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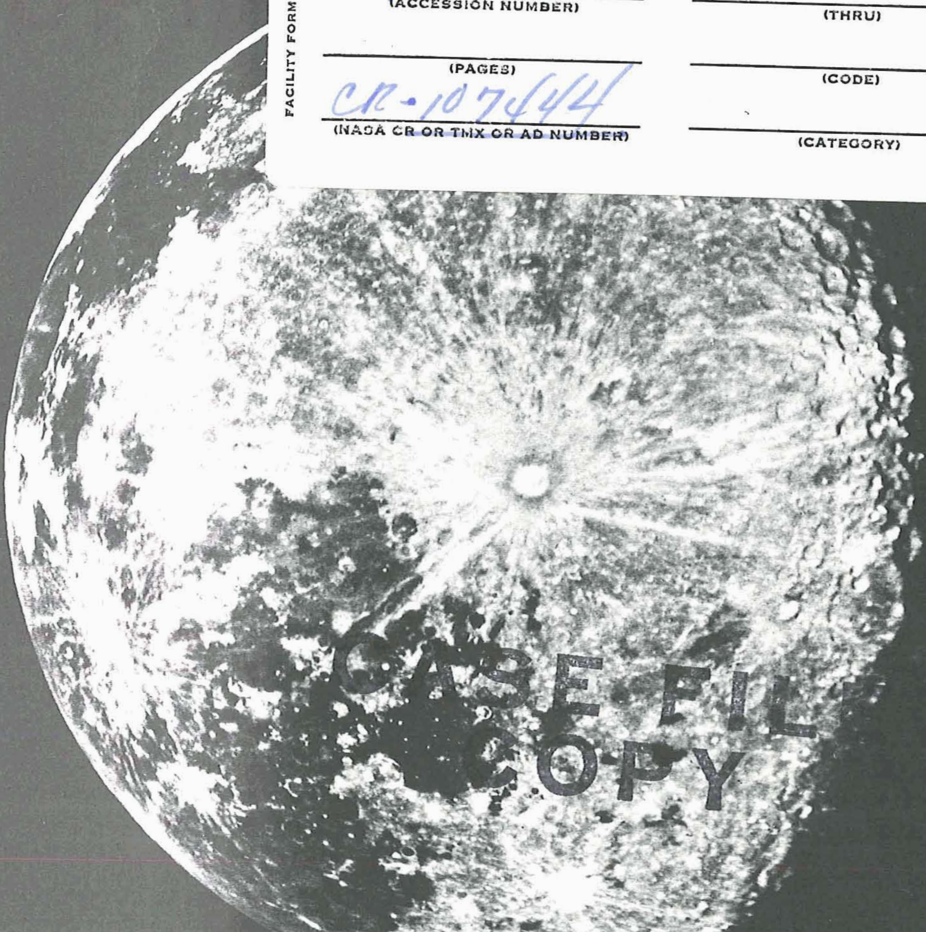
Communications Nos. 163–165



Volume 9 Part 2

THE UNIVERSITY OF ARIZONA

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1969

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The University of Arizona
Tucson, Arizona

GERARD P. KUIPER, *Director*
Lunar and Planetary Laboratory

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No. 163 ARIZONA-NASA ATLAS OF THE INFRARED SOLAR SPECTRUM, REPORT VII

by L. A. BIJL, G. P. KUIPER, AND D. P. CRUIKSHANK

July 1, 1969

ABSTRACT

This paper is a continuation of *Comm. LPL* 161, covering the interval λλ 17731–21492 Å. For purposes of identification a laboratory spectrum of the 1.8 μ water-vapor band is given and Courtoy's CO_2 spectrum is reproduced for the interval λλ 19374–20930 Å.

The present Report continues the record of the solar spectrum beyond λ 17731 Å, the wavelength limit of *Comm. LPL* No. 161. Nearly half of the spectral interval here covered is reproduced in duplicate runs, as may be seen from Table 1 which records the observing data in the form used before. The tracings were obtained on 4 days, July 17-19 and August 1, 1968. The last part of the July 17 flight was disturbed by unusually strong aircraft vibrations due to severe air turbulence. As a result, the record obtained, given in Figs. 1a, c (parts of Chart 33) is of low quality. Fig. 10, a duplicate run of Fig. 2 (Chart 34), is similarly disturbed and will not be included in the final Atlas (no Chart No. assigned here). As before we have added the matching parts of the Michigan *Photometric Atlas of the Near-Infrared Solar Spectrum* λ *8465–* λ *25242,* Figs. 1M-9M.

Two laboratory spectra of the 1.8 μ water-vapor band, taken in the Lunar and Planetary Laboratory, were used in distinguishing water-vapor absorptions from solar absorptions. One of the spectra was taken by using the absorptions at ambient air inside and outside the 4-m spectrometer; the other one was taken with the 4-m spectrometer being flushed with dry nitrogen. The latter matches the amount of water-vapor absorptions in the solar spectrum more closely, so that we reproduced this record (Figs. 11c, d, 12, 13a, b, c) for the central part of the band. In the wings of the band, the absorptions in this spectrum become less clear, due to pressure broadening. Therefore, we reproduced the stronger of the two laboratory spectra for this region (Figs. 11a, b, and 13d).

The identification of the numerous CO_2 bands in this part of the spectrum is almost entirely based on Courtoy's *Spectre Infrarouge à Grande Dispersion et Constantes Moleculaires du CO_2*. With the kind permission of Dr. Courtoy we reproduce his absorption spectra for ready reference in Figs. 14–16.

In Figs. 1, 2, 3a, c (Charts 33, 34, 35a, c) the Corning 2540 filter was used beyond 1.8 μ, with a second-order leak resulting. The calculated zero intensity line for the first-order spectrum is shown by dashed lines. The second-order absorption lines shown are indicated with a double dot above the spectral trace. As before, a single dot above the trace indicates a water-vapor absorption; a triangle, a methane absorption; and a short vertical line, a CO_2 absorption. Where several CO_2 bands occur in the same region, we have tried to separate them by using vertical lines at different levels.

The wavelength scale was again based on Mohler's *Table of Solar Spectrum Wavelengths 11984 A to 25578 A*. The wavelength scale of the laboratory water-vapor spectrum was adapted from that of the solar records through the assistance of Mr. D. C. Benner.

The water-vapor absorptions in the spectrometer during the flights are not negligible. For an evaluation of the contribution of the spectrometer absorption, see *Comm. LPL* 160.

The solar spectra were obtained in the NASA CV-990 by Messrs. Kuiper and Cruikshank. The derivation of the wavelength scale and the identifications were all performed by Mr. Bijl, who also obtained the laboratory spectra of the 1.8 μ H_2O band; and prepared the charts for publication.

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.

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

SOLAR SPECTRUM RECORDS, 4-M SPECTROMETER, NASA CV-990 JET
600 l/mm GRATING, DETECTOR 0.1 mm, $\tau = 0.12$ SEC., FILTER 1 μ, JUL. 17, 19; 1.8 μ, JUL. 18, AUG. 1

FIG.	CHART	λ (Å)	1968 DATE	UT	ALT. (FT.)	OUTSIDE TEMP. (°C)	CABIN ALT. (FT.)	GAIN	SLIT (MM)	GRATING BLAZE (μ)
1	33 a	17731–17886	July 17	20:18	39,000	–52	8500	5–2	0.10	1.6
	b	17731–17886	July 19	20:31	39,000	–53	8500	5–3	0.08	1.6
	c	17886–18044	July 17	20:21	39,000	–52	8500	5–2	0.10	1.6
	d	17886–18044	July 19	20:33/19:59	39,000	–53	8500	5–3	0.08	1.6
2	34 a	18044–18195	July 19	20:02	39,000	–53	8500	5–3	0.08	1.6
	b	18195–18340	July 19	20:05	39,000	–53	8500	5–3	0.08	1.6
	c	18340–18492	July 19	20:08	39,000	–53	8500	5–3	0.08	1.6
	d	18492–18644	July 19	20:11	39,000	–53	8500	5–3	0.08	1.6
3	35 a	18644–18800	July 19	20:14	39,000	–53	8500	5–3	0.08	1.6
	b	18644–18800	July 18	19:00	39,000	–56	8500	5–5	0.09	1.6
	c	18800–18961	July 19	20:18	39,000	–53	8500	5–3	0.08	1.6
	d	18800–18962	July 18	19:03	39,000	–56	8500	5–5/5–4	0.09	1.6
4	36 a	18962–19115	July 18	19:06	39,000	–56	8500	5–4	0.09	1.6
	b	19115–19262	July 18	19:09	39,000	–56	8500	5–4/5–3	0.09	1.6
	c	19262–19413	July 18	19:12	39,000	–56	8500	5–3	0.09	1.6
	d	19413–19565	July 18	19:15	39,000	–56	8500	5–3	0.09	1.6
5	37 a	19565–19710	July 18	19:19	39,000	–56	8500	5–3	0.09	1.6
	b	19710–19859	July 18	19:22	39,000	–56	8500	5–3	0.09	1.6
	c	19859–20009	July 18	19:25	39,000	–56	8500	5–3	0.09	1.6
	d	20009–20156	July 18	19:28	39,000	–56	8500	5–3/5–4	0.09	1.6
6	38 a	20156–20300	July 18	19:31	39,000	–56	8500	5–4	0.09	1.6
	b	20300–20448	July 18	19:34	39,000	–56	8500	5–4	0.09	1.6
	c	20448–20600	July 18	19:37	39,000	–56	8500	5–4	0.09	1.6
	d	20448–20600	Aug. 1	19:51	41,500	–59	9300	5–2	0.12	2.5
7	39 a	20600–20749	July 18	19:40	39,000	–56	8500	5–4	0.09	1.6
	b	20600–20749	Aug. 1	19:55	41,500	–59	9300	5–2	0.12	2.5
	c	20749–20901	July 18	19:44	39,000	–56	8500	5–4	0.09	1.6
	d	20749–20901	Aug. 1	19:58	41,500	–59	9300	5–2	0.12	2.5
8	40 a	20901–21050	July 18	19:48	39,000	–56	8500	5–4	0.09	1.6
	b	20901–21050	Aug. 1	20:01	41,500	–59	9300	5–2/5–3	0.12	2.5
	c	21050–21194	July 18	19:51	39,000	–56	8500	5–4	0.09	1.6
	d	21050–21194	Aug. 1	20:04	41,500	–59	9300	5–3	0.12	2.5
9	41 a	21194–21345	July 18	19:55	39,000	–56	8500	5–4	0.09	1.6
	b	21194–21345	Aug. 1	20:08	41,500	–59	9300	5–3	0.12	2.5
	c	21345–21492	July 18	19:58	39,000	–56	8500	5–4	0.09	1.6
	d	21345–21492	Aug. 1	20:11	41,500	–59	9300	5–3	0.12	2.5

