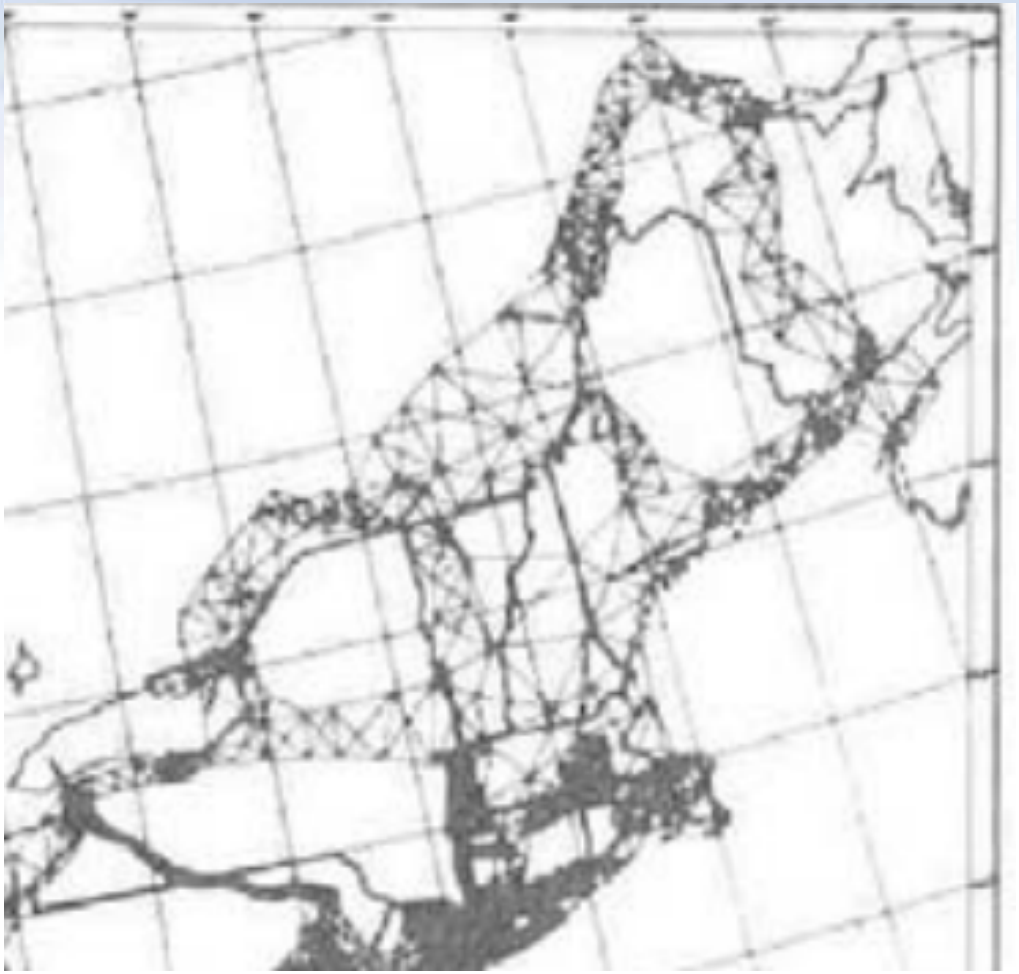
Horizontal Network in June 1931



Early 1900's

- Significant line leveling and Triangulation by USGS (Lincoln Gap in 1915, Mt. Mansfield in 1924)
- USC&GS 1st order leveling in Caledonia, Essex, Franklin Counties (1922)
- USLS Triangulation in 1930's
- Significant triangulation and leveling conducted in 1934-1937 (approx. 1000 mi of leveling, mostly 2nd order)

1940's

- Some leveling, Signficant 1st and 2nd order triangulation
- USGS Transit-Traverse to support updates and improvements to topographic maps
- Nautical Charting
- Aeronautical Charting
- Corps on Engineers/Army Mapping Service

1950's and 1960's

- National **Interstate** and Defense Highways Act of 1956 – initiated 15 years of geodetic/control surveying to support both ground and aerial surveys
- Both state and contract forces

