Maine Geological Survey
DEPARTMENT OF CONSERVATION
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Title: Crustal Subsidence in Eastern Maine

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Re: Interim report on crustal subsidence in eastern Maine

Abstract

Comparison of vertical leveling data from the U. S. Coast and Geodetic Survey 1942 and 1966 surveys of the line from Bangor to Calais, Maine, coupled with geological and historical data, indicates that the coastal zone is warping downward towards the east. Between 1942 and 1966 the relative subsidence was up to 175mm. This is a minimum figure.

Data

The first order level line from Bangor to Calais following the Maine Central Railroad through Ellsworth and Machias was first established in 1927 by the U. S. Coast and Geodetic Survey (now the National Geodetic Survey, NGS). The line was completely resurveyed in 1942 and 1966 and the eastern fifty kilometers from Machias to Calais was resurveyed in 1953. Repeated geodetic leveling data of this type represents perhaps the best single source of quantitative information on relative vertical crustal motion.

The 1942, 1953 and 1966 level data are presented in Table 1 and Figure 1. Field data from the 1927 survey is not available at the time of this writing. Table 2 gives the relative elevation of benchmarks common to the three dates of survey. The 1966 survey has been selected as the base year. Benchmark V8 in Bangor has been assigned the elevation of 10.9400 meters in 1966 and 1942. Elevations of other benchmarks in the line have been computed using

observed, unadjusted differences in elevation between adjacent benchmarks for each epoch. The delta elevation column in Table 1 shows the difference in the observed elevation of each benchmark common to the two epochs. The 1953 survey data has been incorporated into Table 1 by assigning benchmark W92 in Machias an elevation of 32.1747 meters in both 1953 and 1966. It must be emphasized that the elevations shown are relative and will indicate only relative crustal motion. This is the only kind of information that can be directly extracted from level data of this sort without tide gage data and related eustatic variation in sea level.

Figure 1 is a graphic presentation of the same data given in Table 1. The straight black line represents the baseline 1966 data while the red line shows the divergence of the 1942 elevations. The 1953 survey data is shown as a black line from 1973 KM to the end of the line. The terrain is shown in green at a reduced vertical scale. Benchmarks 24±06 at 188.29 KM and 73±81.4 at 214.38 KM have extremely high divergences of 623. mm and 718. mm and are not shown to scale.

Explanation of Data

The data shown in Table 1 and Figure 1 indicates a total divergence of approximately 175. mm between the 1942 and 1966 survey. Four possible explanations of this divergence are:

a. Accumulation of random errors

b. Incorrectly modeled systematic errors

c. Local movement or instability of individual benchmarks

d. Crustal warping or faulting

Accumulation of Random Error, The random error inherent in any surveying measurement progates through a level line as a function of the square root of the length of the line. Based on past experience the NGS estimates that the random error in a first order level line will be 1.5 $\sqrt{L}$ mm for lines observed between 1917 and 1955 and 1.0 $\sqrt{L}$ mm for lines observed after 1955 where L is the length of the line in KM. If the line from Bangor to Calais is considered a closed loop (Bangor-Calais-Bangor) the expected random error would be 1.5 $\sqrt{450}$ = 32. mm. This is substantially less than 175 mm divergence and therefore another cause is indicated.

Systematic Errors, There is a considerable amount of geodetic literature devoted to the study of systematic errors or effects in level lines. These effects are believed to accumulate in proportion to the length of the level line and are due to incorrect compensation for atmospheric refraction and settling of the level instrument and rods among other things. A detailed analysis of the Bangor to Calais line to isolate systematic effects has not been made at this time. However, it is extremely doubtful that systematic errors can account for a significant portion of the total divergence observed on this line.

Instability of Benchmarks, Instability of individual benchmarks may account for some of the "spikes" in the data shown in Figure 1, but cannot account for the trend of motion indicated. Benchmarks 24±06 and 73±81.4 are on an unmarked rock outcrop and an unmarked large boulder respectively. These two benchmarks, originally established by the MCRR, may have been misidentified in 1966.