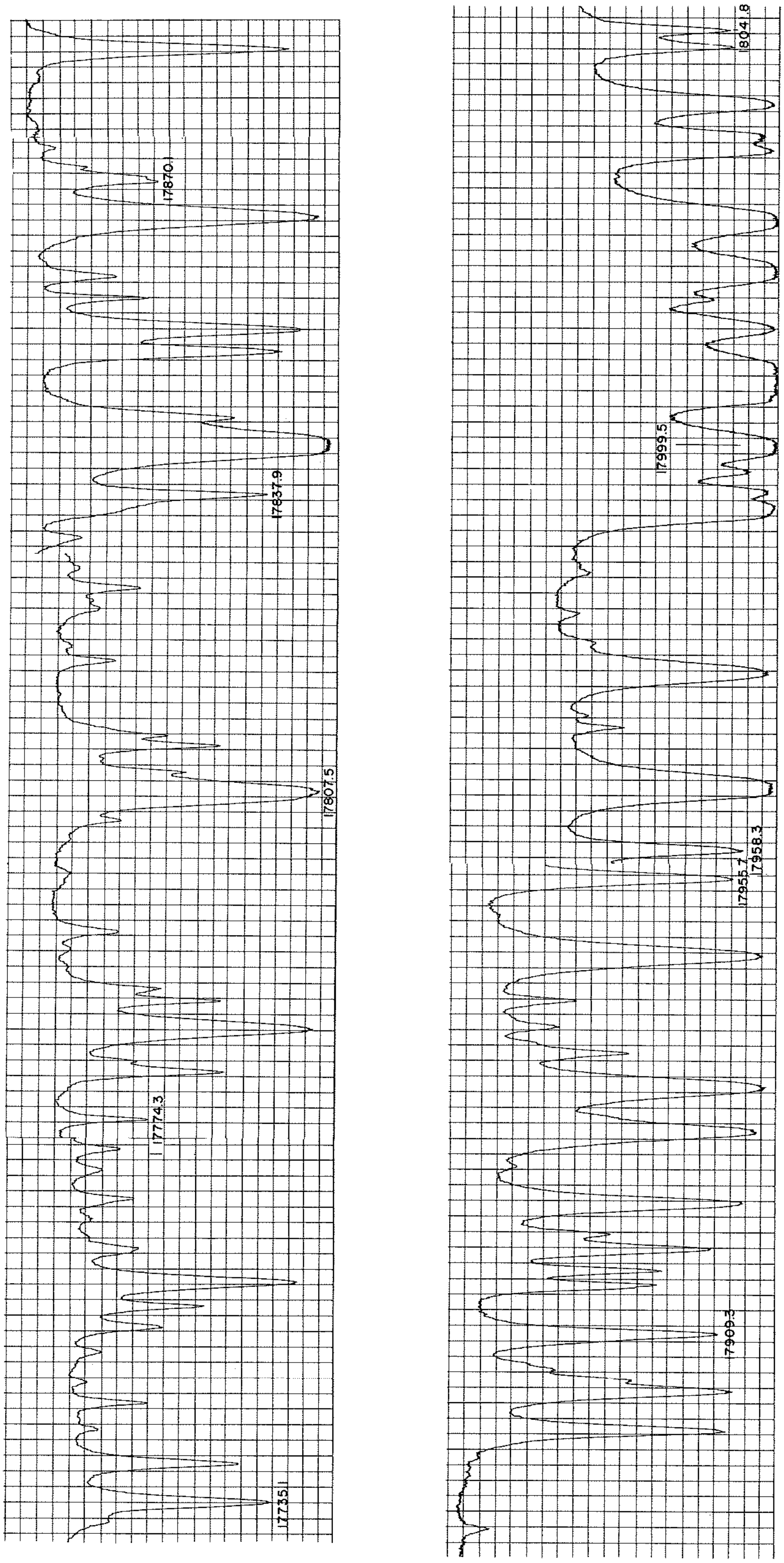

Fig. 1M Part of the Michigan Atlas, that matches *Fig. 1*. (*Figs. 1M–9M* reproduced with permission).

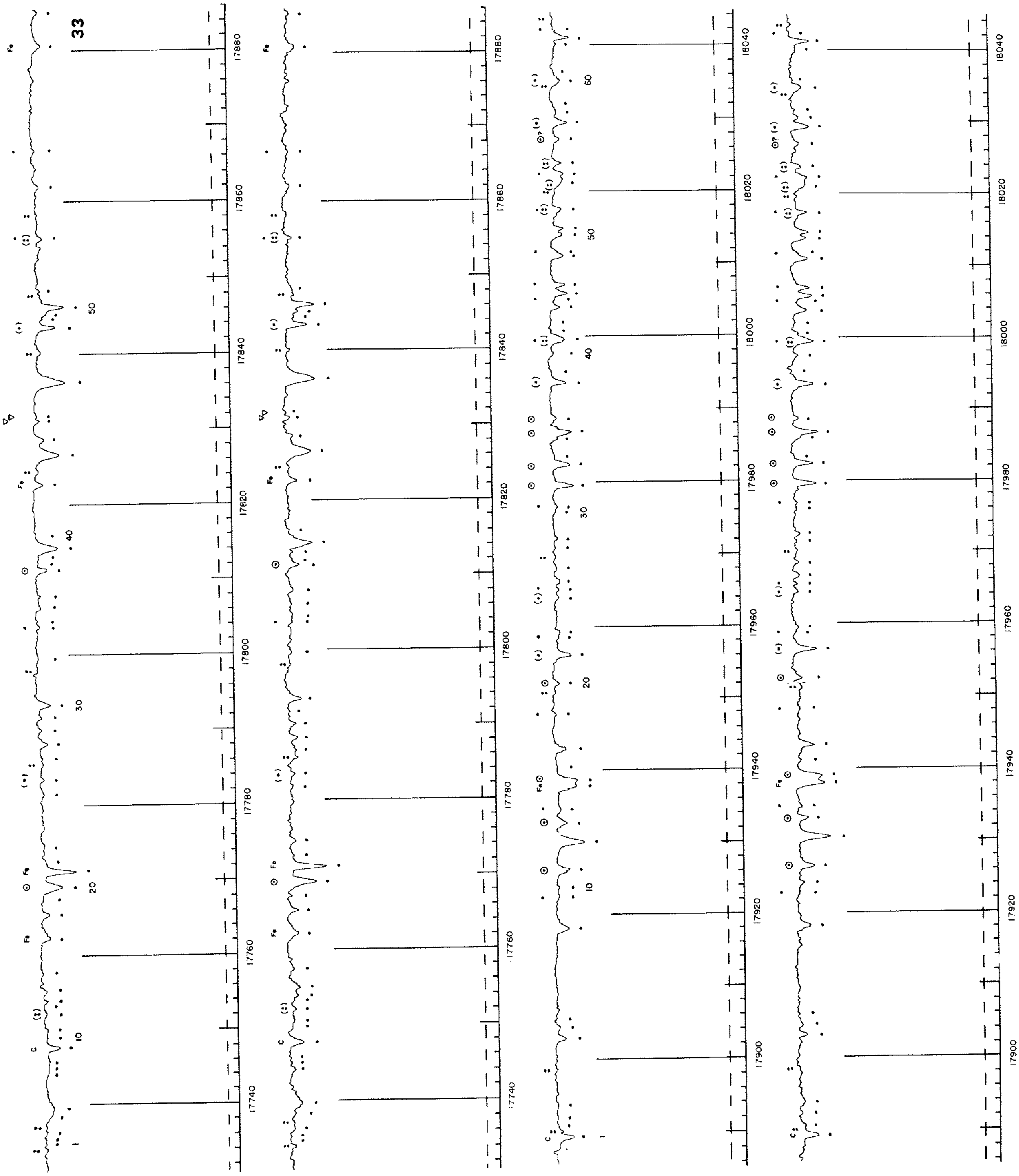

Fig. 1 Solar Spectrum λλ 17731–18044, in four strips (cf. Table 1).

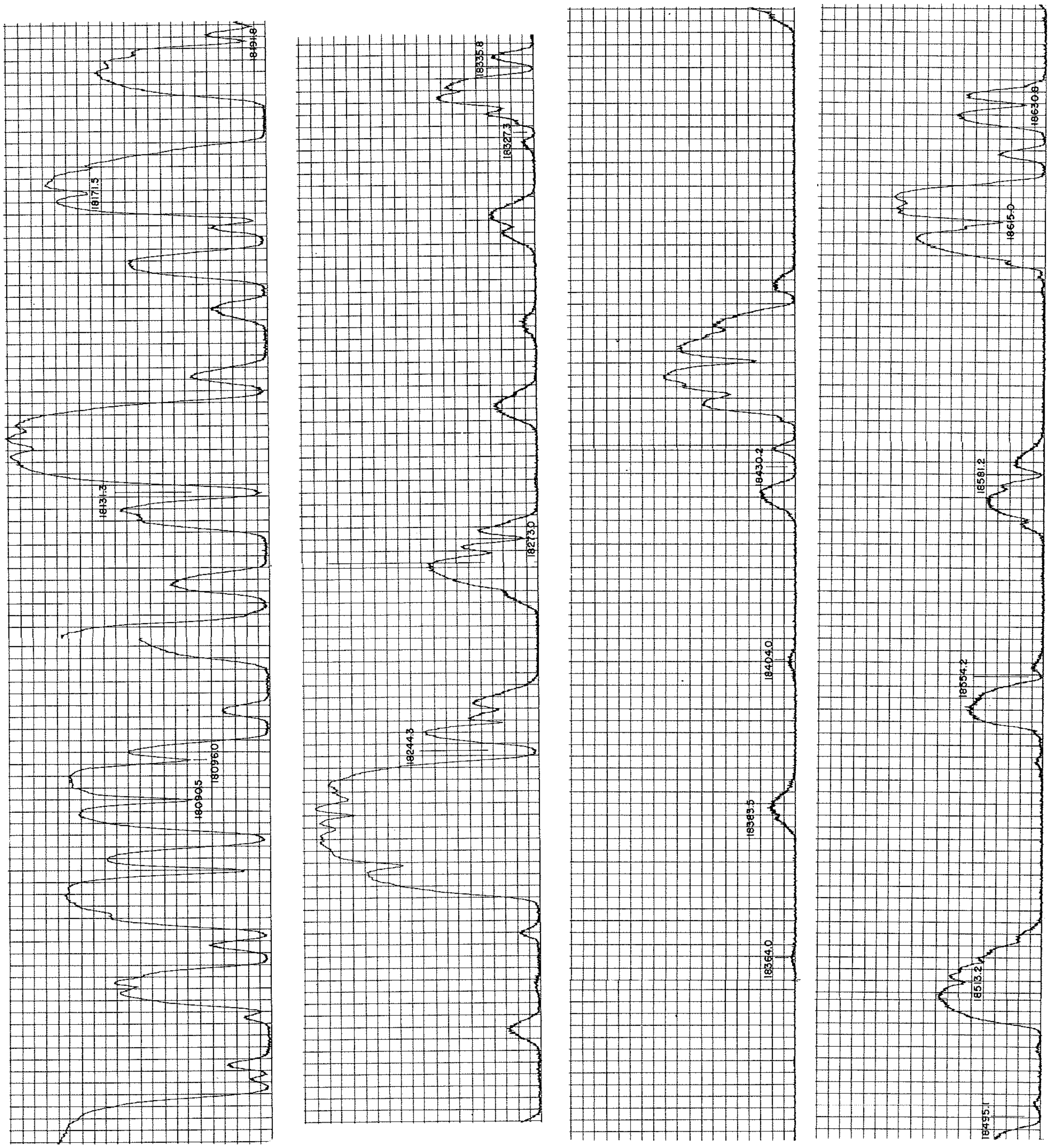

Fig. 2M Part of the Michigan Atlas, that matches *Fig. 2*.

