No. 160 ARIZONA-NASA ATLAS OF INFARED SOLAR SPECTRUM REPORT IV

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ABSTRACT

This paper is a continuation of *Comm. LPL* Nos. 123 and 124, covering the interval λλ 13138–14707 Å. Part of the spectrum of the 1.4 μ H_2O band taken with the 4-meter spectrometer in flight is included to show the absorption in the spectrometer itself. For purposes of further identification, laboratory spectra of the 1.4 μ H_2O band are given in the Addendum.

This paper gives Charts 15c–22 of the Solar Spectrum Atlas. It concludes the section recorded with the 1200 lines/mm grating, the earlier parts having been published in *Comm. LPL* Nos. 123 and 124. Starting at λ 12188 Å (and thus providing overlap), the solar spectrum was recorded with 600 lines/mm gratings, up to λ 30500 Å. This second record also covers the gap of 281 Å (λλ 12857–13138 Å) occurring between Chart 15b (Fig. 9, *Comm. LPL* No. 124) and Chart 15c, the present Fig. 1; this gap was due to shortage of observing time on the August 6 flight. Data concerning Charts 15c–22 are found in Table 1.

As before, the spectral records were obtained by two of us (G. P. K. and D. P. C.); but in this paper the construction of the wavelength scale and the classification of the absorption lines were done entirely by L. A. B. The wavelength scale is based on Mohler's *Table of Solar Spectrum Wavelengths, λ 11984 to λ 25578 A*, with additional consultation of Courtoy's *Spectre Infrarouge à Grande Dispersion et Constantes Moleculaires du CO_2* for the lines in the $3\nu_3$ band of CO_2 at λ 1.43 μ. The greater part of our present scale is based on water-vapor lines, as Mohler's *Table* gives mainly water-vapor lines in this spectral region. His H_2O wavelengths were obtained, however, from very broad and strong lines even though his measurements were done on spectra containing less water vapor than shown in the *Michigan Photometric Atlas of the Infrared Solar Spectrum λ 8465 to λ 25242*. Since in our spectra the water-vapor lines are narrow, we have sometimes used instead the *predicted* wavelengths from Mohler's *Table*. The scale between λ 13180 Å and λ 13265 Å has been interpolated.

As in *Comm. LPL* Nos. 123 and 124, we have

TABLE 1

SOLAR SPECTRUM RECORDS, 4-M SPECTROMETER, NASA CV-990 JET

1 μ GRATING (1200 LINES/MM), SLIT AND CELL 0.10 MM, $\tau = 0.12$ SEC, 1 μ FILTER

FIG.	CHART	λ (Å)	1968 DATE	UT	ALT. (FT.)	TEMP (°C)	CABIN ALT. (FT.)	GAIN
1	15. c	13138–13197	Aug 6	18:45	41,500	−58	8800	5–2
	d	13197–13257	Aug 6	18:48	41,500	−58	8800	5–2
2	16. a	13257–13314	Aug 6	18:51	41,500	−58	8800	5–2
	b	13314–13371	Aug 6	18:55	41,500	−58	8800	5–2
	c	13371–13428	Aug 6	18:58	41,500	−58	8800	5–2
	d	13428–13484	Aug 6	19:01	41,500	−58	8800	5–2
3	17. a	13484–13541	Aug 6	19:05	42,000	−58	8800	5–2
	b	13541–13597	Aug 6	19:08	42,000	−58	8800	5–2
	c	13597–13652	Aug 6	19:11	42,000	−58	8800	5–2
	d	13652–13708	Aug 6	19:15	42,000	−58	8800	5–2
4	18. a	13708–13762	Aug 6	19:18	41,500	−57	8800	5–2, 5–3
	b	13762–13816	Aug 6	19:21	41,500	−57	8800	5–3
	c	13816–13871	Aug 6	19:25	41,500	−57	8800	5–3
	d	13871–13924	Aug 6	19:28	41,500	−57	8800	5–3
5	19. a	13924–13976	Aug 6	19:31	41,500	−57	8800	5–3
	b	13976–14029	Aug 6	19:34	41,500	−57	8800	5–3
	c	14029–14079	Aug 6	19:38	41,300	−56	8800	5–3
	d	14079–14130	Aug 6	19:41	41,300	−56	8800	5–3
6	20. a	14130–14182	Aug 6	19:44	41,500	−57	8800	5–3
	b	14182–14231	Aug 6	19:48	41,500	−57	8800	5–3
	c	14231–14281	Aug 6	19:51	41,500	−57	8800	5–3
	d	14281–14331	Aug 6	19:54	41,500	−57	8800	5–3
7	21. a	14331–14379	Aug 6	19:58	41,500	−58	8800	5–3
	b	14379–14427	Aug 6	20:01	41,500	−58	8800	5–3
	c	14427–14477	Aug 6	20:04	41,500	−58	8800	5–3
	d	14477–14523	Aug 6	20:00	41,500	−58	8800	5–3
8	22. a	14523–14570	Aug 6	20:12	41,500	−59	8800	5–3
	b	14570–14618	Aug 6	20:15	41,500	−59	8800	5–3
	c	14618–14662	Aug 6	20:18	41,500	−59	8800	5–3
	d	14662–14707	Aug 6	20:21	41,500	−59	8800	5–3

TABLE 2

SOLAR LINES NOT RECORDED BEFORE, OR CLASSIFIED ATMOSPHERIC (*)

EQUIVALENT WIDTHS IN MÅ

λ	mÅ	λ	mÅ	λ	mÅ	λ	mÅ	λ	mÅ	λ	mÅ
13153.1	49	13546.3	64	13776.6*	38	13968.2*d*	46	14113.2	55	14437.7	28
13264.4*	39	13552.1	23	13790.3[1]	20	13979.4	20	14121.3	66	14439.4	47
13285.7*	72	13564.7*	108	13828.3	21	13990.9	24	14123.7**d*	35	14460.7	19
13290.8	39	13581.3	54	13831.9	73	13996.1	88	14169.6	19	14465.7*	30
13291.6*	180	13588.2	15	13842.6	12	13998.0	106	14202.3	47	14478.9	21
13292.4	24	13589.2*d*	36	13849.7	52	14004.7	37	14211.2*	16	14498.1*	92
13297.5	88	13626.8	112	13864.2	107	14007.4	110	14213.5	18	14545.2	30
13321.3	110	13632.0*b*	114	13871.0	24	14026.7	42	14244.1	15	14548.8	41
13327.5*	117	13667.3	100	13873.2	17	14039.2	23	14275.7	34	14553.9*	14
13384.5	8	13693.8	158	13876.8	34	14040.2	9	14292.4	140	14566.5*	134
13389.5	72	13697.8*	37	13882.9*d*	38	14043.5*	25	14332.2*	28	14581.6	18
13432.4*	78	13711.7	140	13897.4	136	14060.8	37	14365.7*	23	14589.3*	25
13472.4	23	13722.6	39	13905.7	112	14073.6*	114	14370.3	10	14610.9	25
13494.8	28	13725.1	31	13940.1*	28	14081.0	26	14391.6	74	14654.4*	34
13499.4	20	13744.0	28	13957.0*	18	14081.5	46	14399.8	165	14658.3	13
13499.9	17	13756.0	177	13966.3	14	14084.1*d*	33	14403.4*	95	14679.9*	58
13502.0	125	13772.1	21	13967.2*	40	14099.7*	40	14420.3*	147	14703.1*b*	154

d = double line; *b* = blend with telluric line.

1) In Mich. catalog a 20 mÅ Ni line is given at λ 13791.35.

TABLE 3

LINES BEFORE LISTED AS ⊙ OR ⊙? BUT NOT PRESENT IN OUR RECORDS

λ (Å)	eq. width (mÅ)	λ (Å)	eq. width (mÅ)	λ (Å)	eq. width (mÅ)
13 233.75	27	13 493.90	42	14 385.48	43
13 239.56		13 890.06	21	14 481.82	30
13 360.68	16	13 891.25	21	14 559.56	11
13 427.28	68	13 891.64	55	14 669.61	28
13 471.21	109	13 900.78	18	14 695.52	41
13 478.84	14	13 929.14	18		

included the corresponding parts of the Michigan *Photometric Atlas* (Fig. 1M–8M). Comparing these spectra shows the tremendous advantage of high-altitude observations. Solar lines, previously masked by water-vapor absorptions or classified as "atmospheric," are listed in Table 2 (limited to lines with equivalent width $\geqslant$ 10 mÅ). Lines listed in the Mohler *Table* as "solar" or "probably solar," but absent is our spectra (and therefore probably telluric), are found in Table 3.

Unlike the 0.93 μ and 1.13 μ H_2O bands, the spectrometer absorptions of the 1.4 μ H_2O band are not entirely negligible. These absorptions may be estimated from the spectrum in Fig. A (corresponding in wavelength to the solar spectra, Figs. 4c, d and 5a, b). This spectrum was taken during the flight of August 6 before the solar observations; the aircraft altitude was 33,000 ft (41,500 ft for the solar observations) and the cabin pressure 6800 ft (8800 ft for the solar observations). As the spectrometer was flushed with outside air, both factors, especially the aircraft altitude, will have increased the strength of the H_2O comparison spectrum by a factor computed to be about 4 times for the weaker lines (depth < 0.3) and somewhat less for stronger lines. The equivalent widths of the lines in Fig. A are on the average about ⅔ of those of the water-vapor lines in the solar spectra; therefore, the equivalent widths in the cabin-spectrometer spectrum, if observed separately, would have been about 1/6 of those in the solar records, and this fraction would, for the weaker lines, be its contribution in the solar records. For strong lines the distortion caused by the inside water vapor will be less in the central portions of the lines; the extreme wings, however, will be largely due to the inside air (owing to its higher pressure). Also, the H_2O content may have varied during the record because some cirrus clouds were noted at the 33,000-ft level.

As before, a series of laboratory spectra were taken to match approximately the H_2O strength in the solar spectra. A representative set is reproduced in Figs. 2A–8A of the Addendum, which matches in wavelengths Figs. 2–8 of the text. They have assisted with the H_2O identifications in the solar records, as indicated by dots above the spectral traces. Members of the $3\nu_3$ band of CO_2 are similarly marked with short vertical lines; while all absorption lines in the solar record considered as real are marked with numbered dots below the spectral traces for later reference. The identification by element or the mere classification as solar, both taken from the Mohler *Table,* are added for the stronger lines (equivalent width $\geqslant$ 15 mÅ) on the charts.

Acknowledgments. We wish to thank Messrs. J. Percy, B. McClendon, A. Thomson, and Rev. G. Sill of LPL and Mr. D. Olsen of NASA-Ames for their assistance during the flights. Mrs. A. P. Agnieray and Mr. S. M. Larson assisted in the preparation of the figures. This research was supported by NASA through Grant NsG 161-61 and the University of Arizona Institutional Grant NGR-03-002-091.

REFERENCES

Courtoy, C. P. 1959, *Spectre Infrarouge à Grande Dispersion et Constantes Moleculaires du CO_2,* Annales de la Société Scientifique de Bruxelles, Serie I, Tome 73.

Mohler, O. C., Pierce, A. K., McMath, R. R., and Goldberg, L. 1950, *Photometric Atlas of the Near Infrared Solar Spectrum, λ 8465 to λ 25242,* Ann Arbor.

Mohler, O. C. 1955, *A Table of Solar Spectrum Wavelength, λ 11984A to λ 25578A,* Ann Arbor.