Crustal Warping or Faulting, A preliminary analysis of the Bangor to Calais level line indicates that a significant portion of the observed elevation differences from 1942 to 1966 must be caused by vertical motion of the earth's crust. The direction and magnitude of the 1953 partial survey reinforces this conclusion. Analysis of eustatic sea level change, upward growth of saltmarshes, and the ongoing submergence of historic structures clearly indicates a downward rather than upward vertical crustal motion. The amount of subsidence of the crust indicated in Fig. 1 is a minimal figure. A more thorough analysis of this level line and others in the Coastal Region of Maine is in progress to further test the hypothesis of crustal motion and if crustal motion is verified, to measure its present and past magnitude, its geography and the way the deformation is being accomodated by the Earth's crust.

OUTPUT FOR BANGOR TO CALAIS LINE.

NAME	DISTANCE (KM)	EL 1966 (M)	EL 1953 (M)	DELTA EL. (MM)	EL 1942 (M)	DELTA EL. (MM)
V8	0.00	10.9400	0.0000	0.0	10.9400	0.0
U8	0.48	12.1017	0.0000	0.0	12.0758	25.9
K89	1.56	22.6020	0.0000	0.0	22.6112	-9.2
M89	6.47	39.0068	0.0000	0.0	38.9859	20.9
N89	7.94	25.9022	0.0000	0.0	25.9046	-2.4
Q89	11.99	43.2954	0.0000	0.0	43.2934	2.0
R8	12.95	51.4817	0.0000	0.0	51.4856	-3.9
Q8	14.77	75.4075	0.0000	0.0	75.4132	-5.7
R89	16.52	71.1945	0.0000	0.0	71.2070	-12.5
F8	17.32	60.9915	0.0000	0.0	61.0048	-13.3
T89	19.42	71.6218	0.0000	0.0	71.6372	-15.4
U89	20.97	72.1996	0.0000	0.0	72.2122	-12.6
N8	22.51	77.4193	0.0000	0.0	77.4466	-27.3
V89	22.94	74.0387	0.0000	0.0	74.0607	-22.0
W89	24.45	83.4965	0.0000	0.0	83.5173	-20.8
X89	24.84	79.5483	0.0000	0.0	79.5672	-18.9
Y89	26.21	66.1846	0.0000	0.0	66.2025	-17.9
Z89	27.83	55.6060	0.0000	0.0	55.6303	-24.3
L8	28.05	54.2723	0.0000	0.0	54.2963	-24.0
A9Ó	29.36	58.7762	0.0000	0.0	58.8010	-24.8
K8	30.92	70.9718	0.0000	0.0	70.9933	-21.5

B90	32.51	82.9254	0.0000	0.0	82.9430	-17.6
C90	34.15	83.2884	0.0000	0.0	83.3043	-15.9
J8	34.90	83.3038	0.0000	0.0	83.2887	15.1
D90	35.77	79.3319	0.0000	0.0	79.3499	-18.0
H8	37.30	73.8845	0.0000	0.0	73.8995	-15.0
E90	39.03	75.4932	0.0000	0.0	75.4996	-6.4
F90	40.46	54.1142	0.0000	0.0	54.1338	-19.6
G8	41.22	51.5184	0.0000	0.0	51.4793	39.1
G90	42.15	45.3494	0.0000	0.0	45.3389	10.5
J90	45.36	38.7756	0.0000	0.0	38.7680	7.6
K90	46.64	41.1447	0.0000	0.0	41.1414	3.3
E8	47.36	34.3577	0.0000	0.0	34.3561	1.6
Z88	48.42	45.6724	0.0000	0.0	45.6667	5.7
L90	49.44	42.0929	0.0000	0.0	42.0925	0.4
C8	52.41	60.1703	0.0000	0.0	60.1763	-6.0
M90	54.29	33.9503	0.0000	0.0	33.9517	-1.4
B8	55.20	21.4880	0.0000	0.0	21.4924	-4.4
N90	56.42	30.5936	0.0000	0.0	30.6047	-11.1
A8	59.63	27.7033	0.0000	0.0	27.7087	-5.4
Q90	61.45	31.5401	0.0000	0.0	31.5416	-1.5
R90	63.00	22.8085	0.0000	0.0	22.8267	-18.2
Z7	63.62	21.9173	0.0000	0.0	21.9855	-68.2
S90	63.81	21.5011	0.0000	0.0	21.5205	-19.4