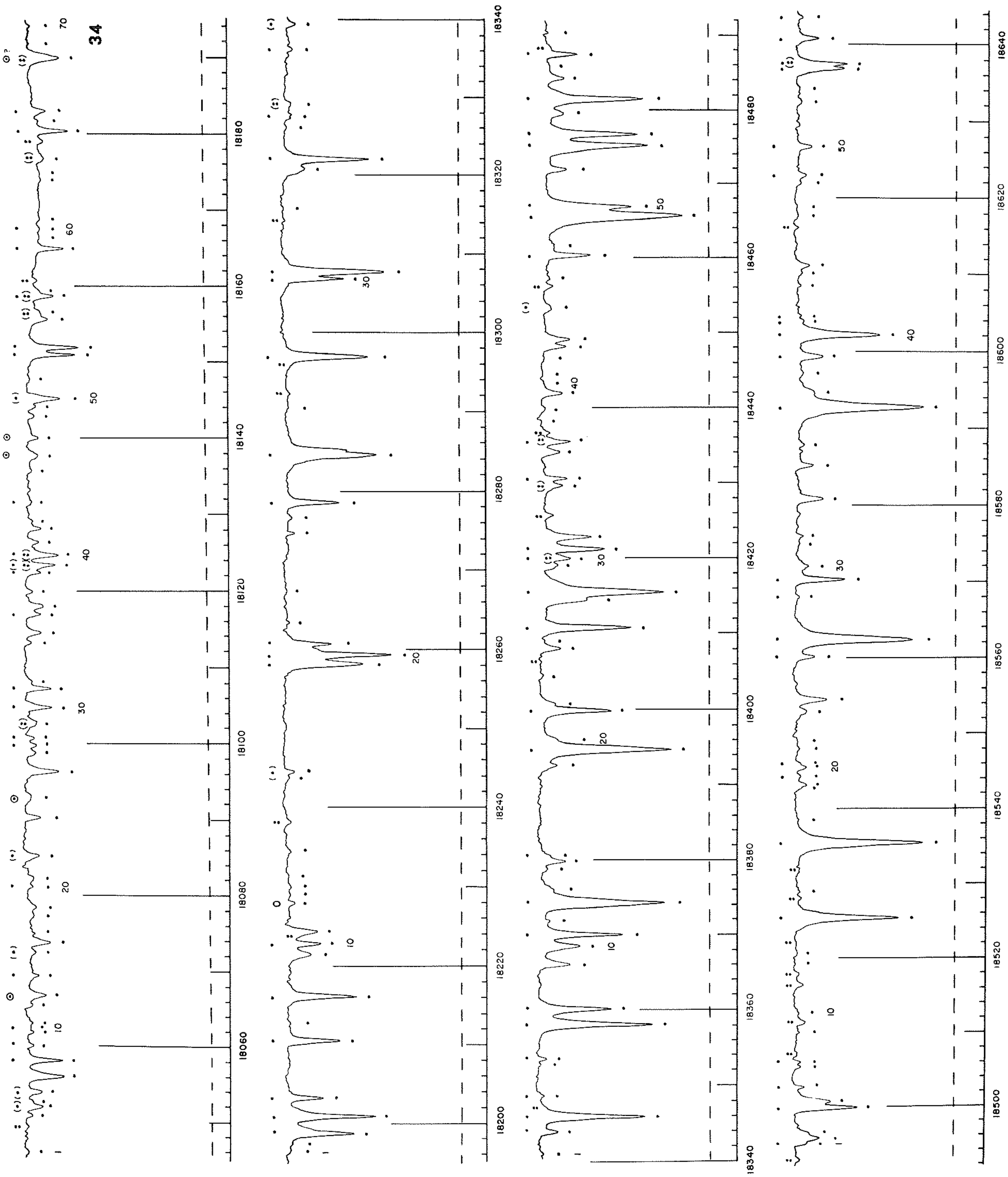

Fig. 2 Solar Spectrum λλ 18044–18644, in four strips (cf. Table 1). See also Fig. 10.

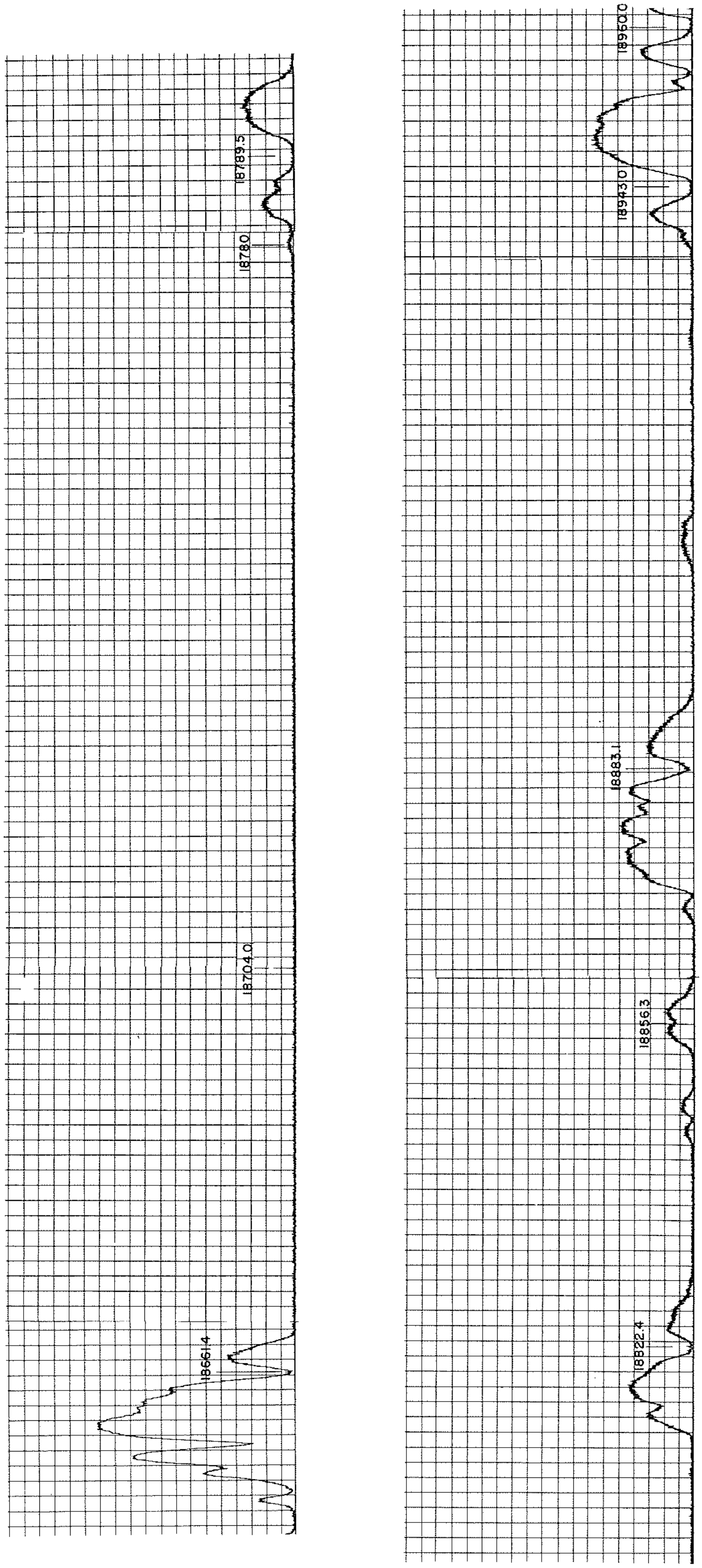

Fig. 3M Part of the Michigan Atlas, that matches *Fig. 3.*

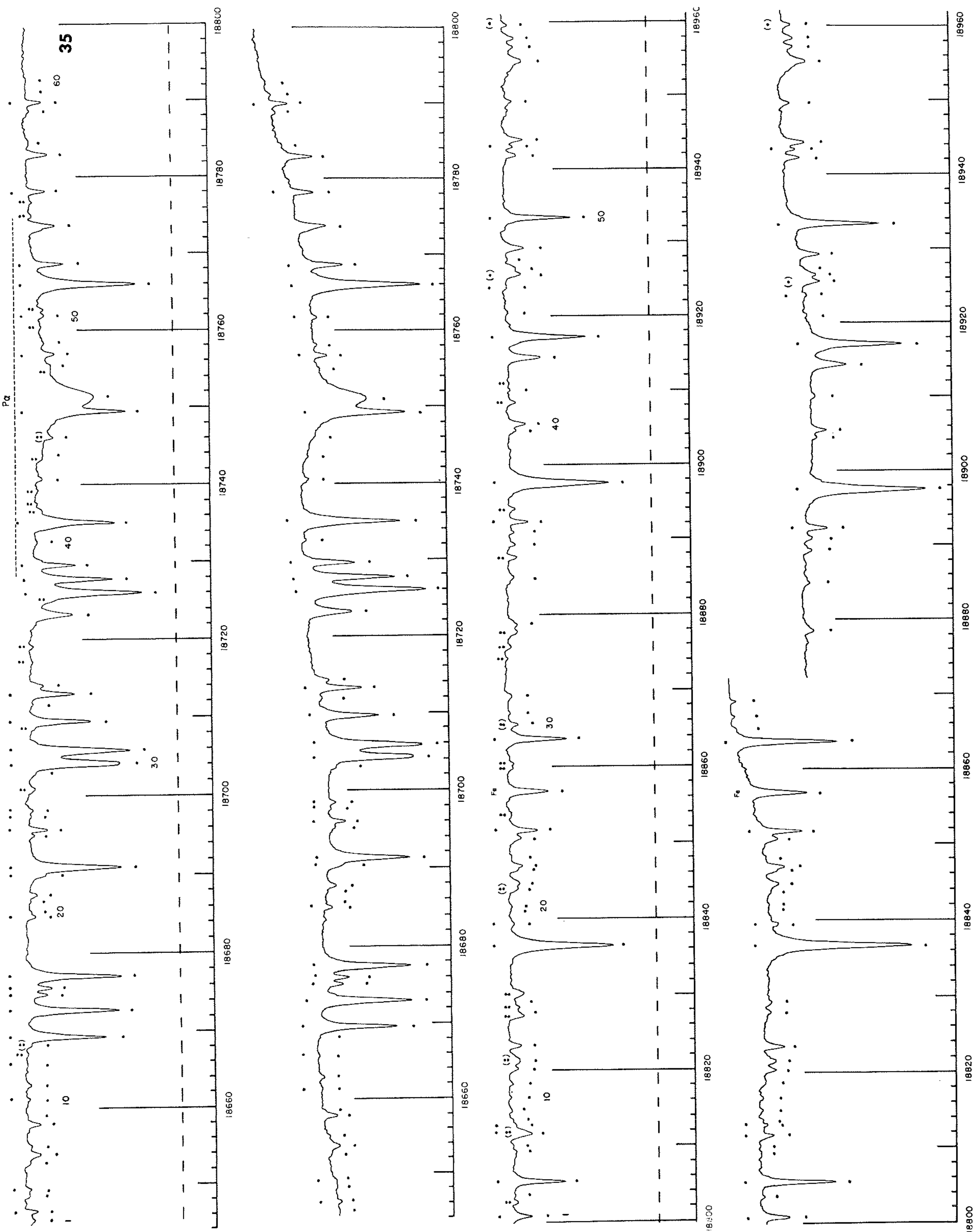

Fig. 3 Solar Spectrum λλ 18644–18962, in four strips (cf. Table 1).