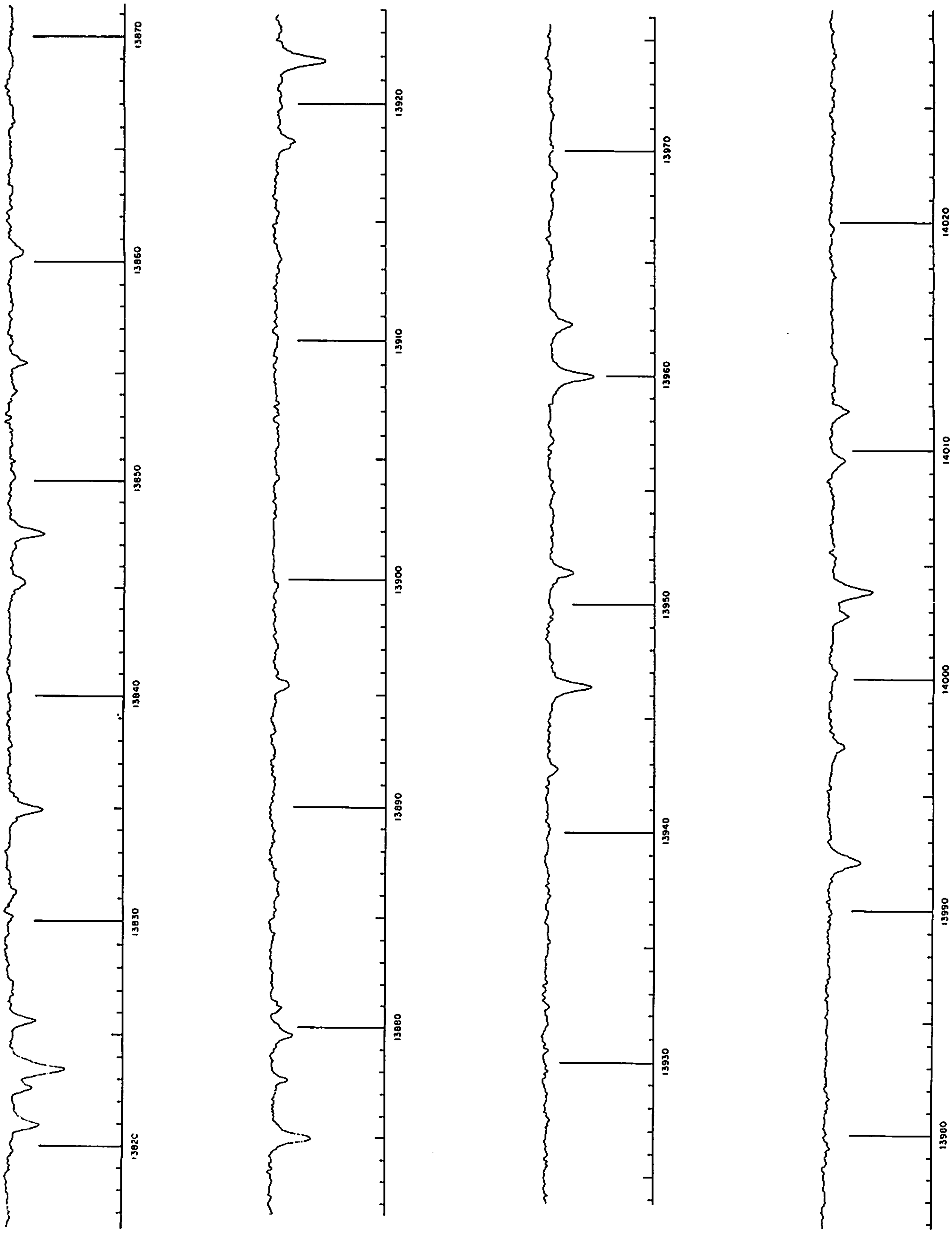

Fig. A Absorptions of water vapor in the spectrometer, λλ 13817–14029 Å, matching Figs. 4c, d, and 5a, b. For further explanation see text.

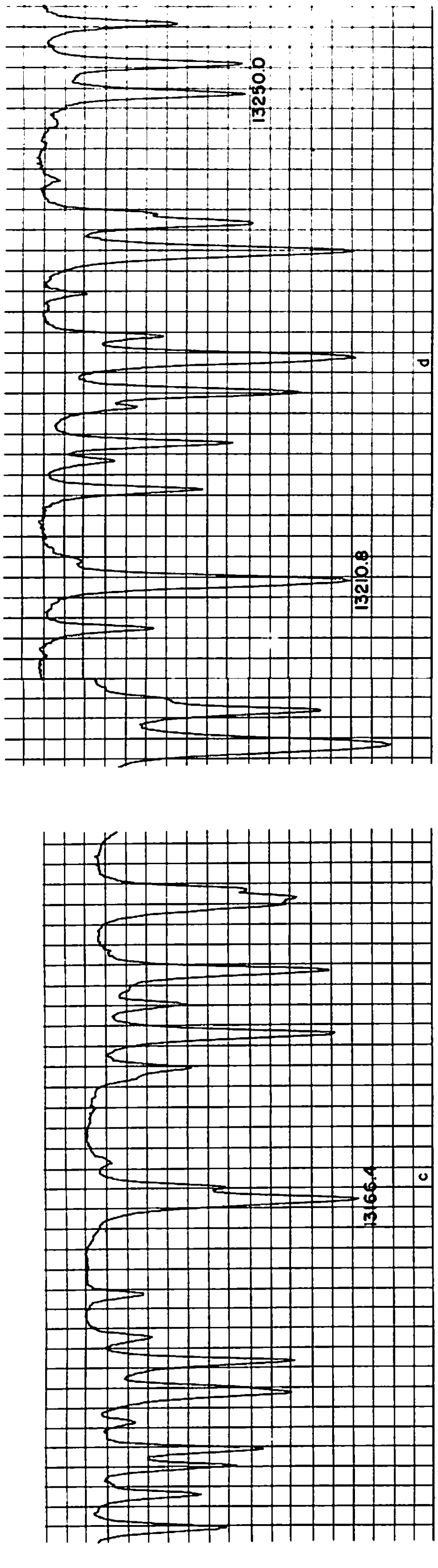

Fig. 1M Part of Michigan Atlas that matches Fig. 1 (1M–9M reproduced with permission.)

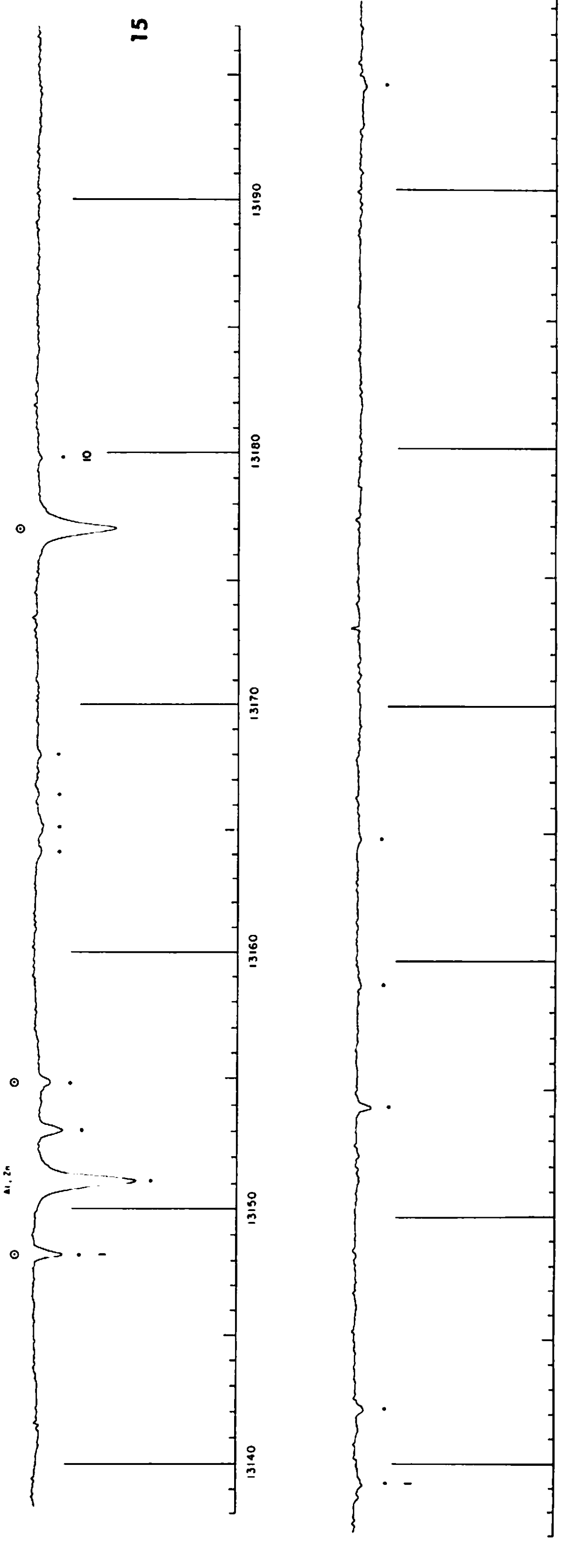

Fig. 1 Solar Spectrum λλ 13138–13257, in two strips (cf. Table 1).

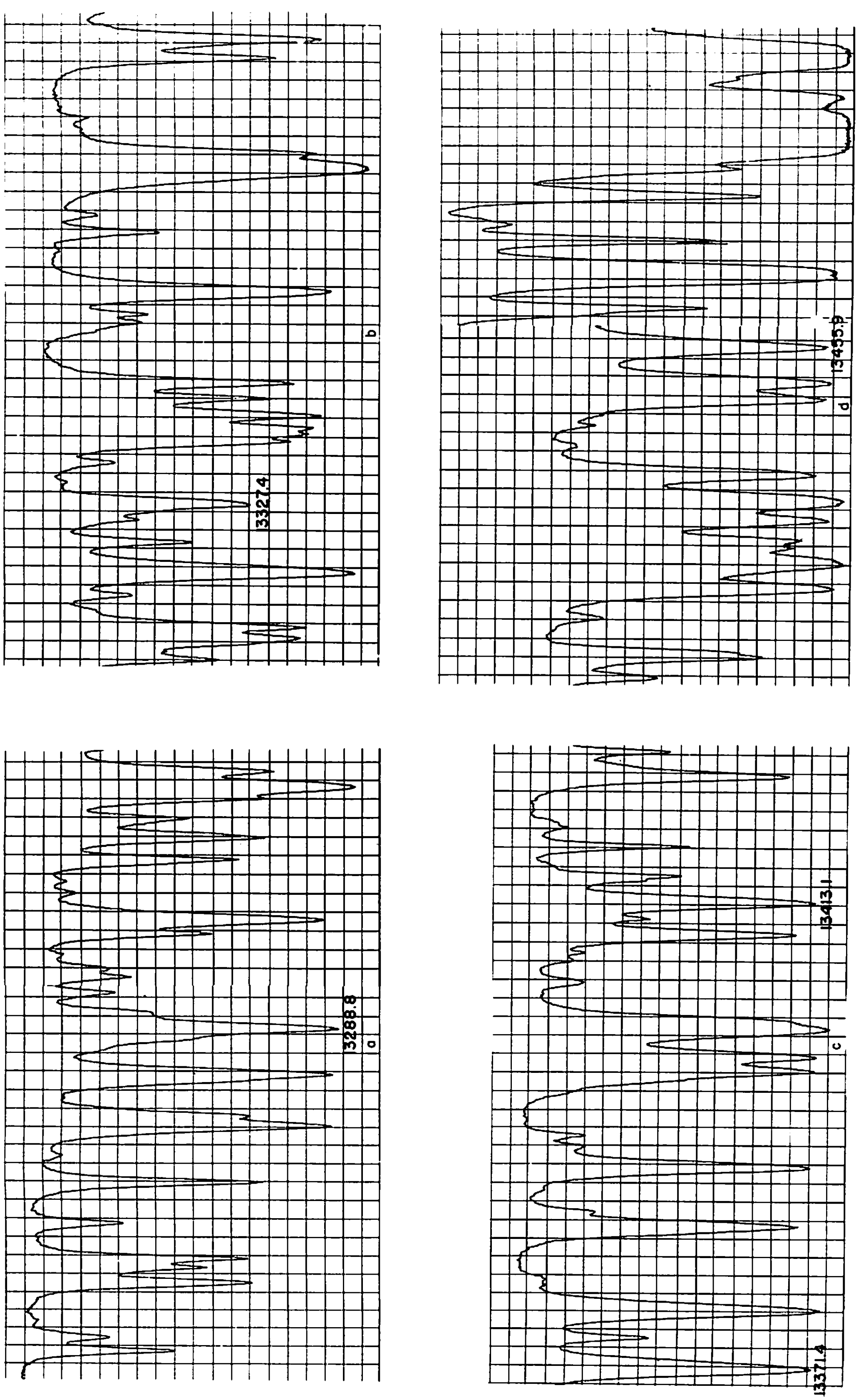

Fig. 2M Part of Michigan Atlas that matches Fig. 2.