C1(USGS)	64.89	22.8286	0.0000	0.0	22.8505	-21.9
T90	67.04	19.2574	0.0000	0.0	19.2782	-20.8
U90	67.50	22.4980	0.0000	0.0	22.5180	-20.0
V90	68.89	22.0303	0.0000	0.0	22.0531	-22.8
X7	70.36	13.9013	0.0000	0.0	13.9240	-22.7
W90	71.42	28.1869	0.0000	0.0	28.2240	-37.1
W7	72.60	40.8423	0.0000	0.0	40.8754	-33.1
X90	74.43	58.0931	0.0000	0.0	58.1226	-29.5
V7	75.90	57.8449	0.0000	0.0	57.8818	-36.9
Y90	77.63	46.1620	0.0000	0.0	46.1879	-25.9
Z90	79.36	58.1427	0.0000	0.0	58.1687	-26.0
J91	79.53	60.7439	0.0000	0.0	60.7734	-29.5
A91	79.90	71.5272	0.0000	0.0	71.5566	-29.4
D91	82.16	81.2745	0.0000	0.0	81.3040	-29.5
C91	85.63	85.1756	0.0000	0.0	85.2085	-32.9
R88	87.22	67.7903	0.0000	0.0	67.8284	-38.1
S7	88.77	51.0457	0.0000	0.0	51.0852	-39.5
Q88	90.46	48.7565	0.0000	0.0	48.7898	-33.3
R7	93.68	27.3749	0.0000	0.0	27.4110	-36.1
P88	97.12	29.0249	0.0000	0.0	29.0312	-6.3
N88	98.97	32.9813	0.0000	0.0	33.0179	-36.6
P7	101.86	16.6188	0.0000	0.0	16.6229	-4.1
S88	104.75	32.7014	0.0000	0.0	32.7342	-32.8
T88	105.85	34.2040	0.0000	0.0	34.2372	-33.2

V88	110.46	20.7810	0.0000	0.0	20.8137	-32.7
K7	113.90	28.0173	0.0000	0.0	28.0290	-11.7
W88	117.06	23.7982	0.0000	0.0	23.8281	-29.9
J7	118.30	20.4801	0.0000	0.0	20.4646	15.5
Y88	119.85	18.2801	0.0000	0.0	18.3181	-38.0
37(USGS)	122.21	11.4082	0.0000	0.0	11.4537	-45.5
Y93	123.81	23.1917	0.0000	0.0	23.2061	-14.4
68(USGS)	126.28	20.7603	0.0000	0.0	20.8014	-41.1
Z93	127.41	21.4725	0.0000	0.0	21.4902	-17.7
A94	129.43	32.2584	0.0000	0.0	32.3028	-44.4
S94	130.73	31.6604	0.0000	0.0	31.7063	-45.9
58(USGS)	132.49	17.7382	0.0000	0.0	17.7831	-44.9
T94	134.27	27.4933	0.0000	0.0	27.5339	-40.6
U94	135.40	26.5734	0.0000	0.0	26.6249	-51.5
V94	136.09	29.9610	0.0000	0.0	29.9987	-37.7
129(USGS)	137.40	39.4711	0.0000	0.0	39.5176	-46.5
X94	139.57	38.1631	0.0000	0.0	38.2178	-54.7
R94	140.84	22.0985	0.0000	0.0	22.1455	-47.0
57(USGS)	143.01	17.4389	0.0000	0.0	17.4924	-53.5
Q94	144.79	24.3150	0.0000	0.0	24.3887	-73.7
P94	146.08	36.5818	0.0000	0.0	36.6548	-73.0
71(USGS)	148.31	21.6106	0.0000	0.0	21.6641	-53.5
N94	149.87	3.6961	0.0000	0.0	3.7475	-51.4