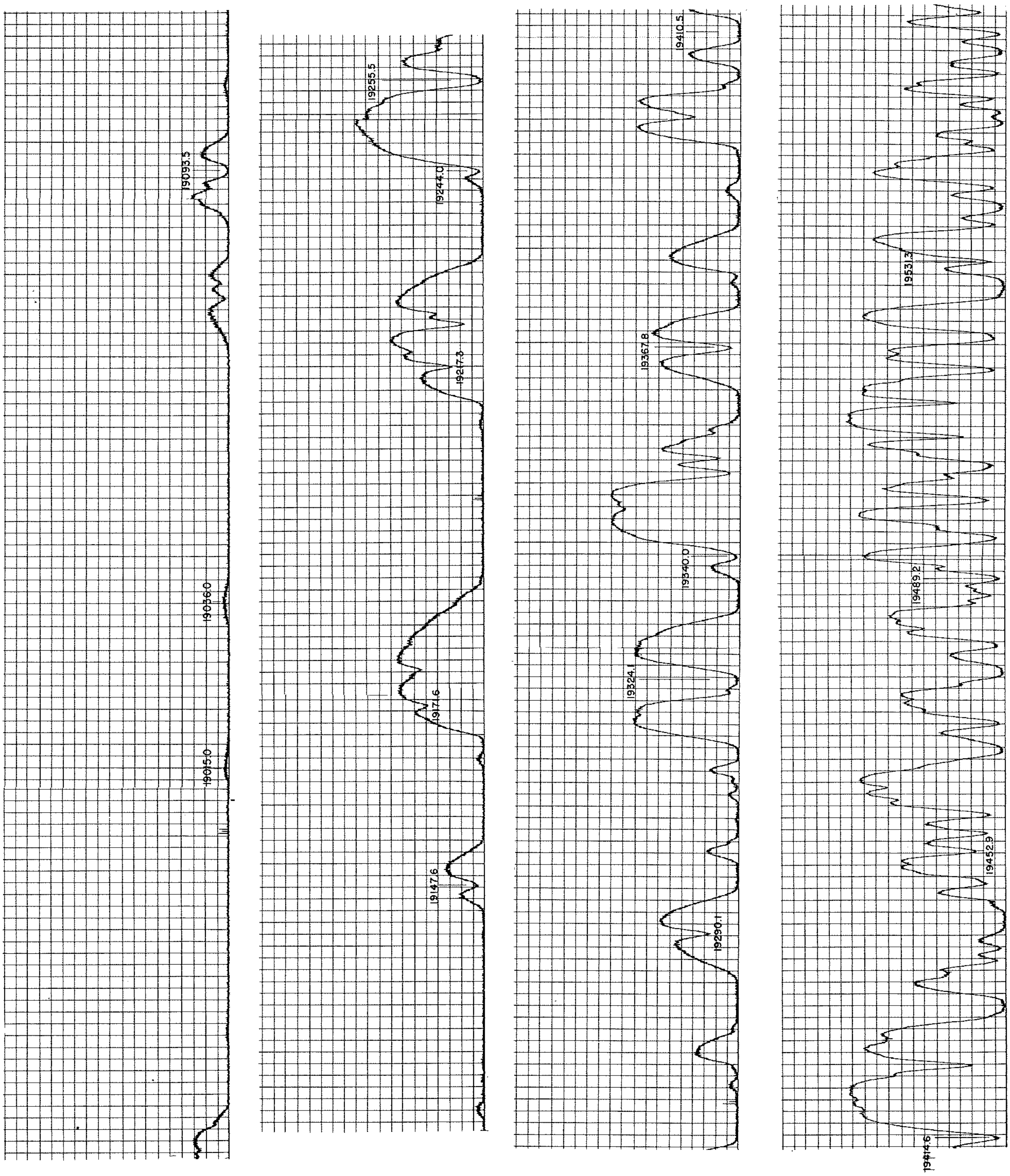

Fig. 4M Part of the Michigan Atlas, that matches *Fig. 4.*

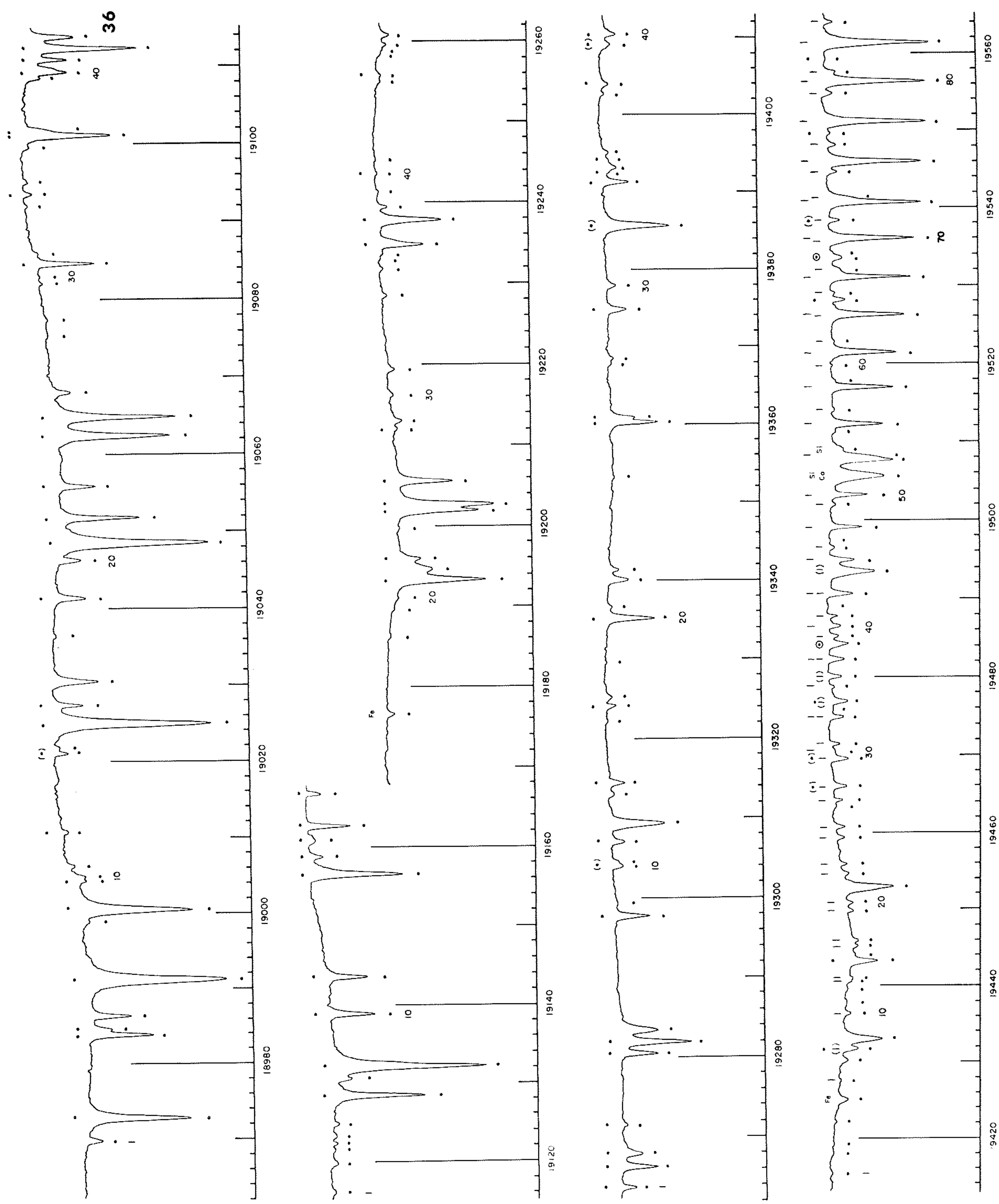

Fig. 4 Solar Spectrum λλ 18962–19565, in four strips (cf. Table 1).

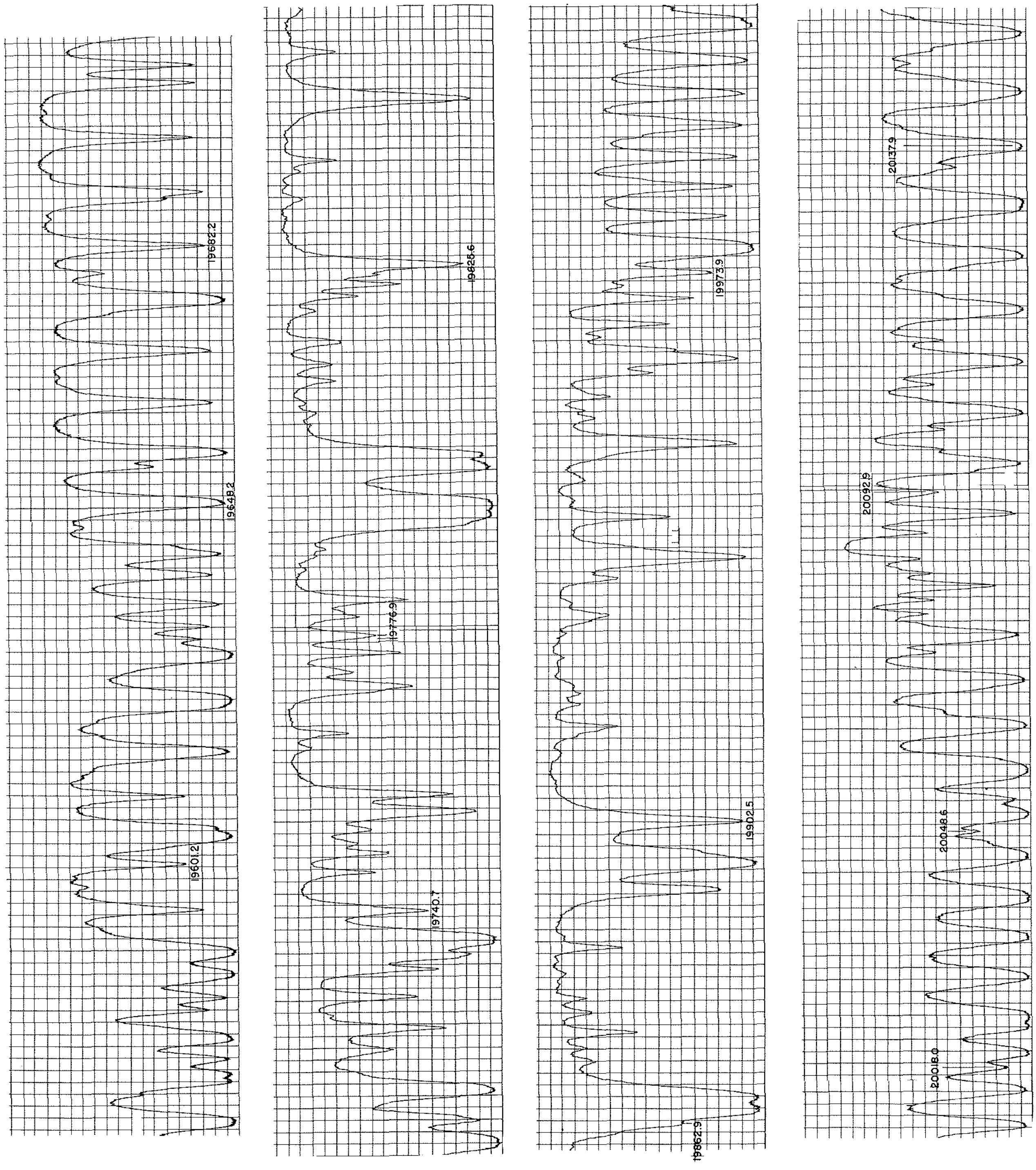

Fig. 5M Part of the Michigan Atlas, that matches *Fig. 5*.