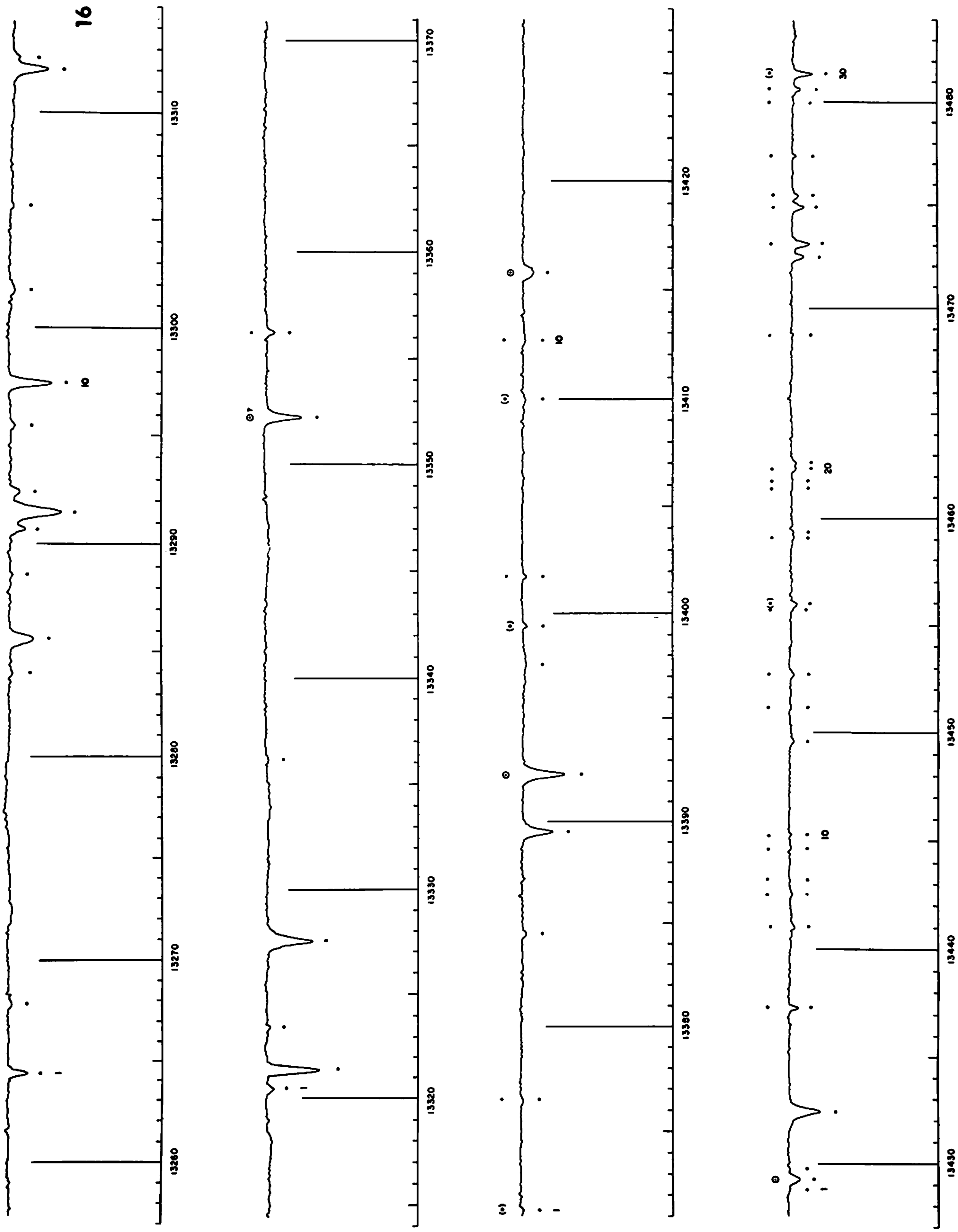

Fig. 2 Solar Spectrum λλ 13257–13484, in four strips (cf. Table 1).

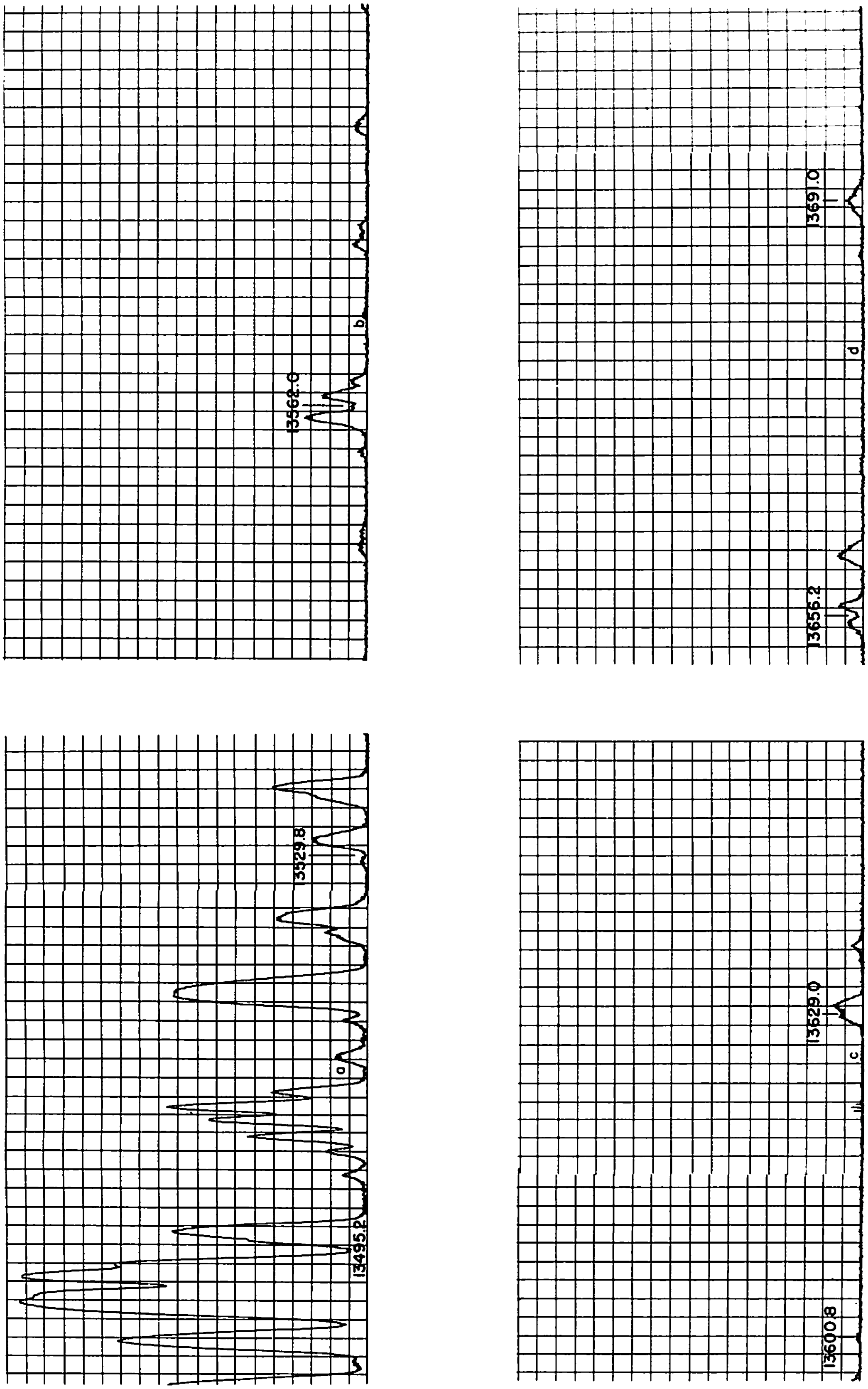

Fig. 3M Part of Michigan Atlas that matches Fig. 3.

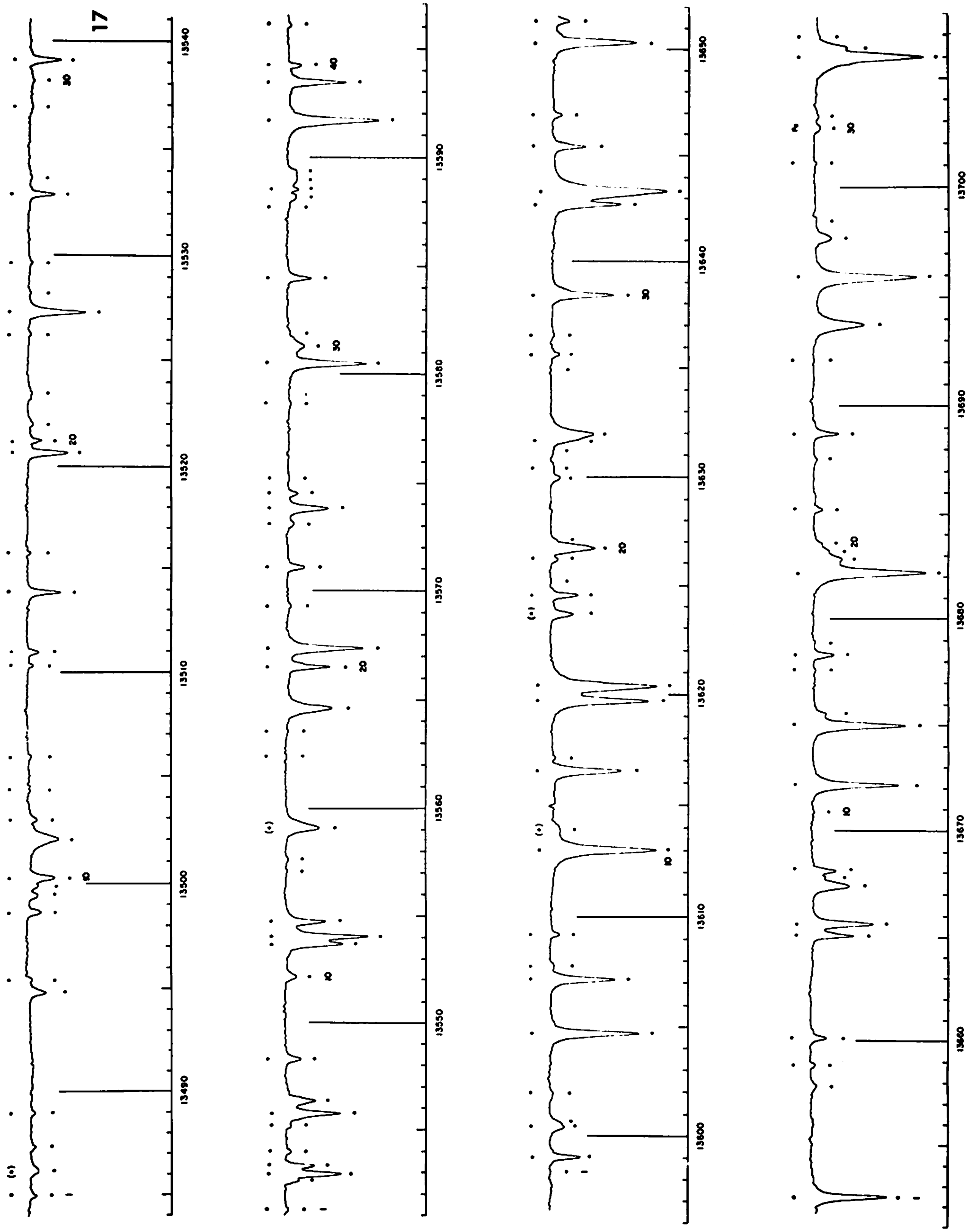

Fig. 3 Solar Spectrum λλ 13484–13708, in four strips (cf. Table 1).