AGA Geodemeter Model 4

1961 Atlas Missile

K&E/Cubic Precision Ranger III

Kern DKM 2-AE

3-Wire Leveling – Zeiss Ni2 Both Metric and Yard Rods


NE HARN 1992
Y173
LIME
STGE
P182
MILL
GRE2
F200
EAST
EASA
SHER
OLDT
0250
RGLY
EPPI
CAR2
ALBU
049
PRT2
0221
COWA
BRIG
UMBA
K169
K064
ASBE
LYNO
0230
D047
REDS
MORR
MS23
GORH
ROCK
GM21
RUNW
0130
2590
A196
0500
ADDI
L034
BRAD
RANG
CONT
TICO
IEC
0170
0220
KILL
SCOT
DST4
9529
GUNS
0460
CLAR
ELID
TABO
WNDG
T30K
0210
CNR1
0300
1025
SAMA
DOVE
MONA
BEAZ
TT40
0090
0190
WEST
0488
KELL
414A
MDHO
PROS
TAGH
CENT
3143
PUGL
MERI
ANTE
PLAN
ARMO

- Formed Vermont Geodetic Survey in 1993
- Bought GPS field equipment and Digital Bar-Code level in 1994

Leveling and GPS 1994-1995

- Conducted 1st or second order levels to 18 HARN marks
- VTGS Began to work with VT Mapping Program (VMP). Established all ground control for Rutland and Windsor Counties 1:5000 orthophoto project. Relationship with VMP continues until around 2010.

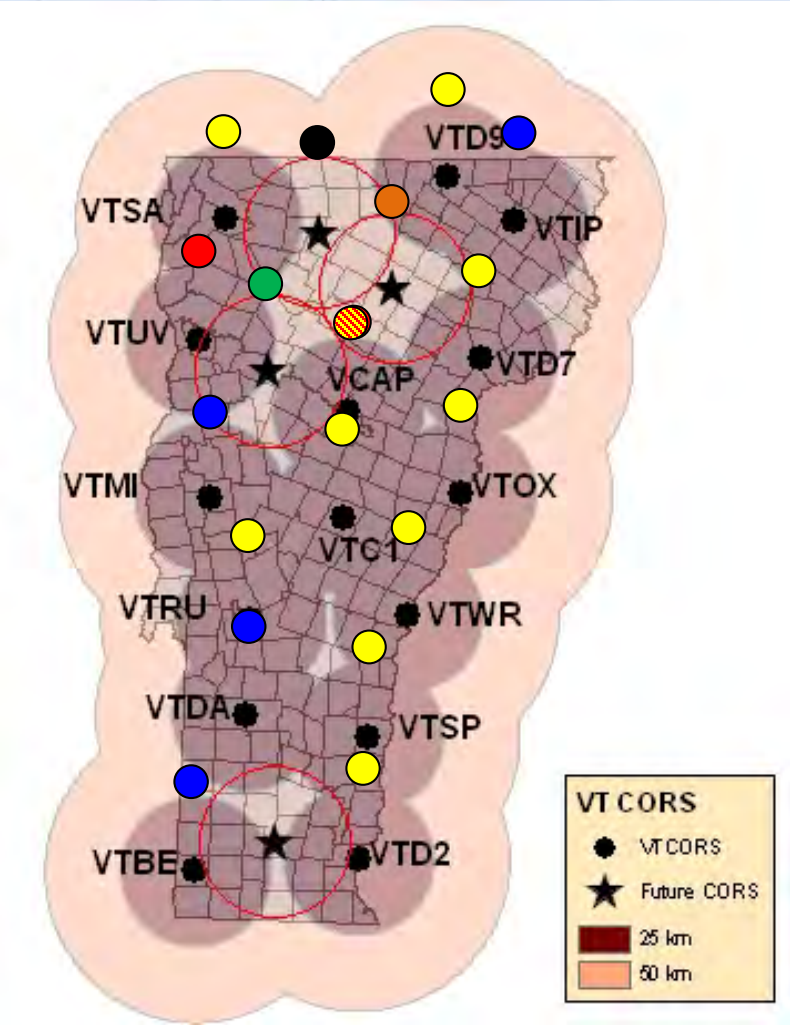
Leveling

- VTGS conducted annual leveling project until around 2007. One or two followed in 2013-2015.
- Around 1000 km of leveling were added to the network by VTGS.