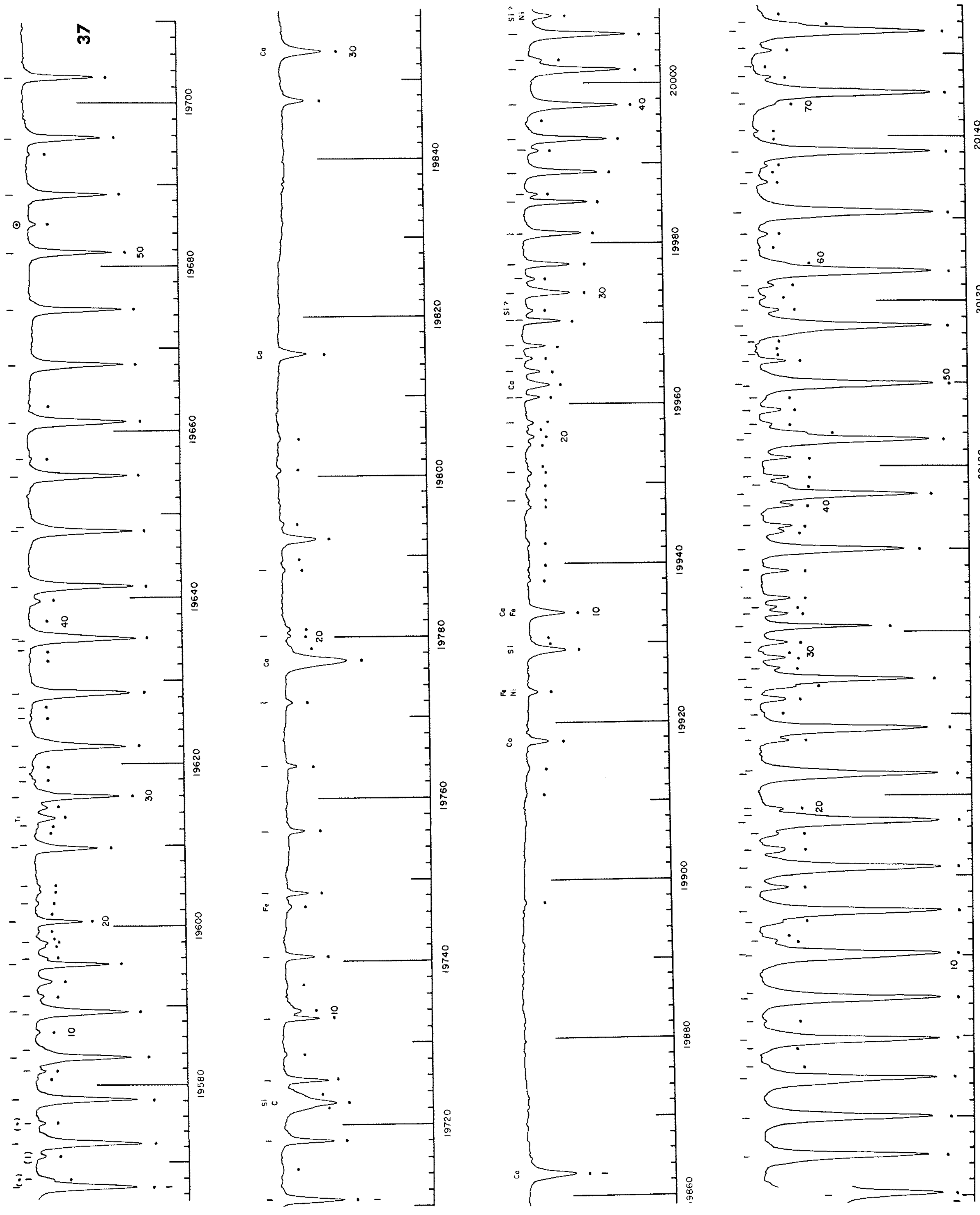

Fig. 5 Solar Spectrum λλ 19565–20156, in four strips (cf. Table 1).