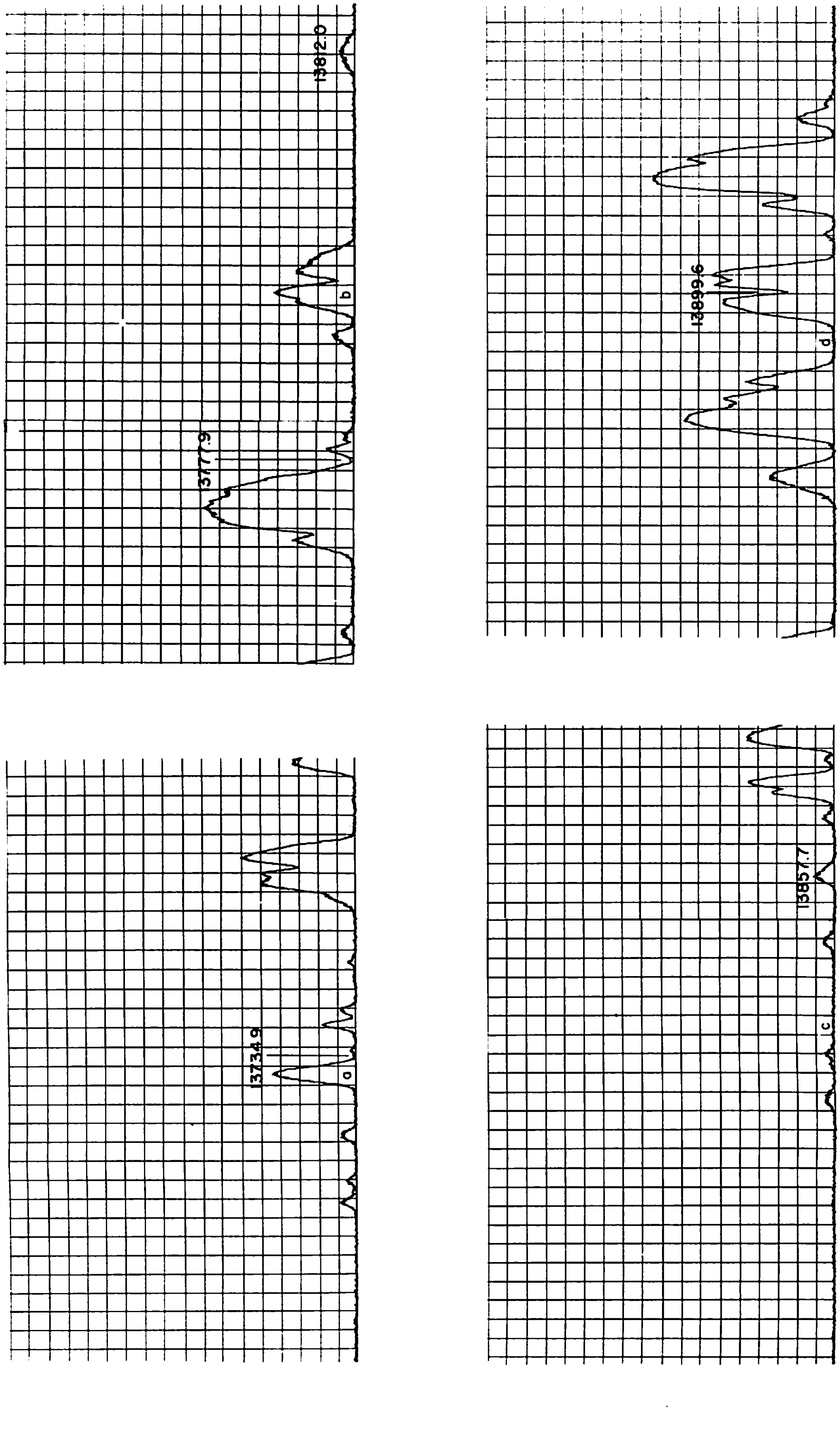

Fig. 4M Part of Michigan Atlas that matches Fig. 4.

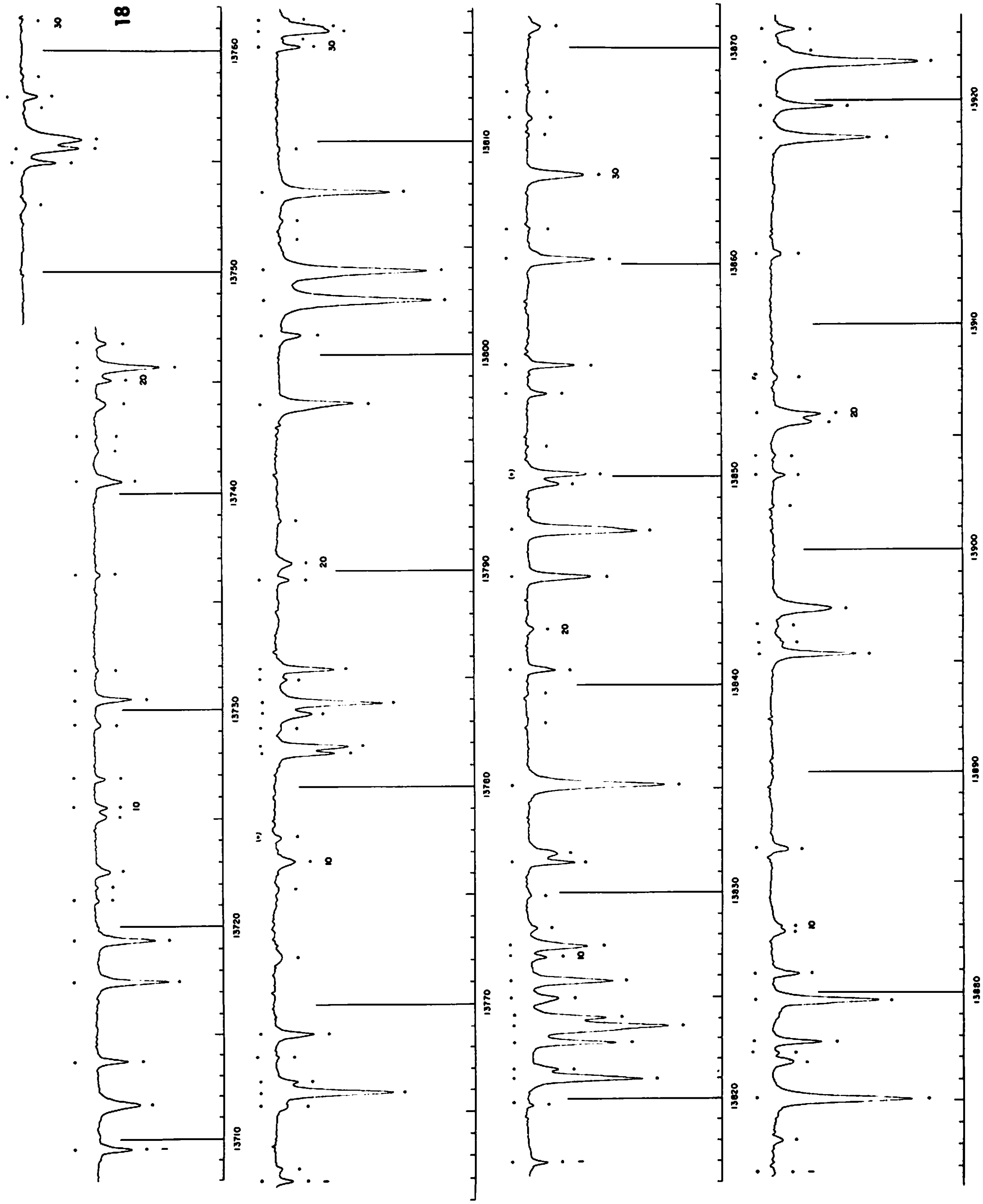

Fig. 4 Solar Spectrum λλ 13708–13924, in four strips (cf. Table 1).

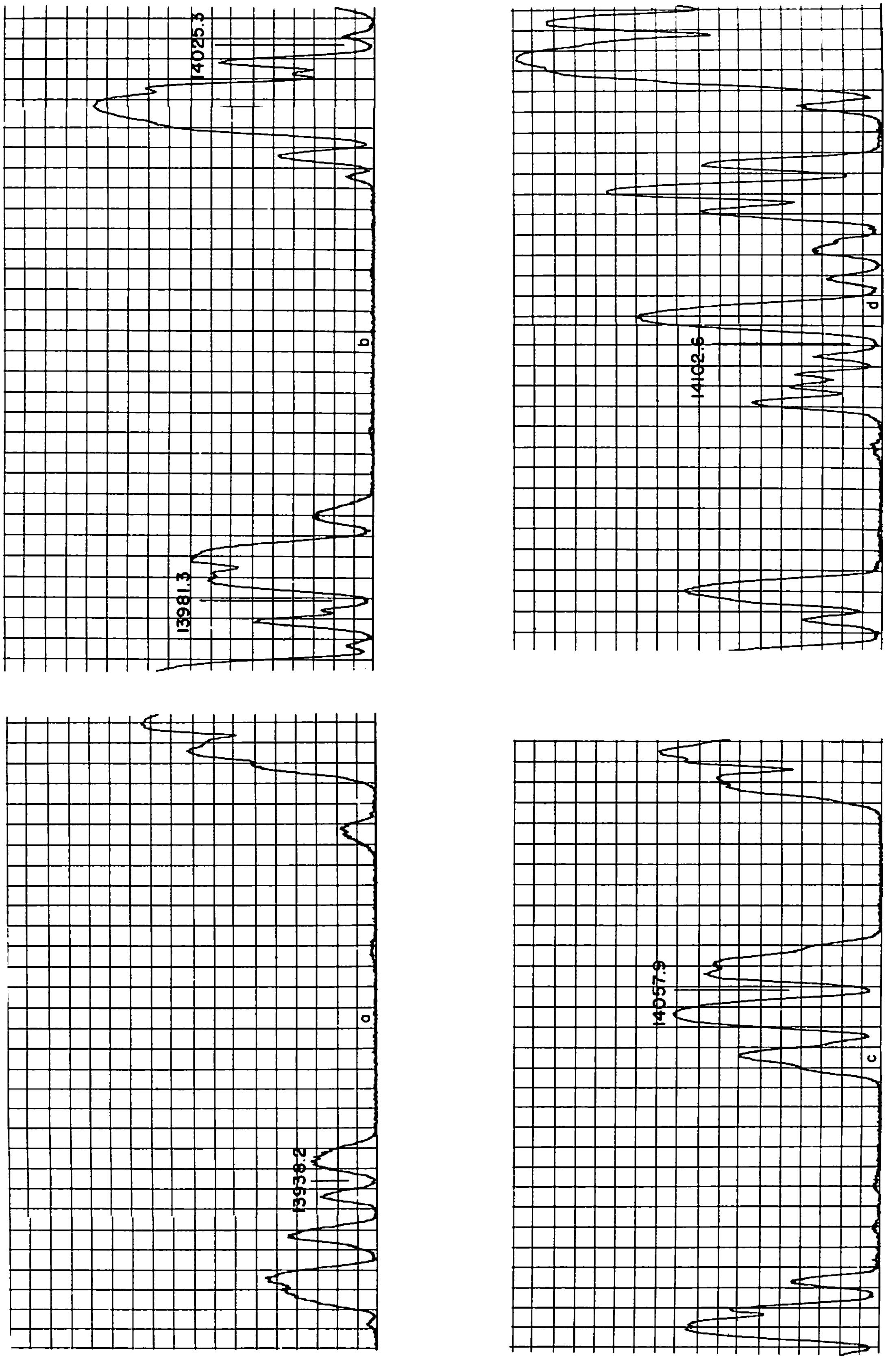

Fig. 5M Part of Michigan Atlas that matches Fig. 5.

Fig. 5 Solar Spectrum λλ 13924–14130, in four strips (cf. Table 1).