VCAP 1994 (National in 1996)

9th oldest station currently in operation

Vermont CORS Expansion (VECTOR)
Vermont Enhanced CORS and Transmission Of Realtime



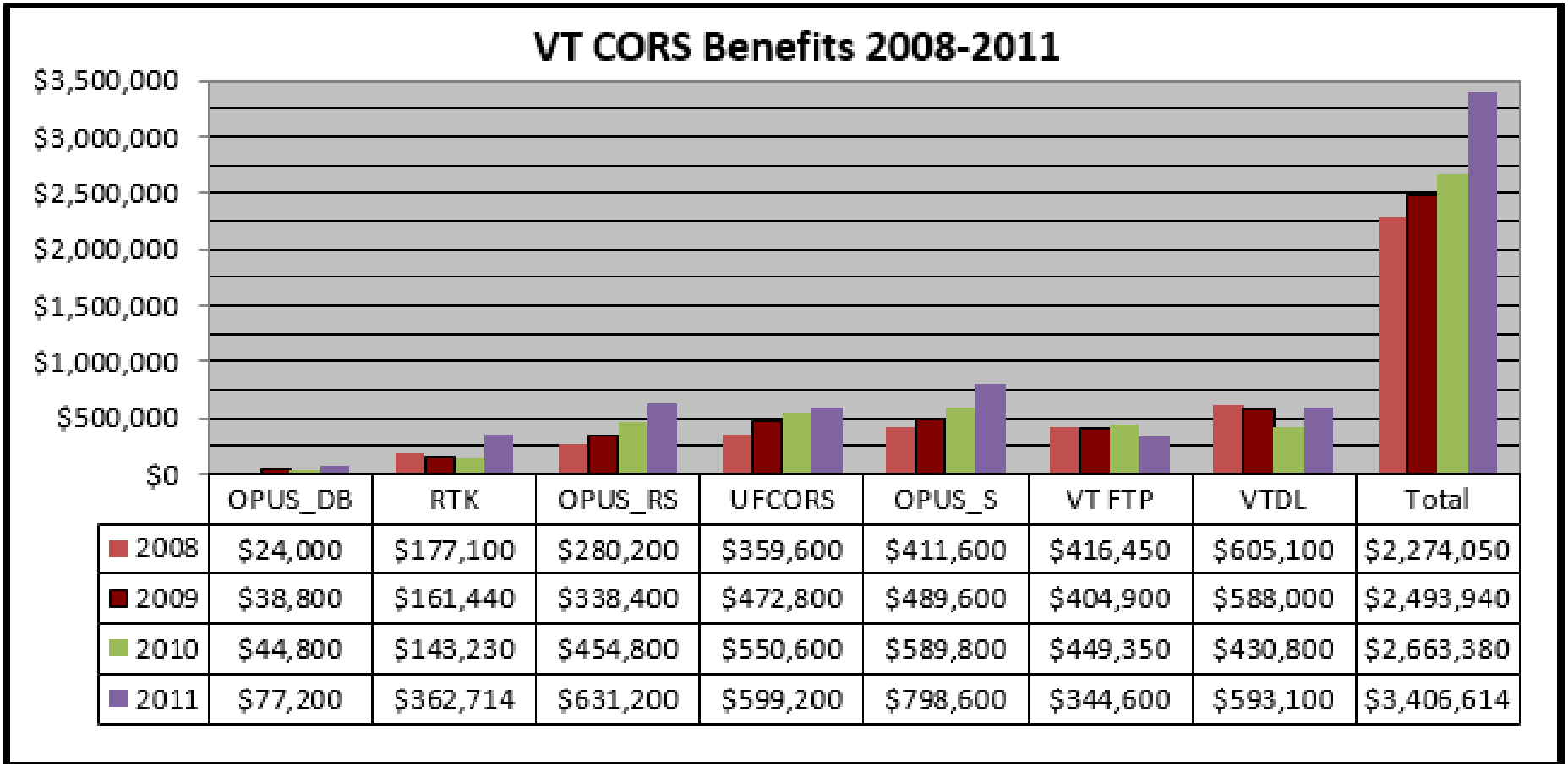
- 1996 - VCAP
- 2004 - VTUV
- 2006 – VTD2, VTSP, VTWR, VTOX, VTD7, VTD9, VTC1, VTSA, VTRU, (VCAP Upgrade)
- 2008 – VTBE, VTDA, VTMI, VTIP
- 2011 – VTRI
- 2013 – VTEB
- 2014 - VTJS