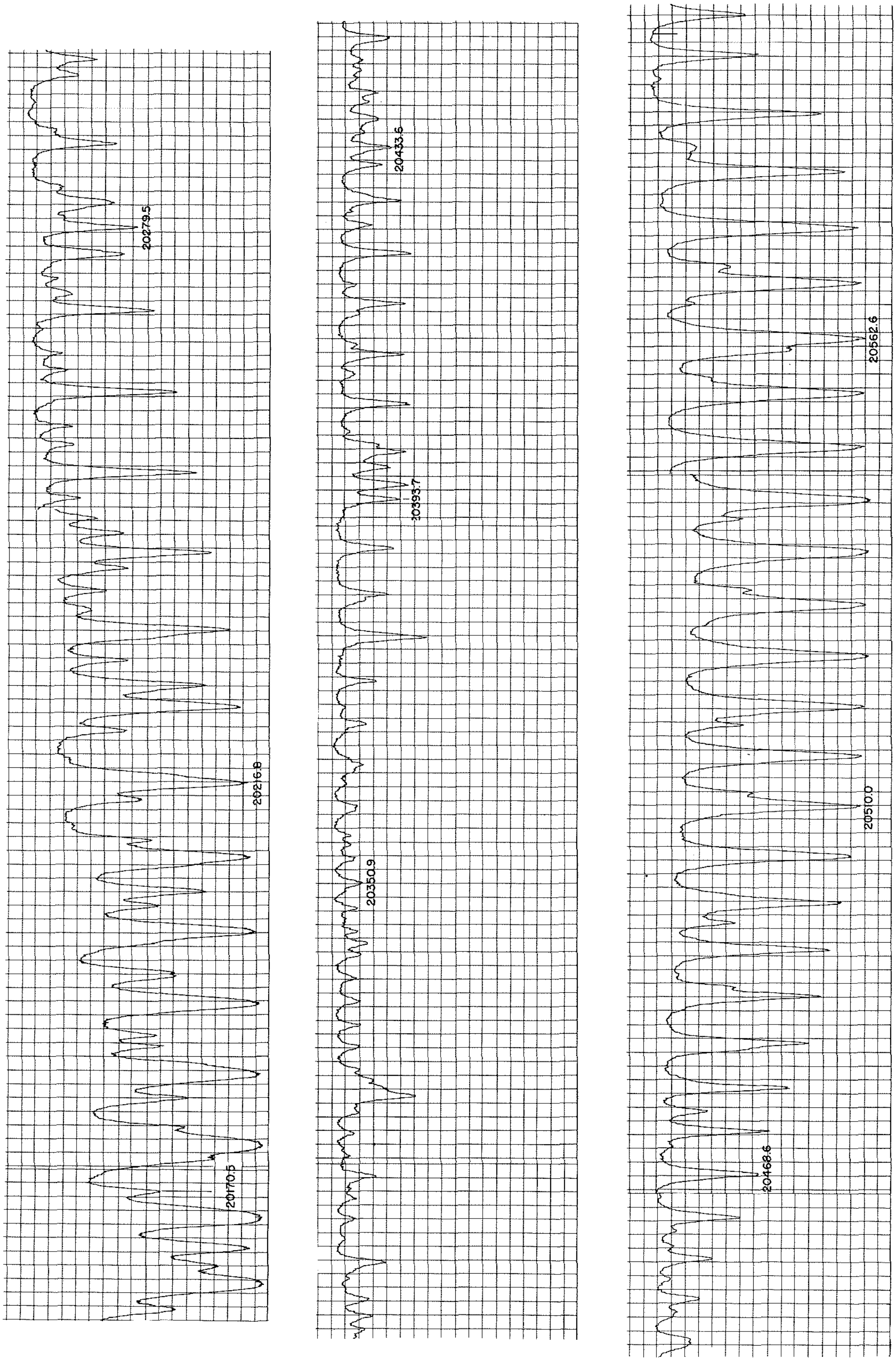

Fig. 6M Part of the Michigan Atlas, that matches *Fig. 6.*

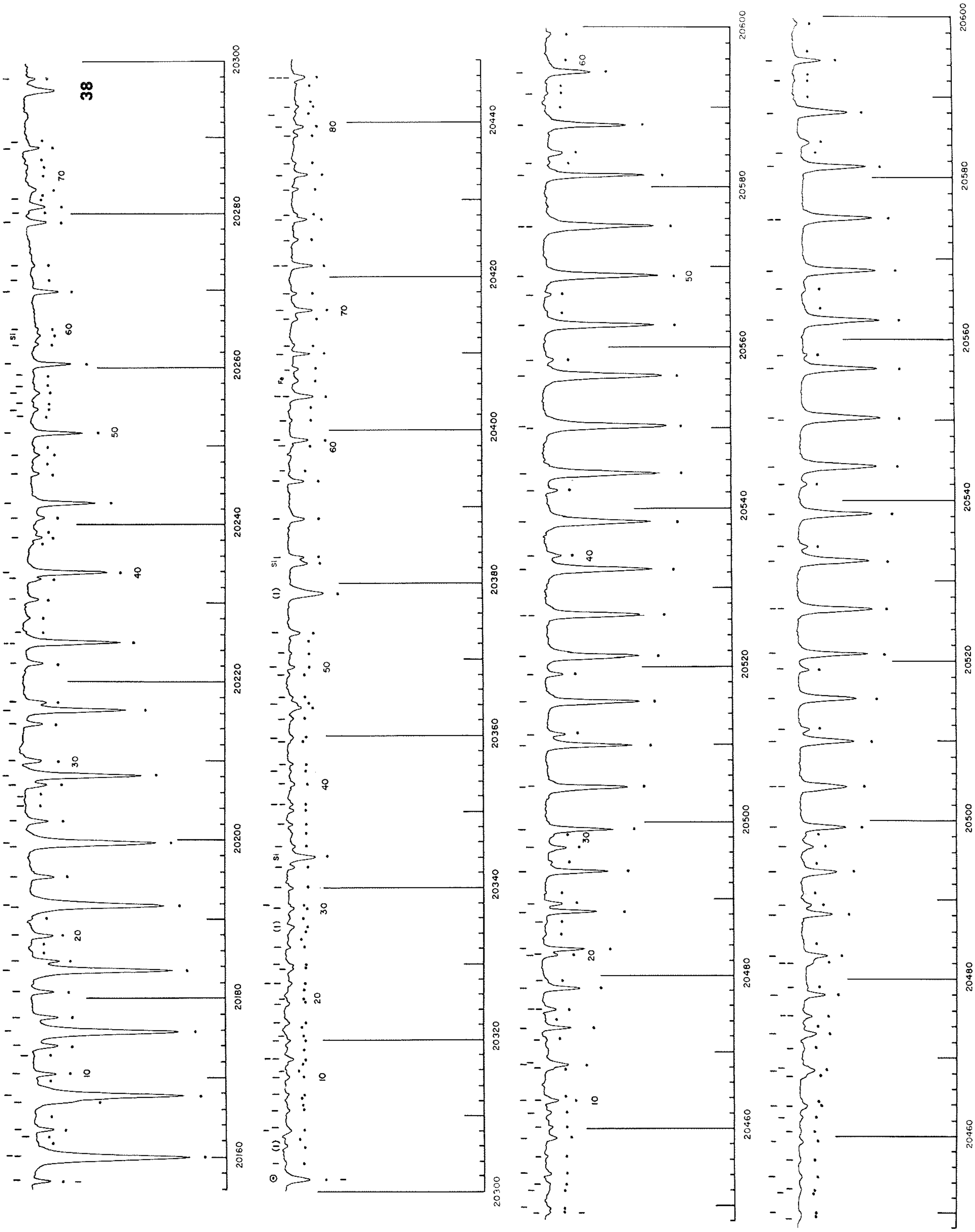

Fig. 6 Solar Spectrum λλ 20156–20600, in four strips (cf. Table 1).

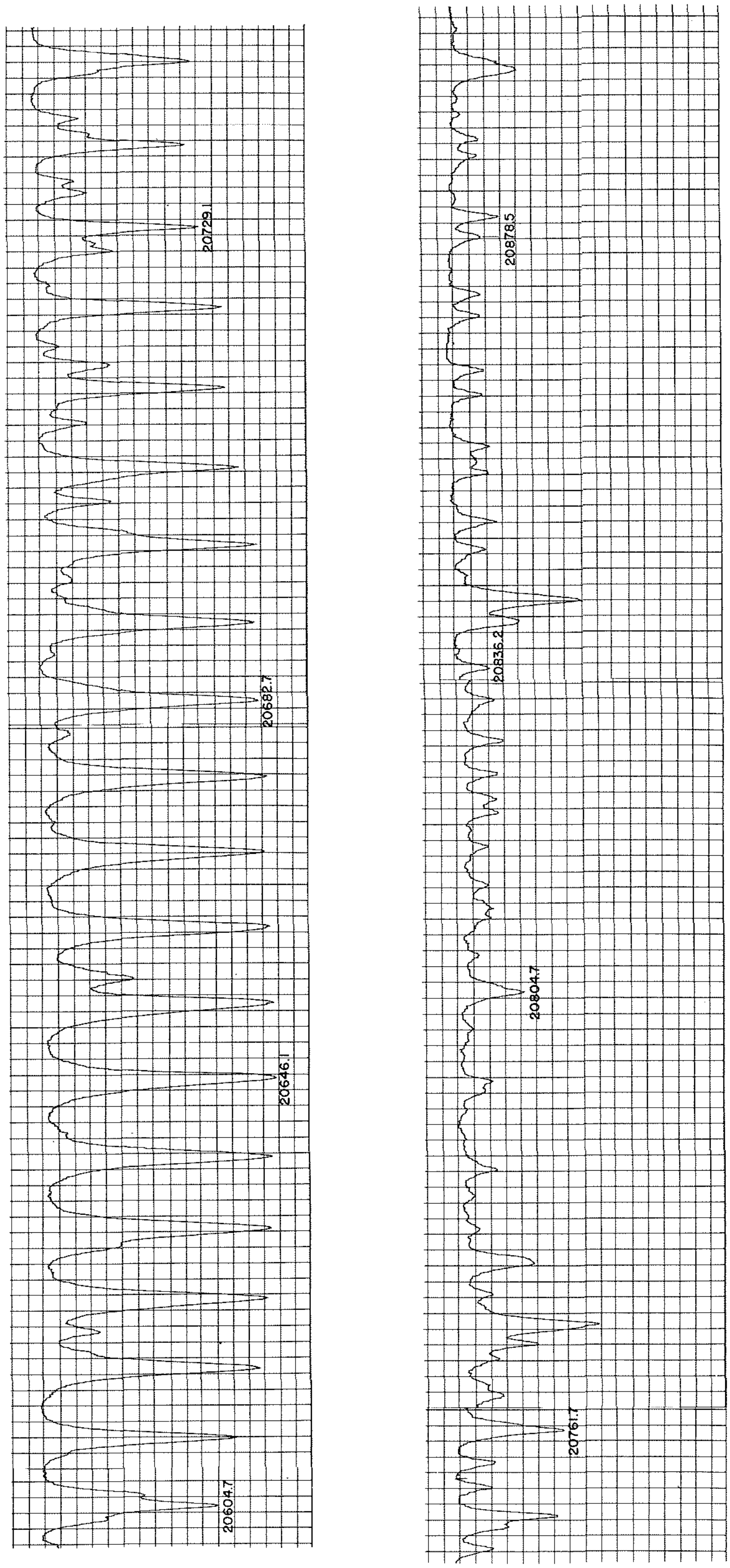

Fig. 7M Part of the Michigan Atlas, that matches *Fig. 7*.

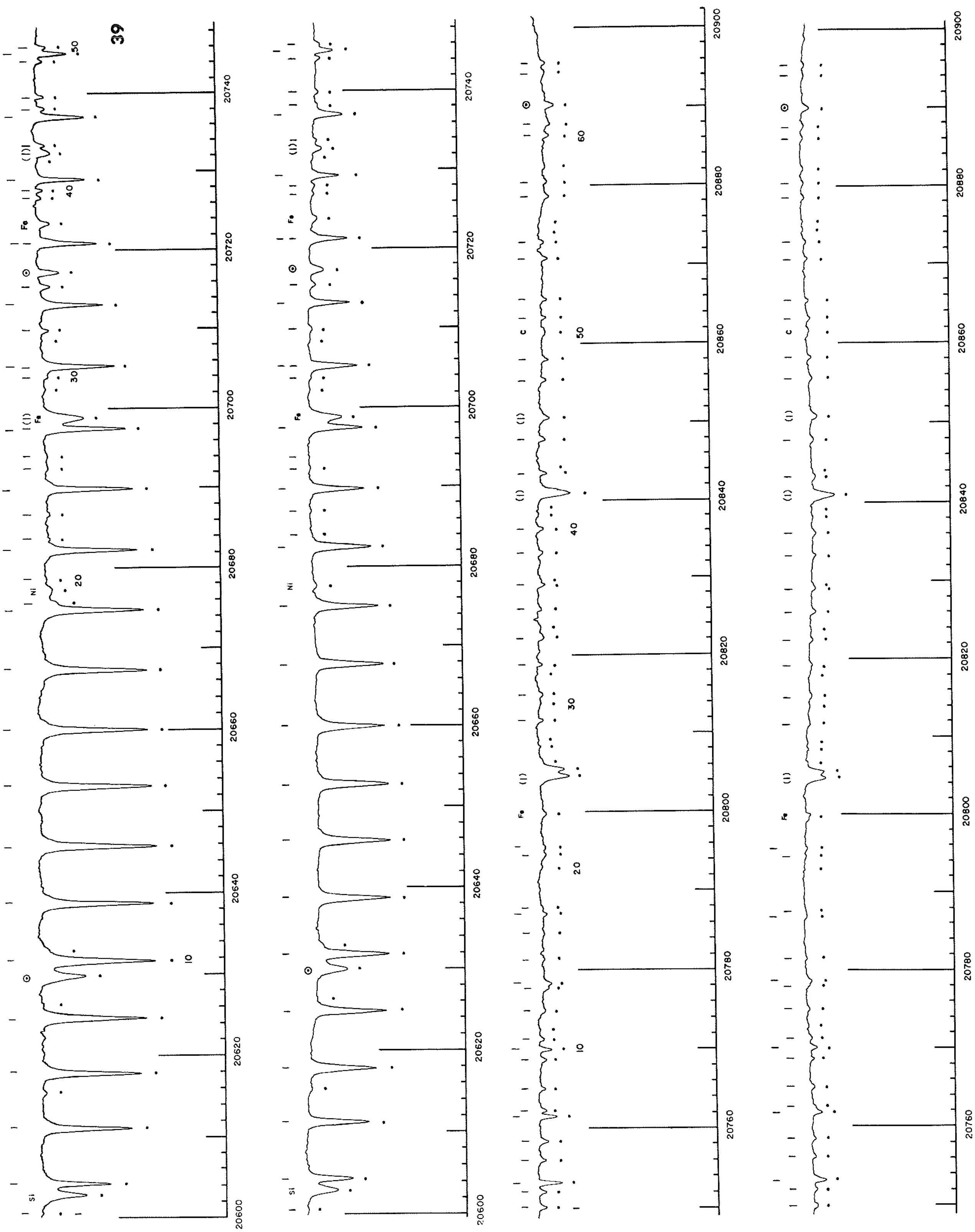

Fig. 7 Solar Spectrum λλ 20600–20901, in four strips (cf. Table 1).