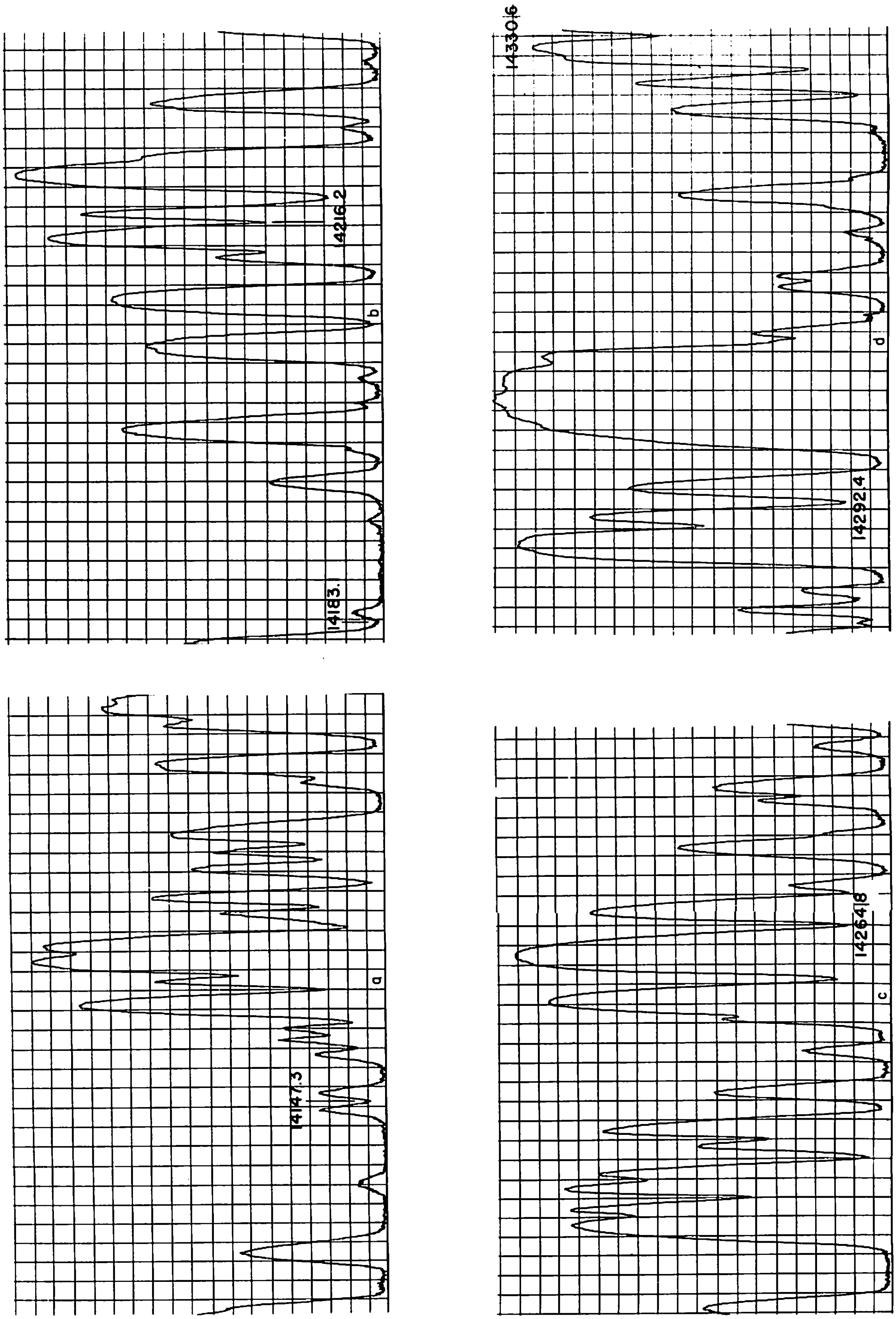

Fig. 6M Part of Michigan Atlas that matches Fig. 6.

Fig. 6 Solar Spectrum λλ 14130–14331, in four strips (cf. Table 1).

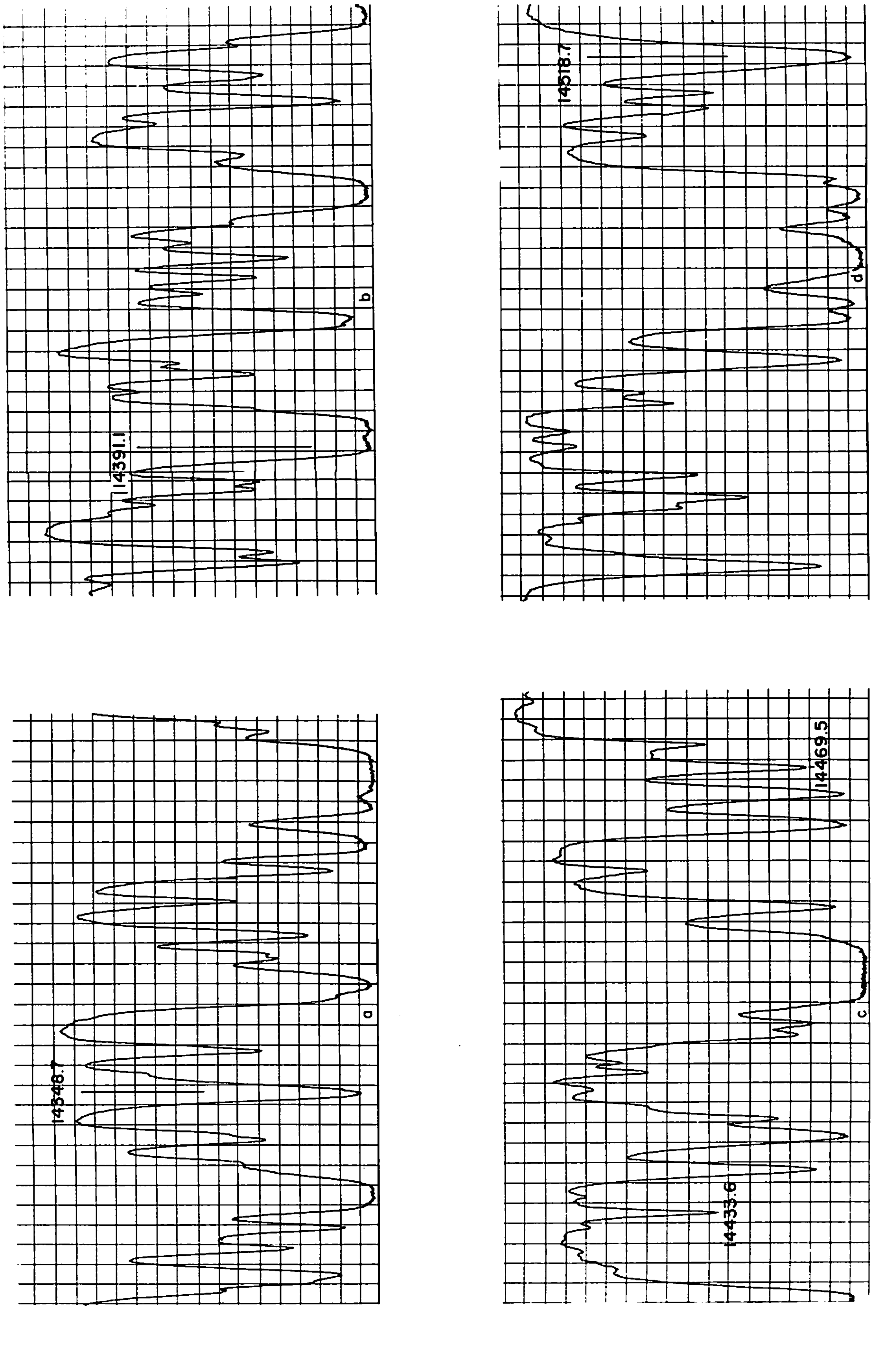

Fig. 7M Part of Michigan Atlas that matches Fig. 7.

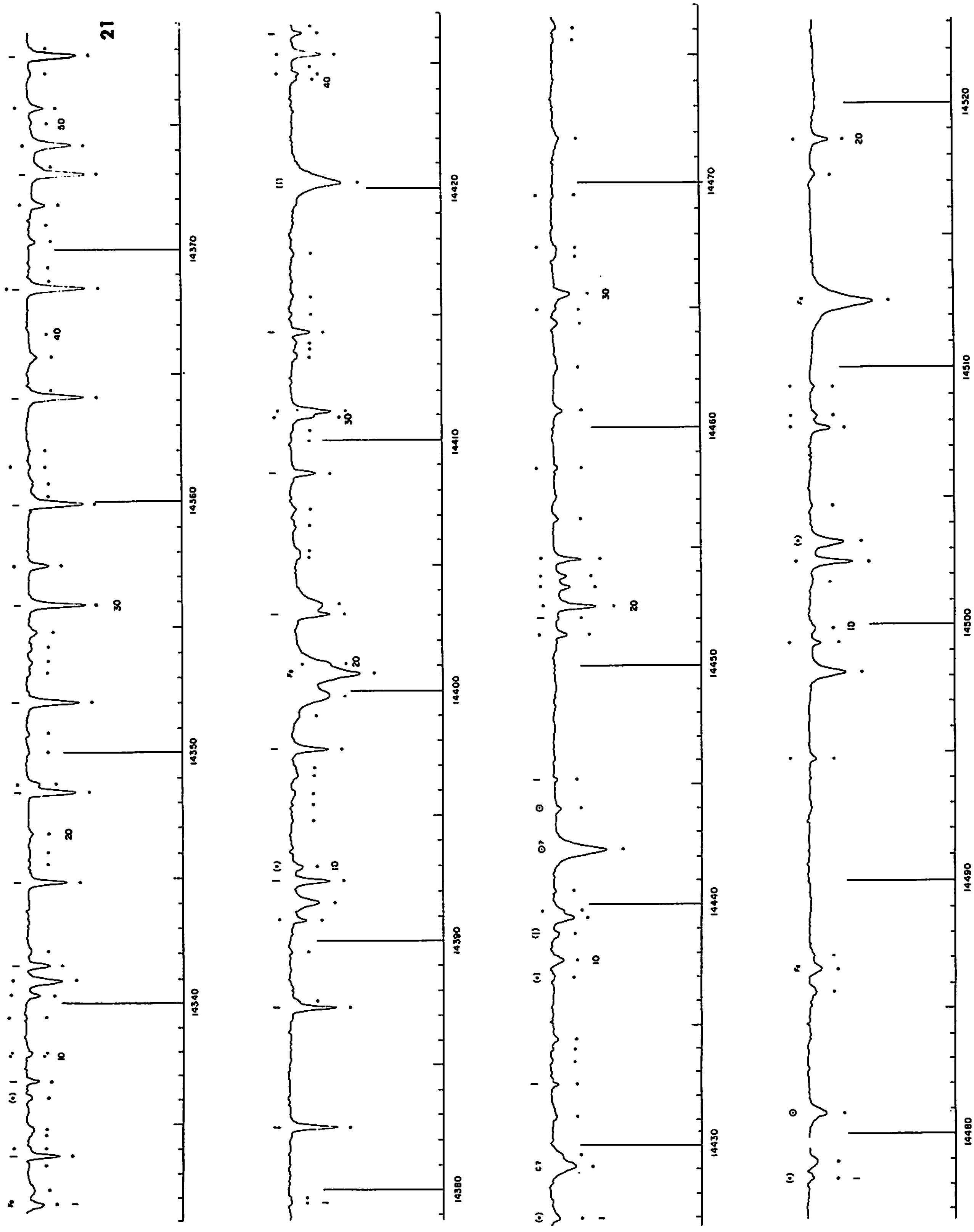

Fig. 7 Solar Spectrum λλ 14331–14523, in four strips (cf. Table 1).