Product	*User Benefit*
UFCORS	$200/download
VT Web Download (VTDL)	$100/1-hour file
VT FTP Download	$50/1-hour file
OPUS_S	$600/solution
OPUS_RS	$600/solution
OPUS_DB	$400/submission
RTK	$100/hour

Table 1 – User Benefits per VT CORS Product

Product	*2011 Usage*
UFCORS Downloads	2996 2-hr files (ave)
VT Web Download (VTDL)	5931 1-hr files
VT FTP Download	6892 1-hr files
OPUS_S	1331 Solutions
OPUS_RS	1052 Solutions
OPUS_DB	193 Submissions
RTK	3627 Hours

Table 2 – VT CORS Data and Product Usage in 2011



	OPUS_DB	RTK	OPUS_RS	UFCORS	OPUS_S	VT FTP	VTDL	Total
2008	$24,000	$177,100	$280,200	$359,600	$411,600	$416,450	$605,100	$2,274,050
2009	$38,800	$161,440	$338,400	$472,800	$489,600	$404,900	$588,000	$2,493,940
2010	$44,800	$143,230	$454,800	$550,600	$589,800	$449,350	$430,800	$2,663,380
2011	$77,200	$362,714	$631,200	$599,200	$798,600	$344,600	$593,100	$3,406,614

Figure 2 – Taxpayer Benefits 2008 -2011

OPUS Share (DB)

- 1044 stations positioned in VT since 2009
  - Many of these stations have redundant observations
- 64 marks observed in 2018 (GPSonBM) to support the generation of Geoid18

VECTOR

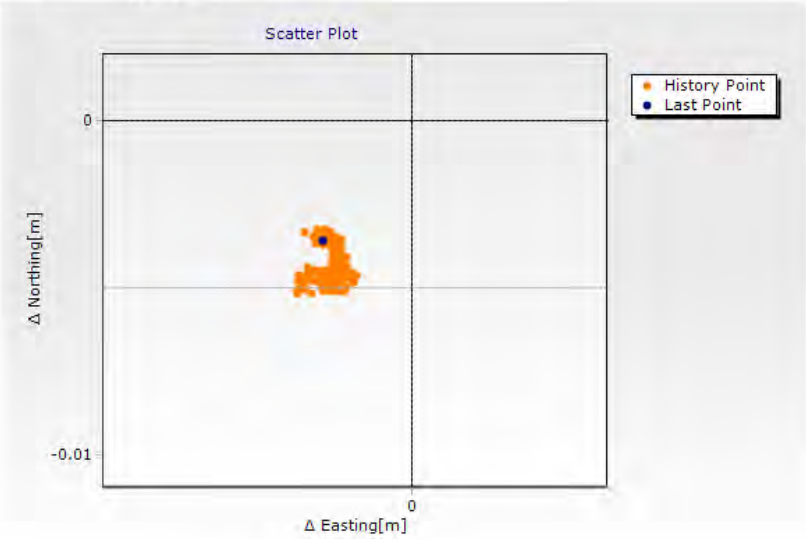
- Home
  - Sensor Map
  - Position Scatter Plot
  - Status Messages
  - **Network Information**
    - I95 Ionosphere
    - IRIM/GRIM
  - Reference Data Shop
  - **My Account**
    - Personal Data
    - Change Password
    - Logins
    - Sessions
  - Active Subscriptions
  - **Organization Details**
    - Active Subscriptions
    - Expiring Subscriptions
  - Logout
- External Links
  - VTrans