M94	151.49	4.3903	0.0000	0.0	4.4476	-57.3
L94	153.26	6.3588	0.0000	0.0	6.4137	-54.9
K94	154.60	4.2851	0.0000	0.0	4.3387	-53.6
EM(MIT)	156.34	13.4116	0.0000	0.0	13.4681	-56.5
44(USGS)	156.38	13.3870	0.0000	0.0	13.4433	-56.3
J94	156.83	15.0914	0.0000	0.0	15.1535	-62.1
H94	158.37	14.3842	0.0000	0.0	14.4433	-59.1
52+83	158.64	15.0939	0.0000	0.0	15.1519	-58.0
G94	159.94	15.8695	0.0000	0.0	15.9290	-59.5
F94	161.11	32.9189	0.0000	0.0	32.9791	-60.2
E94	162.45	30.2551	0.0000	0.0	30.3142	-59.1
X6	163.74	32.7169	0.0000	0.0	32.6294	87.5
D94	163.77	32.4890	0.0000	0.0	32.5457	-56.7
B94	167.71	26.3758	0.0000	0.0	26.4420	-66.2
Z92	169.24	28.8468	0.0000	0.0	28.9138	-67.0
5332	169.90	25.0582	0.0000	0.0	25.1235	-65.3
Y92	170.88	22.4490	0.0000	0.0	22.5200	-71.0
W92	172.70	32.1747	32.1747	0.0	32.2456	-70.9
V92	174.04	31.6297	31.6319	-2.2	31.7019	-72.2
5510	175.46	33.9968	33.9947	2.1	34.0675	-70.7
U6	175.59	37.3957	37.4019	-6.2	37.4789	-83.2
U92	177.21	60.7052	60.7037	1.5	60.7762	-71.0
T6	177.81	56.3886	56.3850	3.6	56.4577	-69.1
X92	178.47	47.4436	47.4371	6.5	47.5163	-72.7

T92	180.03	28.2910	28.2857	5.3	28.3627	-71.7
89	180.23	27.2178	27.2121	5.7	27.2897	-71.9
S92	181.52	26.7446	26.7375	7.1	26.8168	-72.2
R92	182.47	28.3660	28.3613	4.7	28.4386	-72.6
Q92	184.08	29.0506	29.0455	5.1	29.1284	-77.8
92(MIT)	184.68	28.0630	28.0561	6.9	28.1364	-73.4
R6	184.90	26.7833	26.7681	15.2	26.8328	-49.5
P92	185.45	28.6377	28.6342	3.5	28.7178	-80.1
N92	187.31	40.7614	40.7602	1.2	40.8448	-83.4
24+06	188.29	44.7166	44.7159	0.7	44.0933	623.3
Q6	188.70	45.6674	45.6687	-1.3	45.7543	-86.9
M96	190.43	41.8372	41.8394	-2.2	41.9307	-93.5
L96	192.23	36.4123	36.4159	-3.6	36.5051	-92.8
O6	193.77	41.9439	41.9549	-11.0	42.0527	-108.8
K96	195.21	32.9612	32.9720	-10.8	33.0699	-108.7
J96	196.11	29.3299	29.3424	-12.5	29.4411	-111.2
H96	197.57	28.2631	28.2486	14.5	28.3345	-71.4
G96	198.80	27.9680	27.9832	-15.2	28.0919	-123.9
F96	201.04	24.4795	24.4945	-15.0	24.6039	-124.4
87+610	202.77	38.2894	38.2918	-2.4	38.4009	-111.5
E96	203.29	34.7439	34.7626	-18.7	34.8811	-137.2