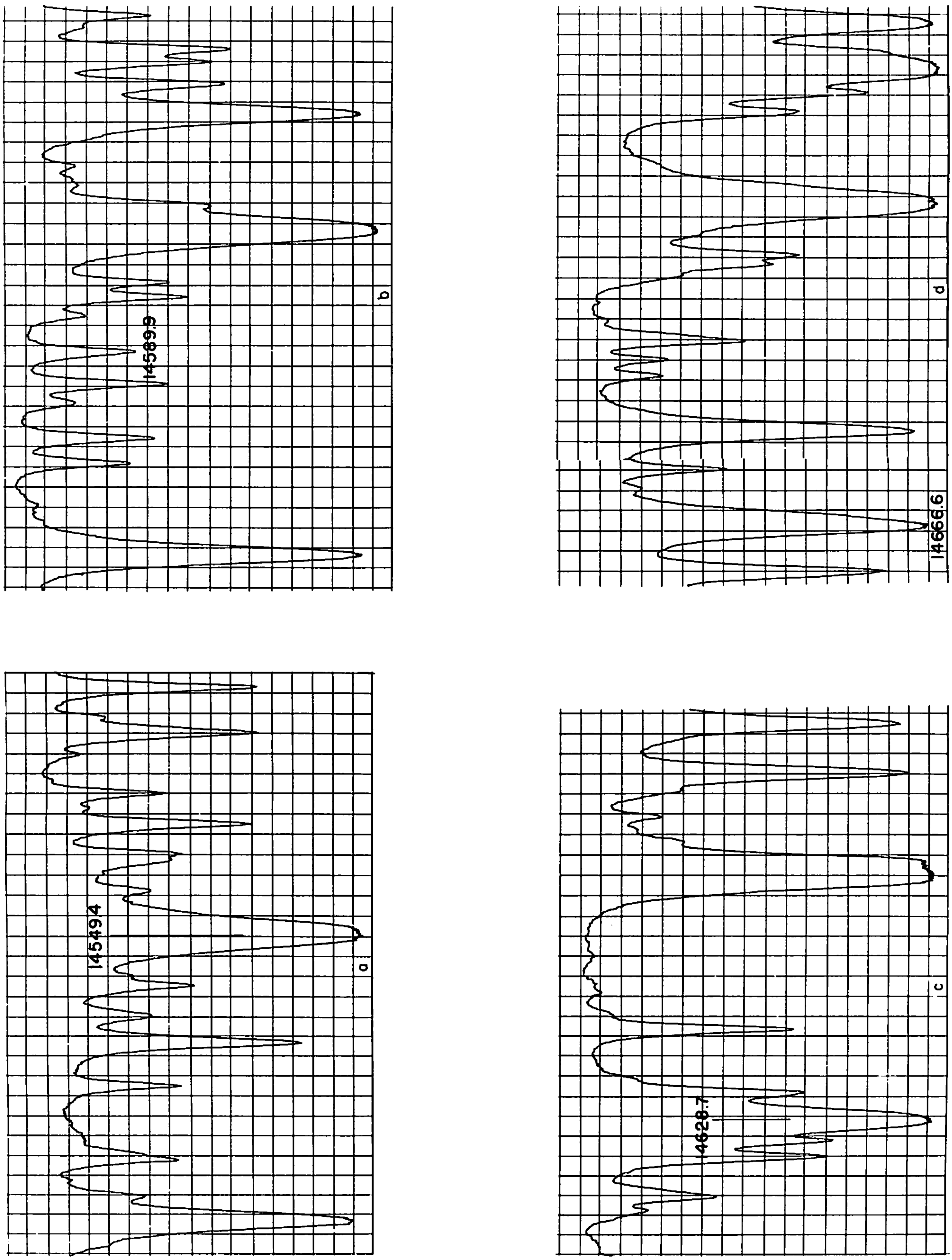

Fig. 8M Part of Michigan Atlas that matches Fig. 8.

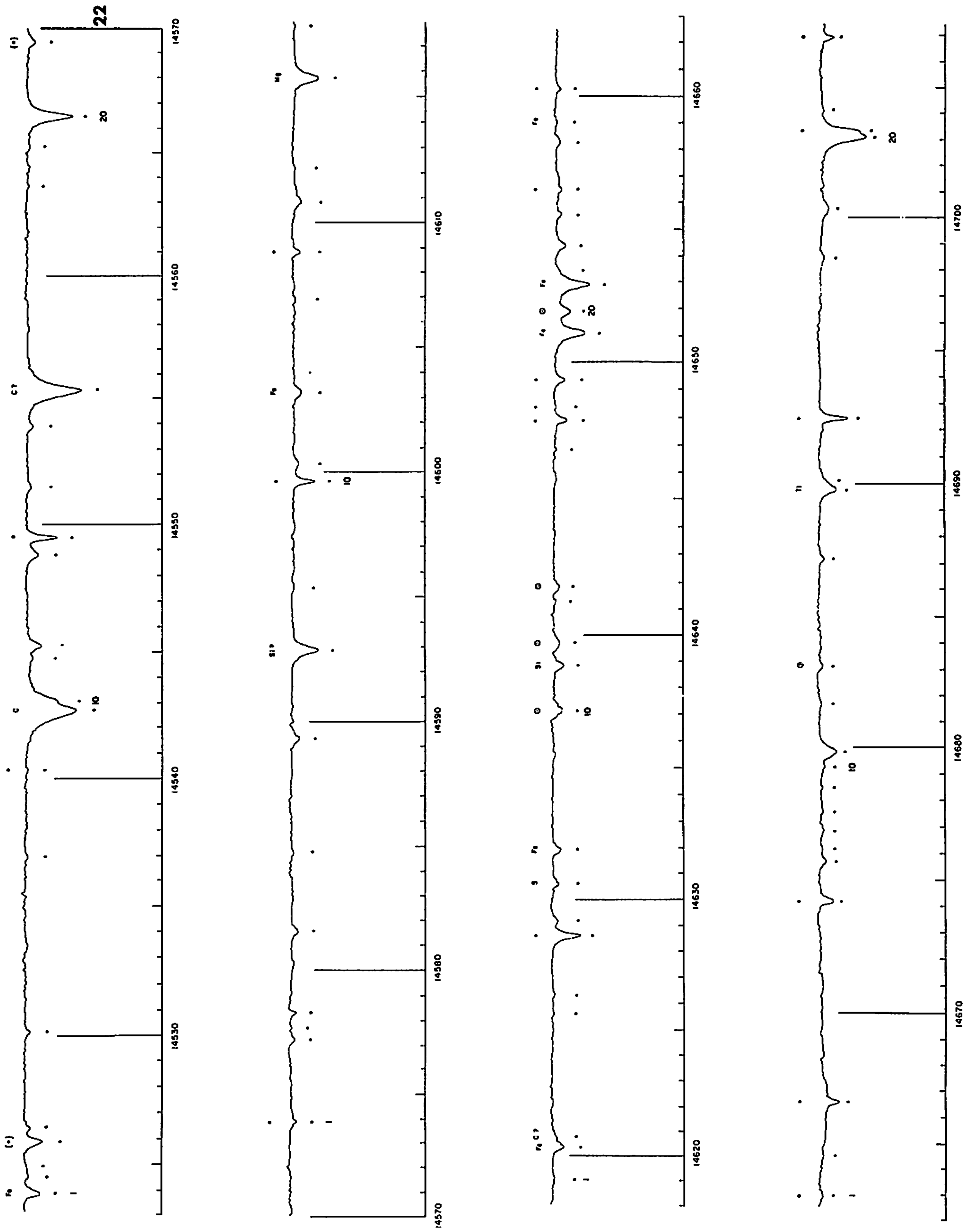

Fig. 8 Solar Spectrum λλ 14523–14707, in four strips (cf. Table 1).

ADDENDUM

SPECTRUM OF THE 1.13μ H_2O BAND

by LAURENS A. BIJL

In this Addendum, laboratory spectra are reproduced of the 1.4 μ H_2O band. They were made with the 4-m LPL spectrometer together with several runs not reproduced. All absorptions shown are due to water vapor in the ambient air. The 4-m spectrometer itself was flushed with dry nitrogen, although not completely dried out, with the absorptions adjusted to the desired level.

This laboratory spectrum shows strong line-broadening compared to the solar spectrum, due to the increased pressure. Lines, clearly resolved in the solar spectrum, are sometimes hardly seen as a blend in the laboratory spectra.

The slit-width and detector-size used in the laboratory runs were the same as in the solar flights. The scanning rate, however, was made 5 times slower (and the time-constant 5 times longer) to reduce the noise level that apparently resulted from the incandescent lamp. A Corning 2540 filter (> 1 μ) was used, as in the solar records.

The grating drive was readjusted after the solar flights, so that the phase of the small periodic error in dispersion does not match the solar spectrum (as may be seen from the wavelength scale).

The wavelength scale was based on the observed and predicted wavelengths of Mohler's (1955) *Table*.

Mrs. A. P. Agnieray and Mr. S. M. Larson assisted in the preparation of the figures.

REFERENCE

Mohler, O. C. 1955, *A Table of Solar Spectrum Wavelengths* λ *11986A to* λ *25578A*, Ann Arbor.

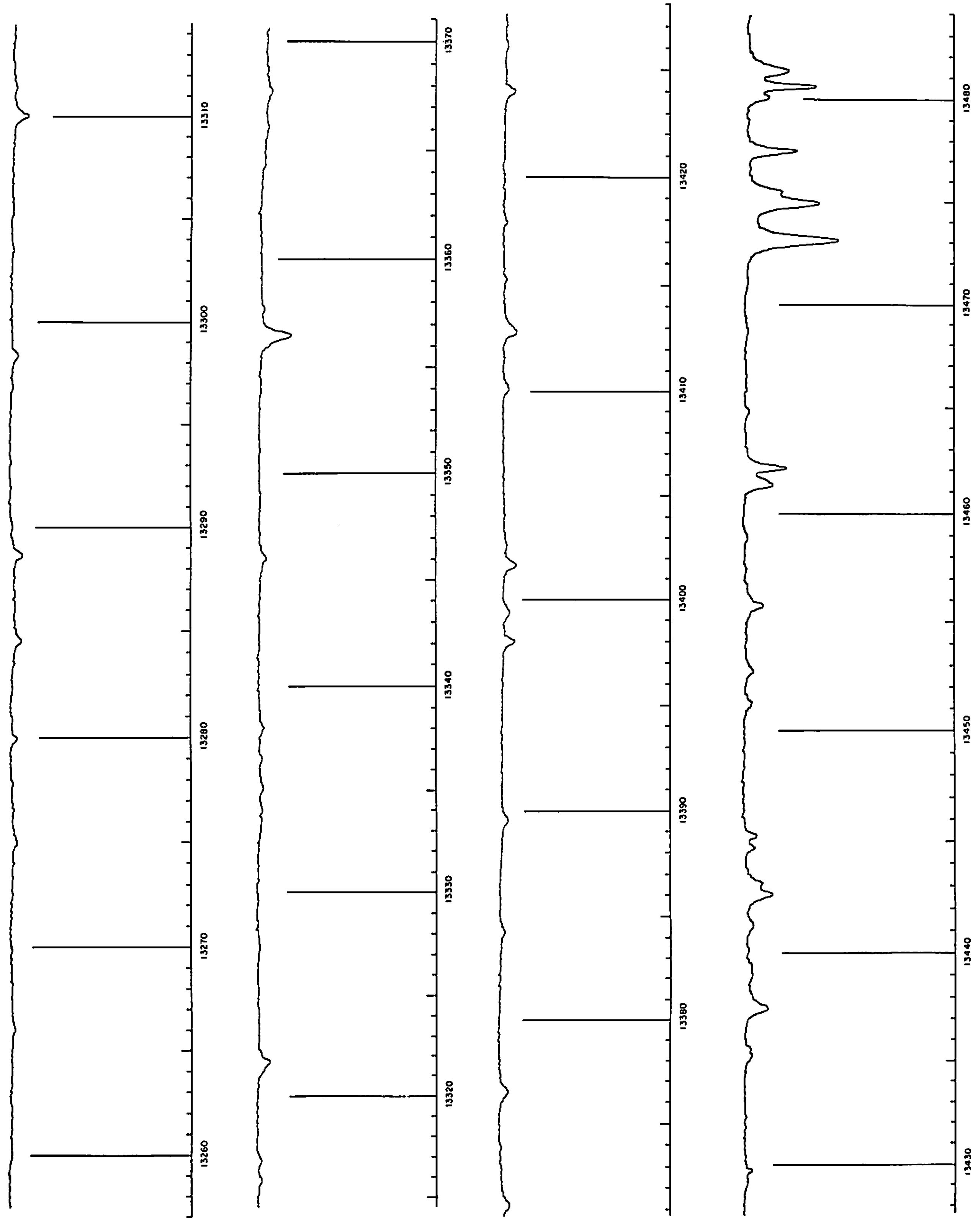

Fig. 1A Laboratory spectrum of water vapor, λλ 13257–13484 Å.