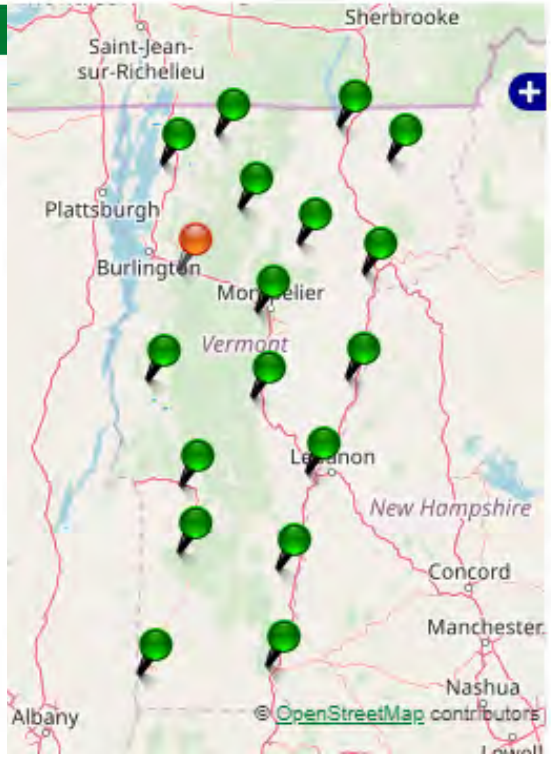
Logged in as NOAA/dan

Position Scatter Plot

Timespan: Last 24 hours

Sensor: VCAP

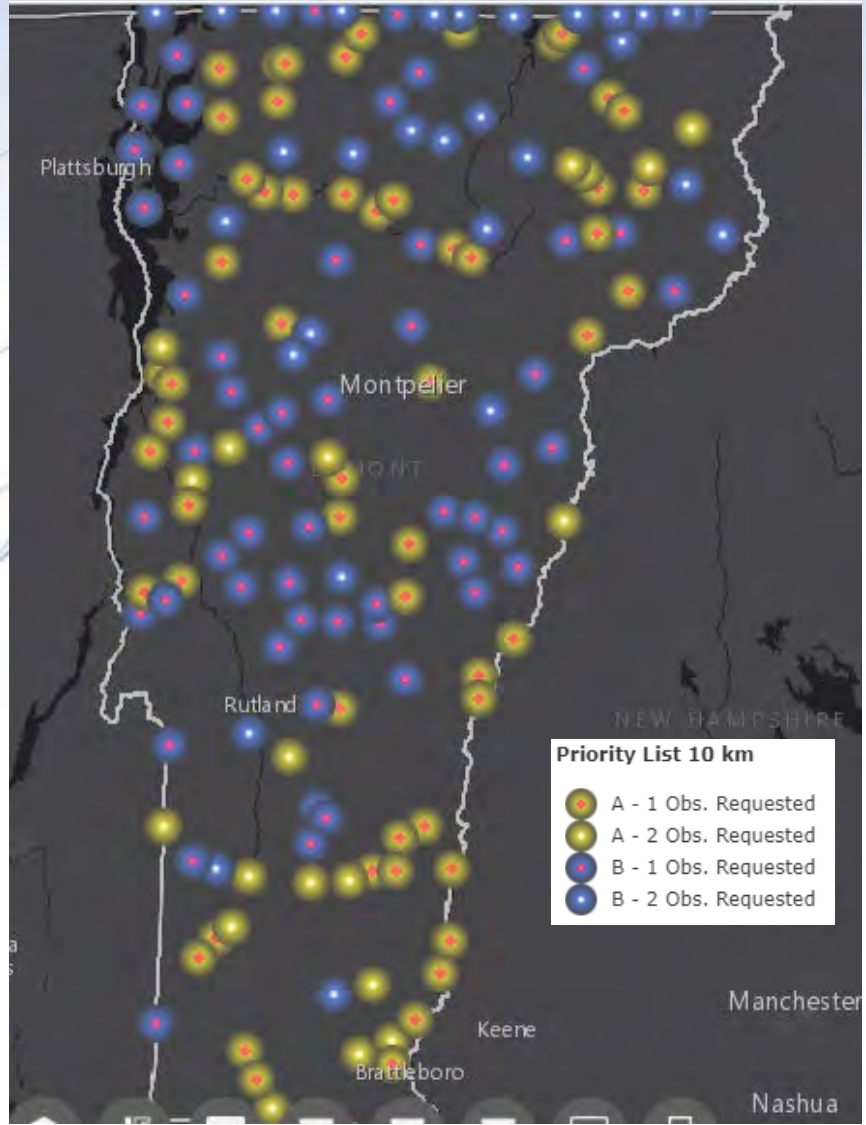




18 sensors:

- VCAP
- VJSC
- VTBE
- VTC1
- VTD2
- VTD7
- VTD9
- VTDA
- VTEB
- VTHA
- VTIP
- VTMI
- VTOX
- VTRI
- VTRU
- VTSA
- VTSP
- VTWR

GPSonBM 2019



- 612 priority marks in VT
  - 156 A1 marks
  - 101 A2 marks
- 357 Priority A observations

Questions?

Presentation available at:
https://www.ngs.noaa.gov/web/science_edu/presentations_library/

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