L6	204.40	35.0295	35.0430	-13.5	35.1423	-112.8
C96	206.67	38.6784	38.6982	-19.8	38.8188	-140.4
B96	208.38	38.2100	38.2309	-20.9	38.3560	-146.0
A96	209.00	41.8254	41.8469	-21.5	41.9686	-143.2
Z91	210.35	43.5581	43.5906	-32.5	43.7176	-159.5
Y91	212.23	48.9760	49.0028	-26.8	49.1228	-146.8
X91	213.87	35.4716	35.4891	-17.5	35.6136	-142.0
73+814	214.38	34.0694	34.0995	-30.1	33.3510	718.4
W91	215.23	30.0322	30.0637	-31.5	30.1890	-156.8
V91	218.99	22.9927	23.0216	-28.9	23.1628	-170.1
K19	219.62	25.5015	25.5298	-28.3	25.6685	-167.0
U91	220.88	22.9693	22.9994	-30.1	23.1389	-169.6
T91	222.02	16.6031	16.6340	-30.9	16.7796	-176.5
S91	223.33	9.9082	9.9356	-27.4	10.0878	-179.6
G6	224.24	5.9386	5.9650	-26.4	6.1134	-174.8
1B(GSC)	225.02	16.4367	16.4663	-29.6	16.6126	-175.9

R; T=1.15/4.01 14:32:48

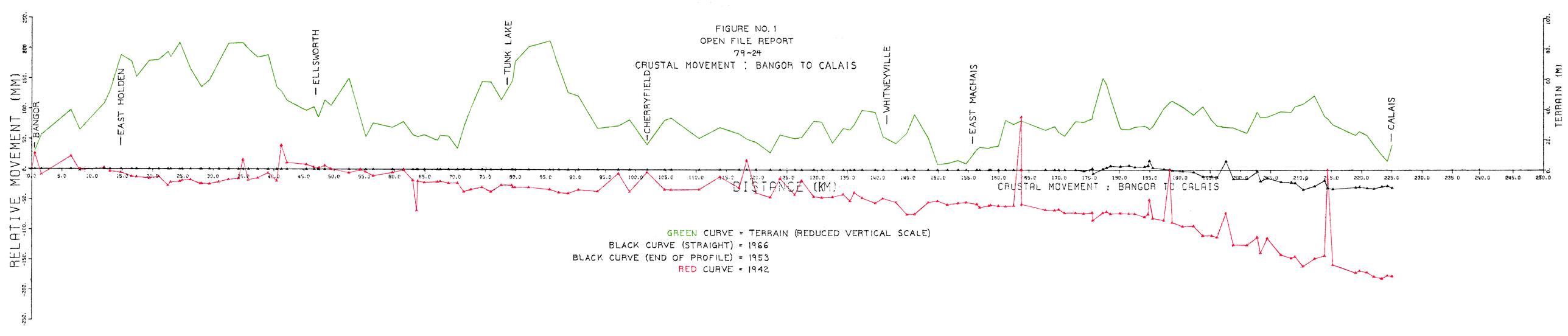
FIGURE NO. 1
OPEN FILE REPORT
79-24
CRUSTAL MOVEMENT : BANGOR TO CALAIS
BANGOR
EAST HOLDEN
ELLSWORTH
TUNK LAKE
CHERRYFIELD
WHITNEYVILLE
EAST MACHAIS
CALAIS
RELATIVE MOVEMENT (MM)
TERRAIN (M)
DISTANCE (KM)
CRUSTAL MOVEMENT : BANGOR TO CALAIS
GREEN CURVE = TERRAIN (REDUCED VERTICAL SCALE)
BLACK CURVE (STRAIGHT) = 1966
BLACK CURVE (END OF PROFILE) = 1953
RED CURVE = 1942