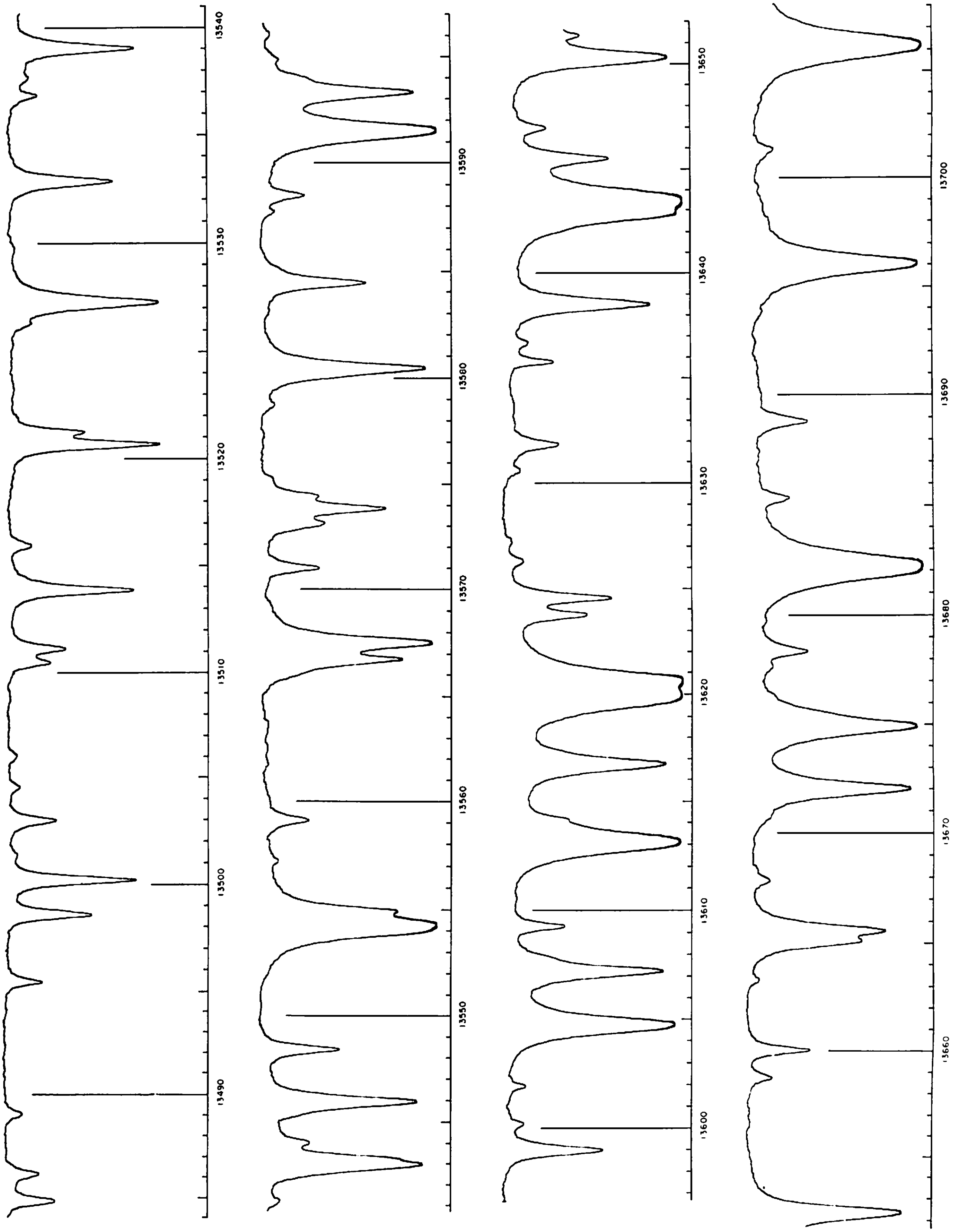

Fig. 2A Laboratory spectrum of water vapor, λλ 13484–13708 Å.

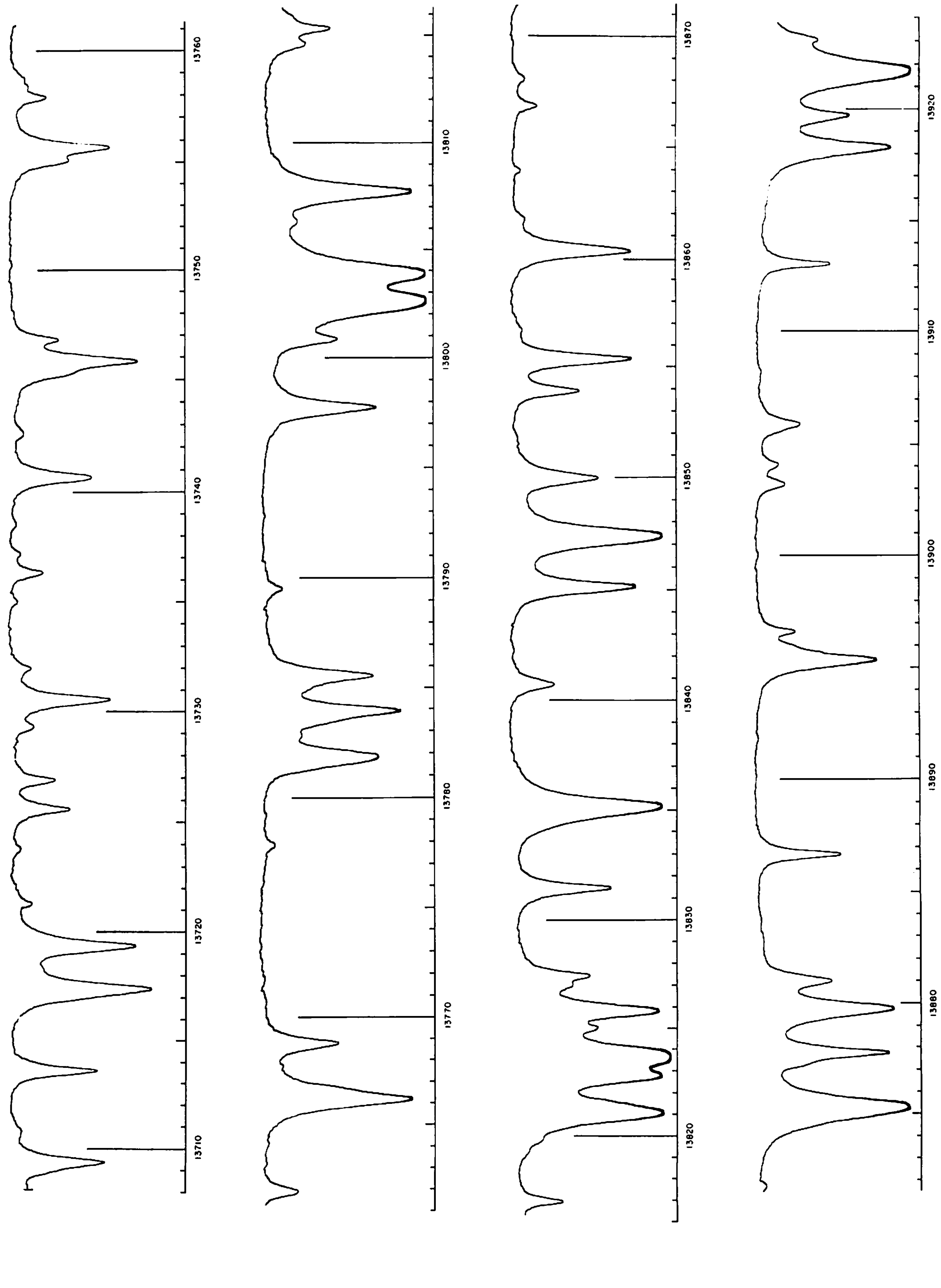

Fig. 3A Laboratory spectrum of water vapor, λλ 13708–13924 Å.

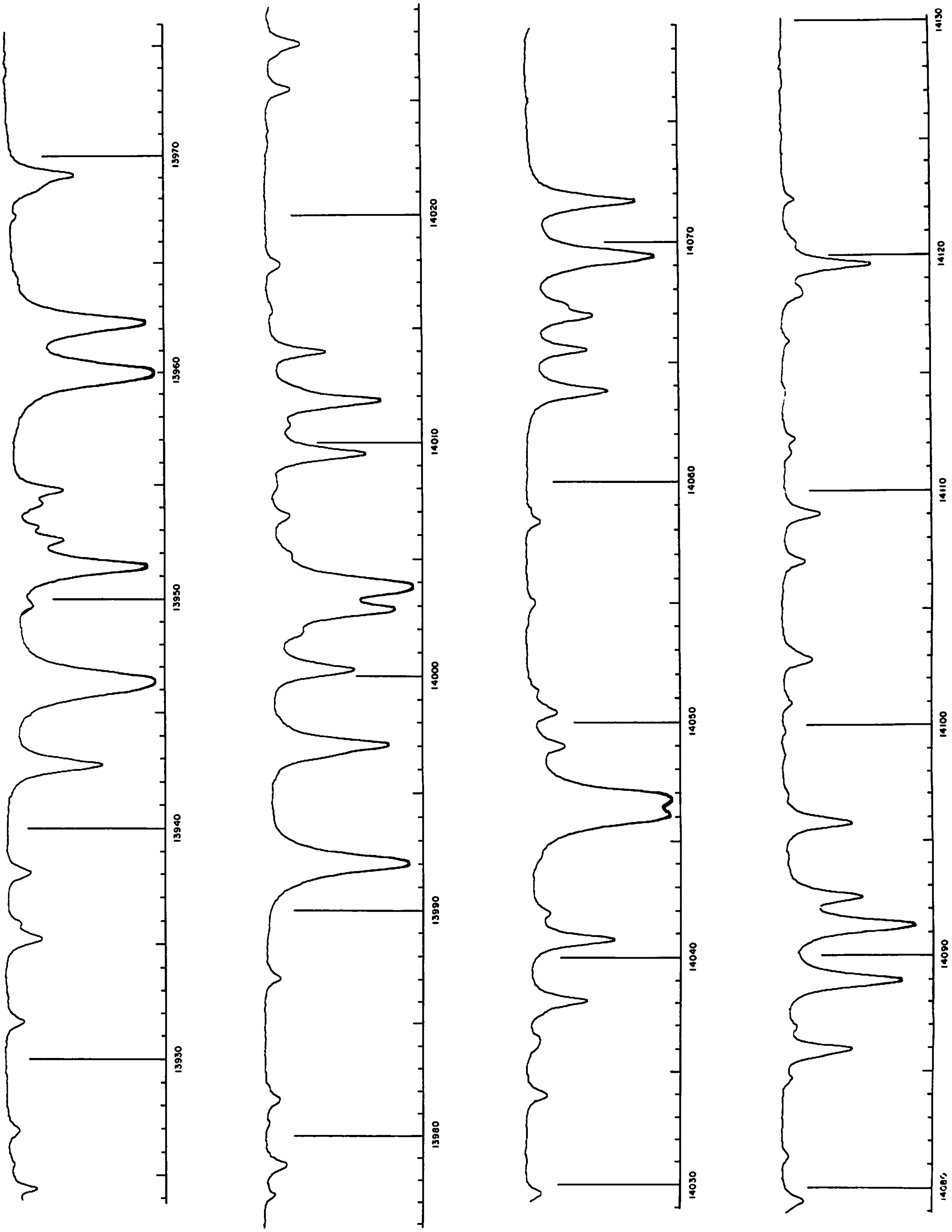

Fig. 4A Laboratory spectrum of water vapor, λλ 13924–14130 Å.