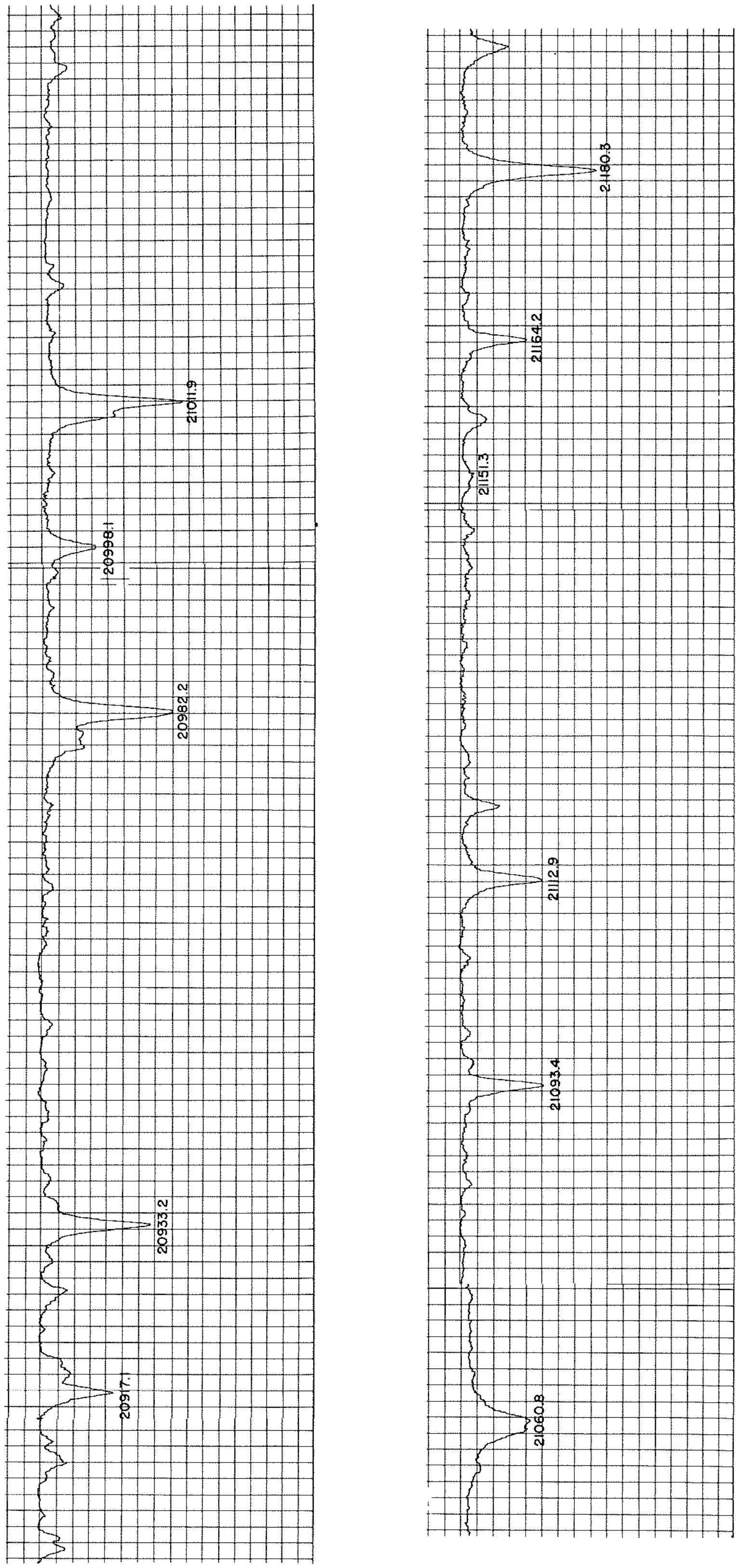

Fig. 8M Part of the Michigan Atlas, that matches *Fig. 8*.

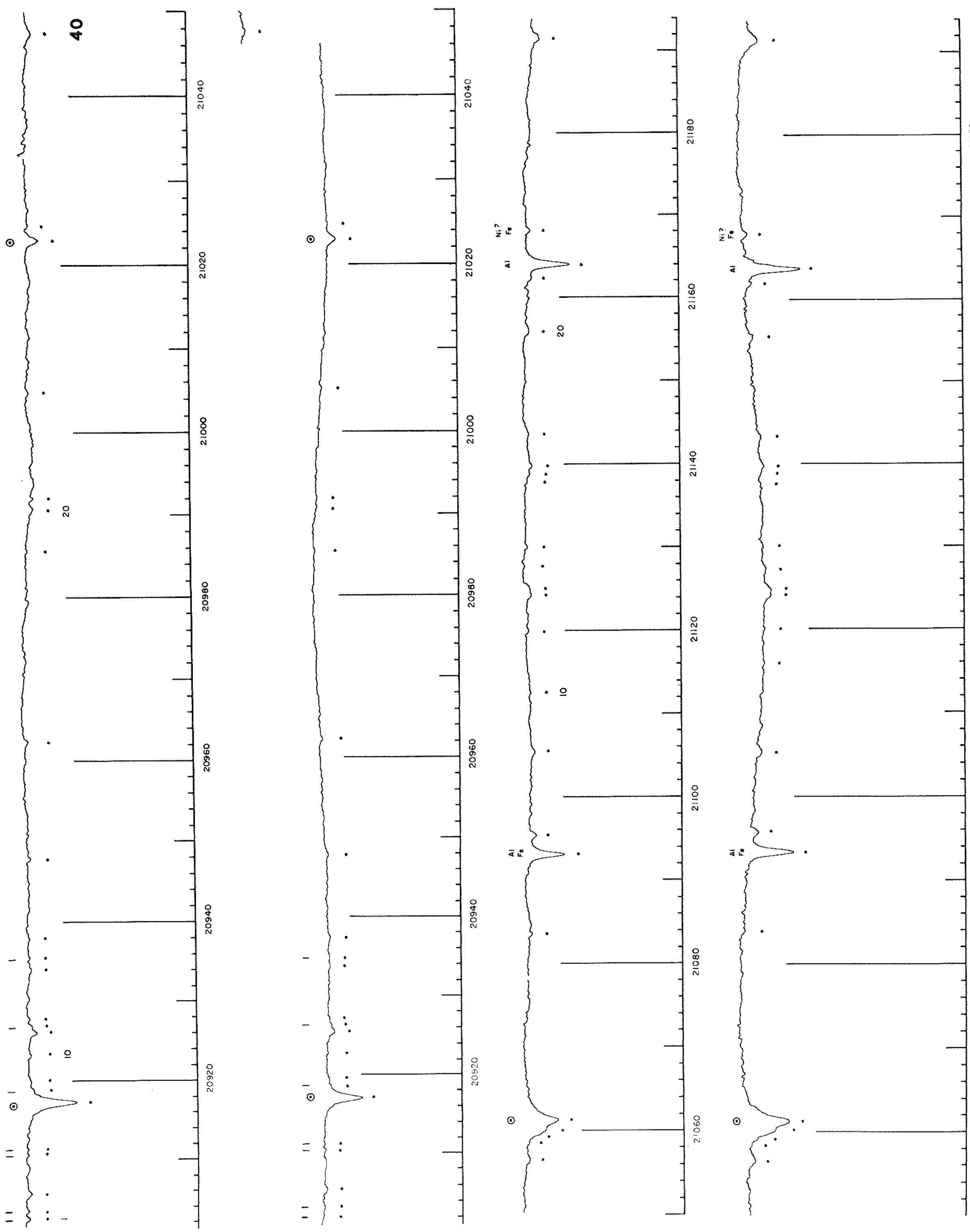

Fig. 8 Solar Spectrum λλ 20901–21194, in four strips (cf. Table 1).

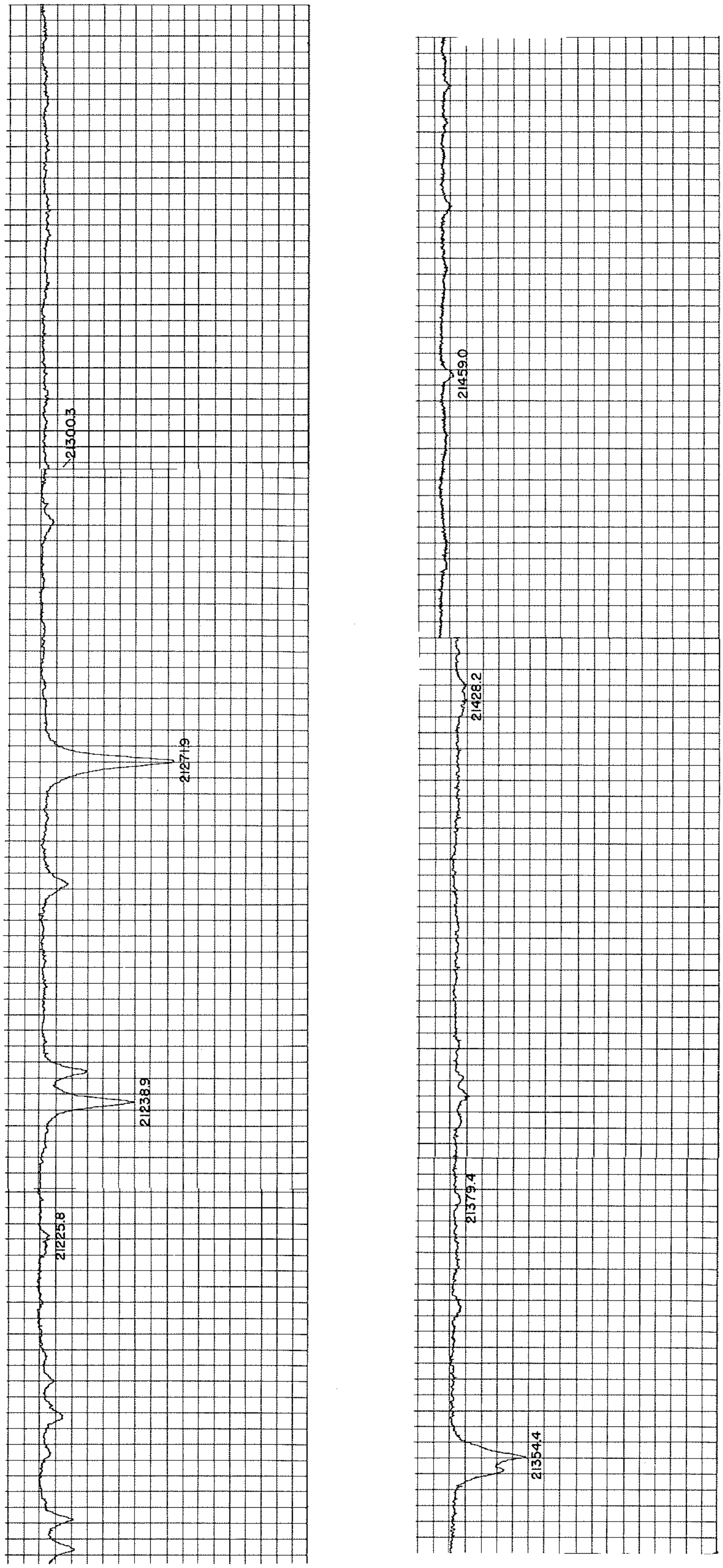

Fig. 9M Part of the Michigan Atlas, that matches *Fig. 9*.