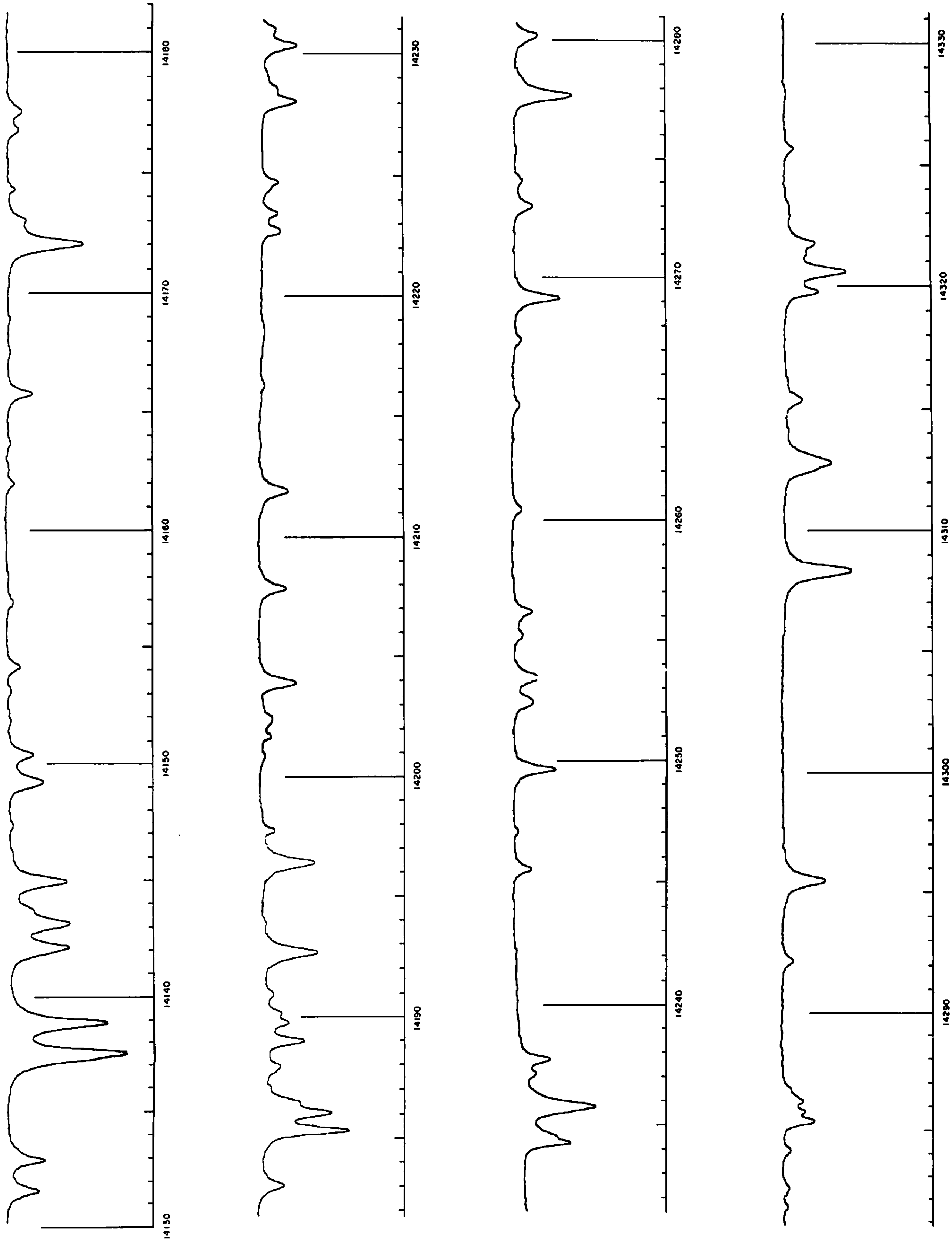

Fig. 5A Laboratory spectrum of water vapor, λλ 14130–14331 Å.

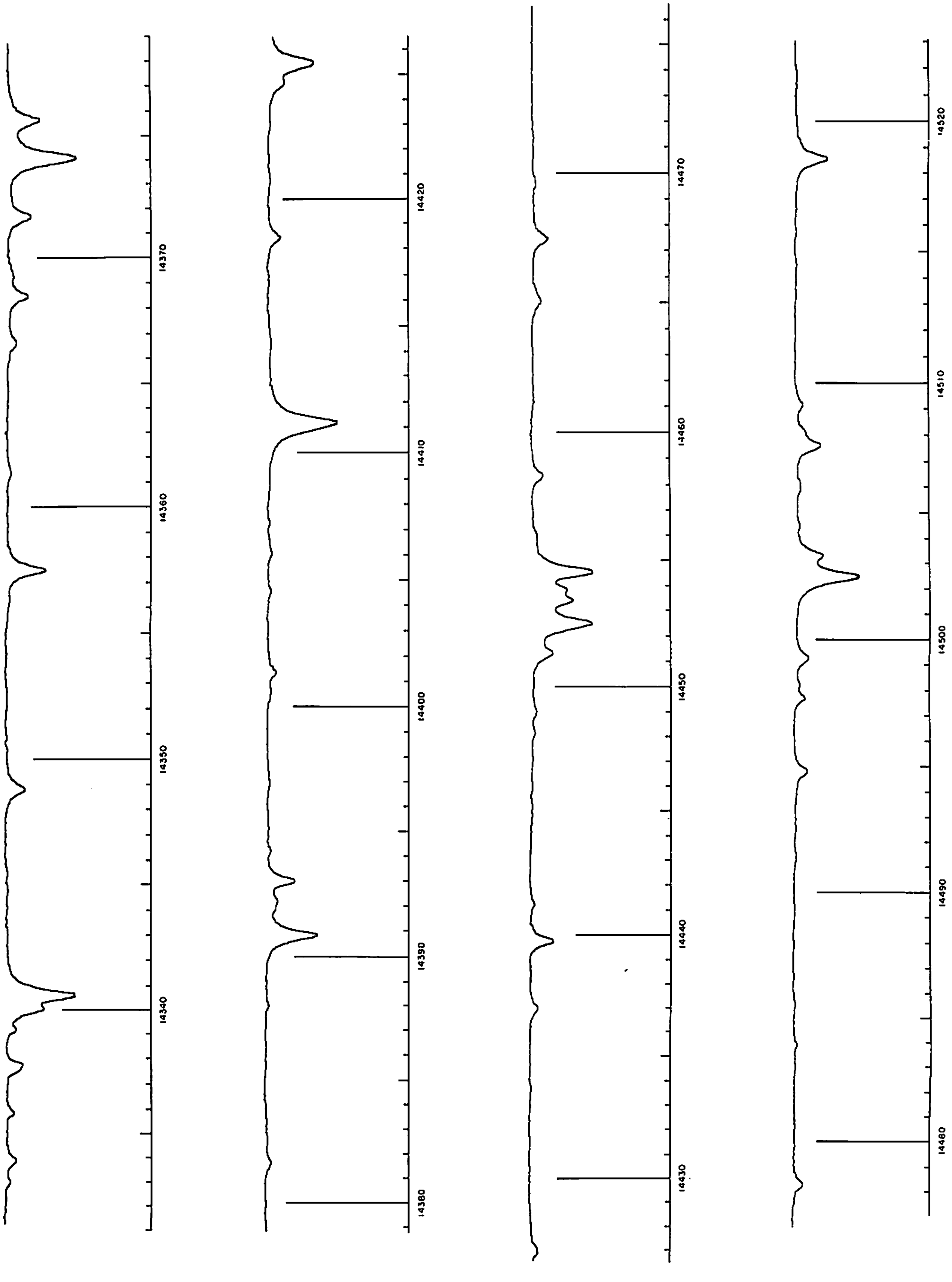

Fig. 6A Laboratory spectrum of water vapor, λλ 14331–14523 Å.

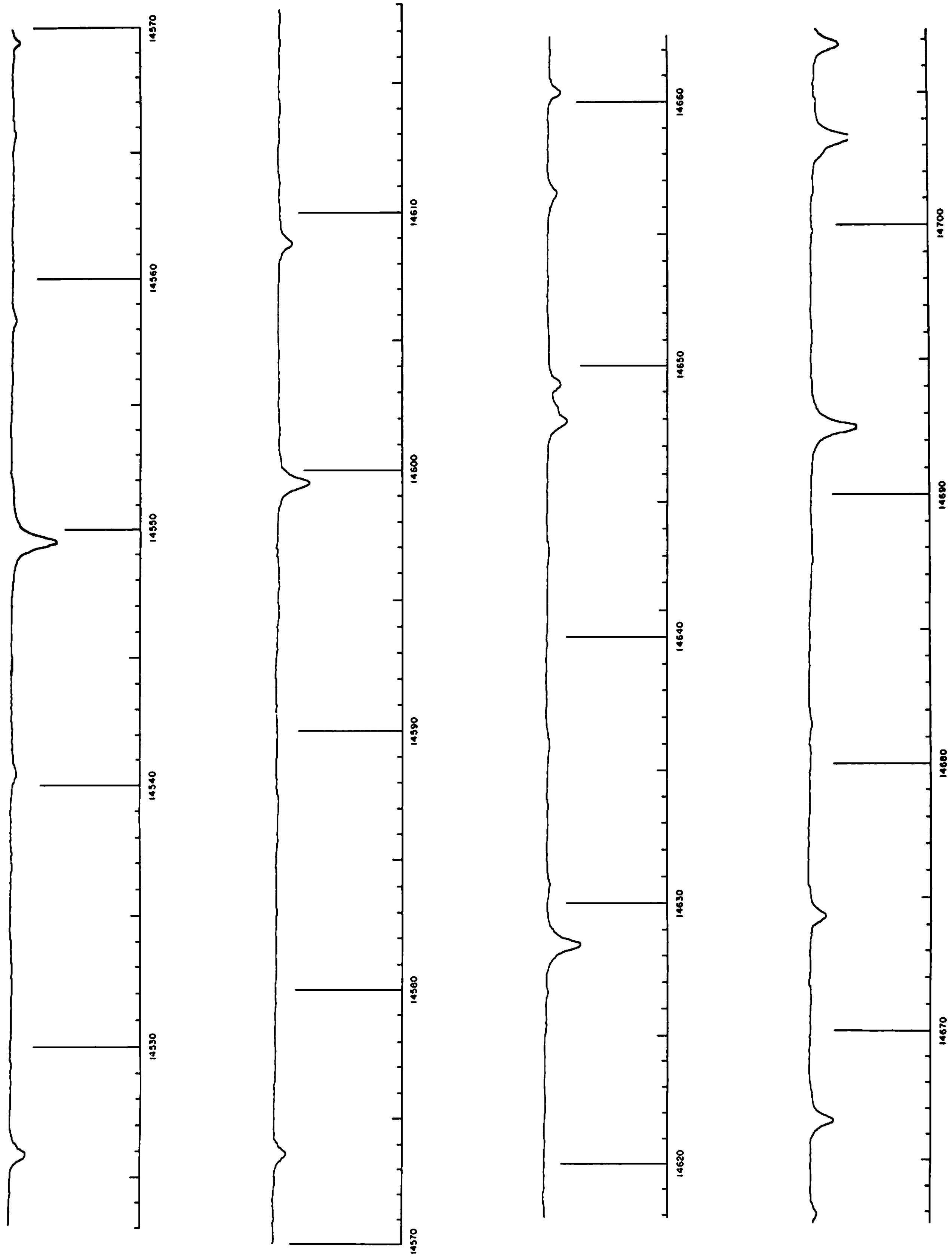

Fig. 7A Laboratory spectrum of water vapor, λλ 14523–14707 Å.