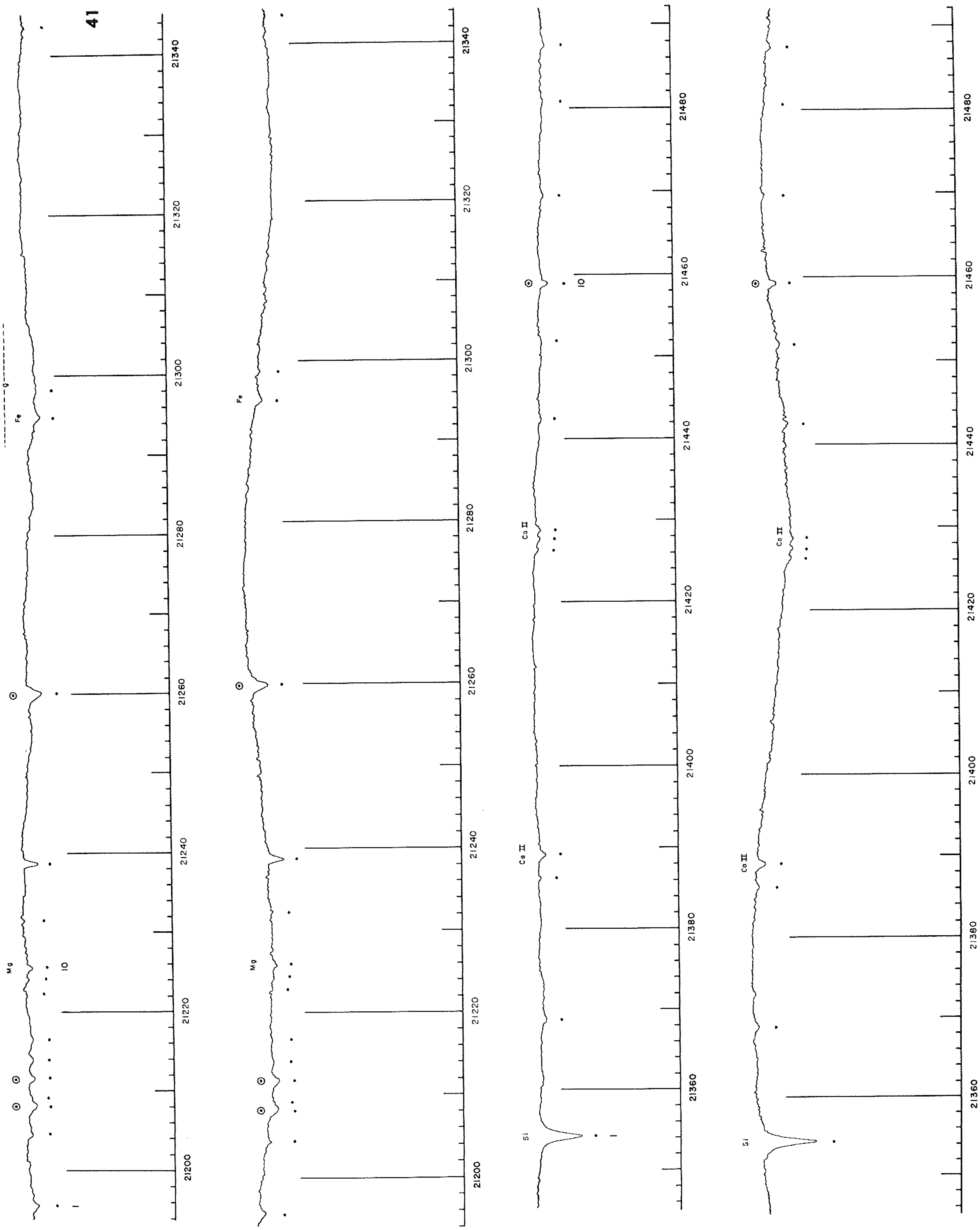

Fig 9 Solar Spectrum λλ 21194–21492, in four strips (cf. Table 1).

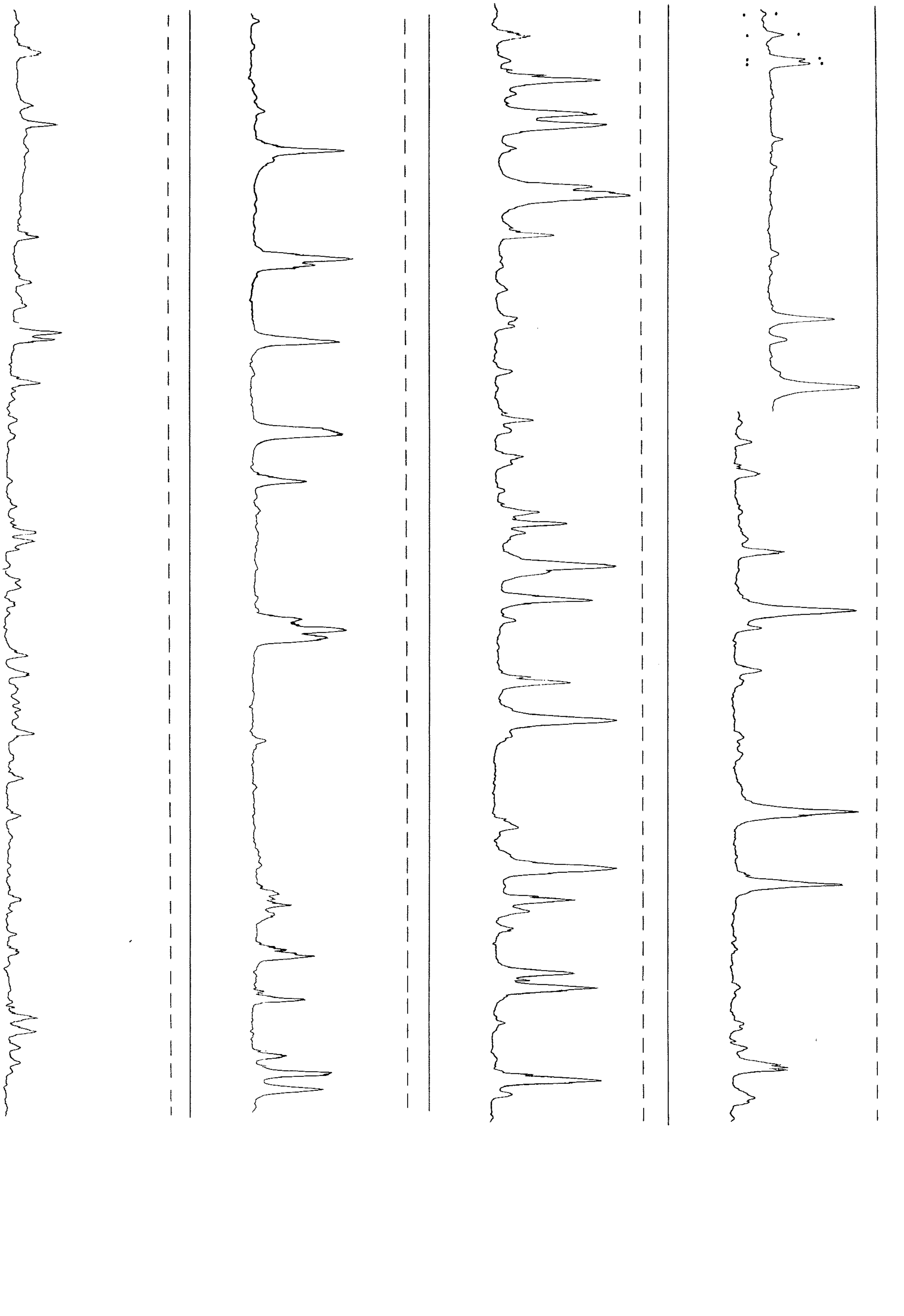

Fig. 10 Solar Spectrum λλ 18044–18644, the spectral interval also covered by *Fig. 2*. Explanation in text.

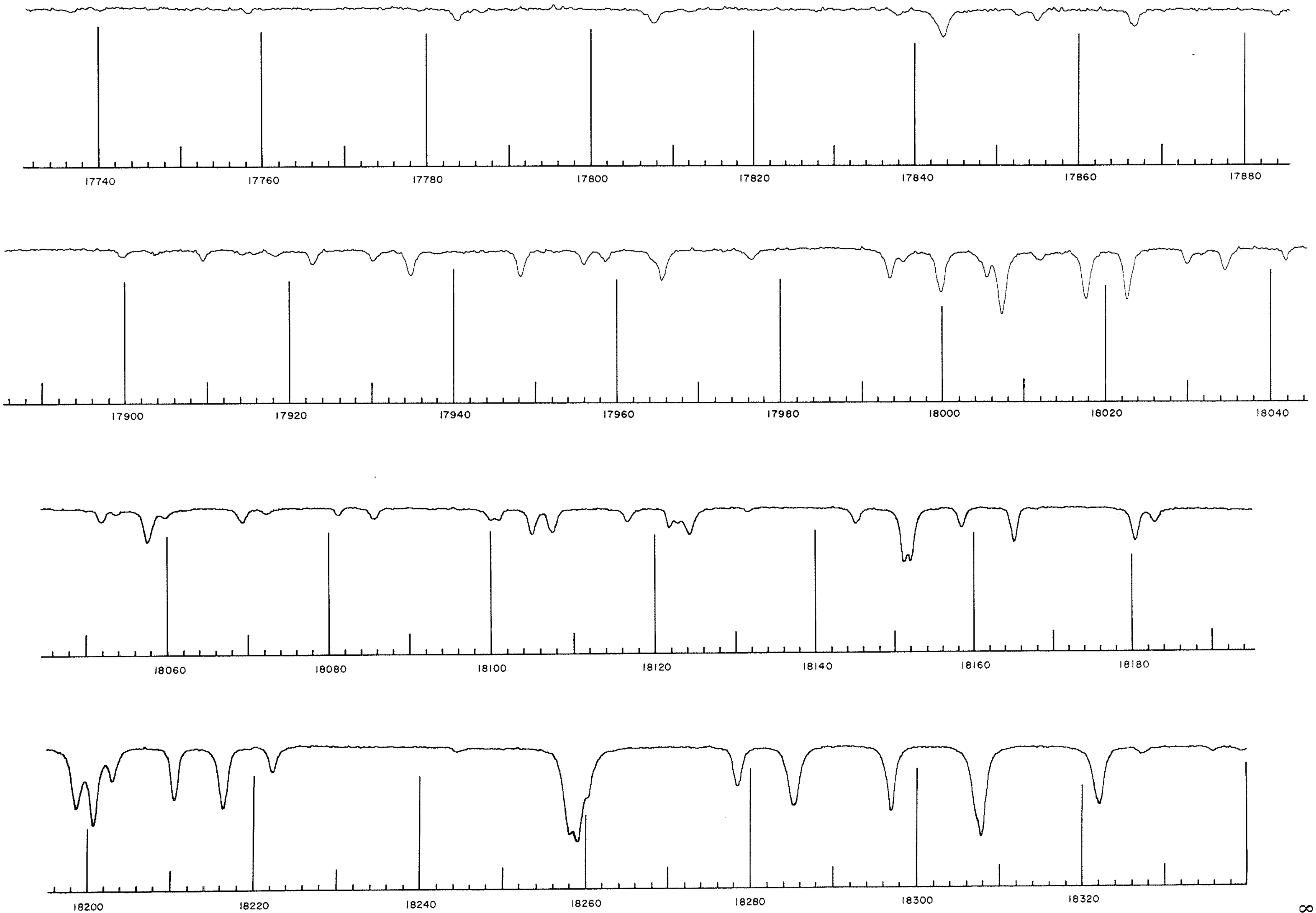

Fig. 11 Laboratory Spectrum of water vapor λλ 17731–18340 Å, that matches the solar spectrum *Figs. 1, 2a, b.*
Strips *a* and *b*: Spectrometer not flushed.
Strips *c* and *d*: Spectrometer flushed with dry nitrogen.

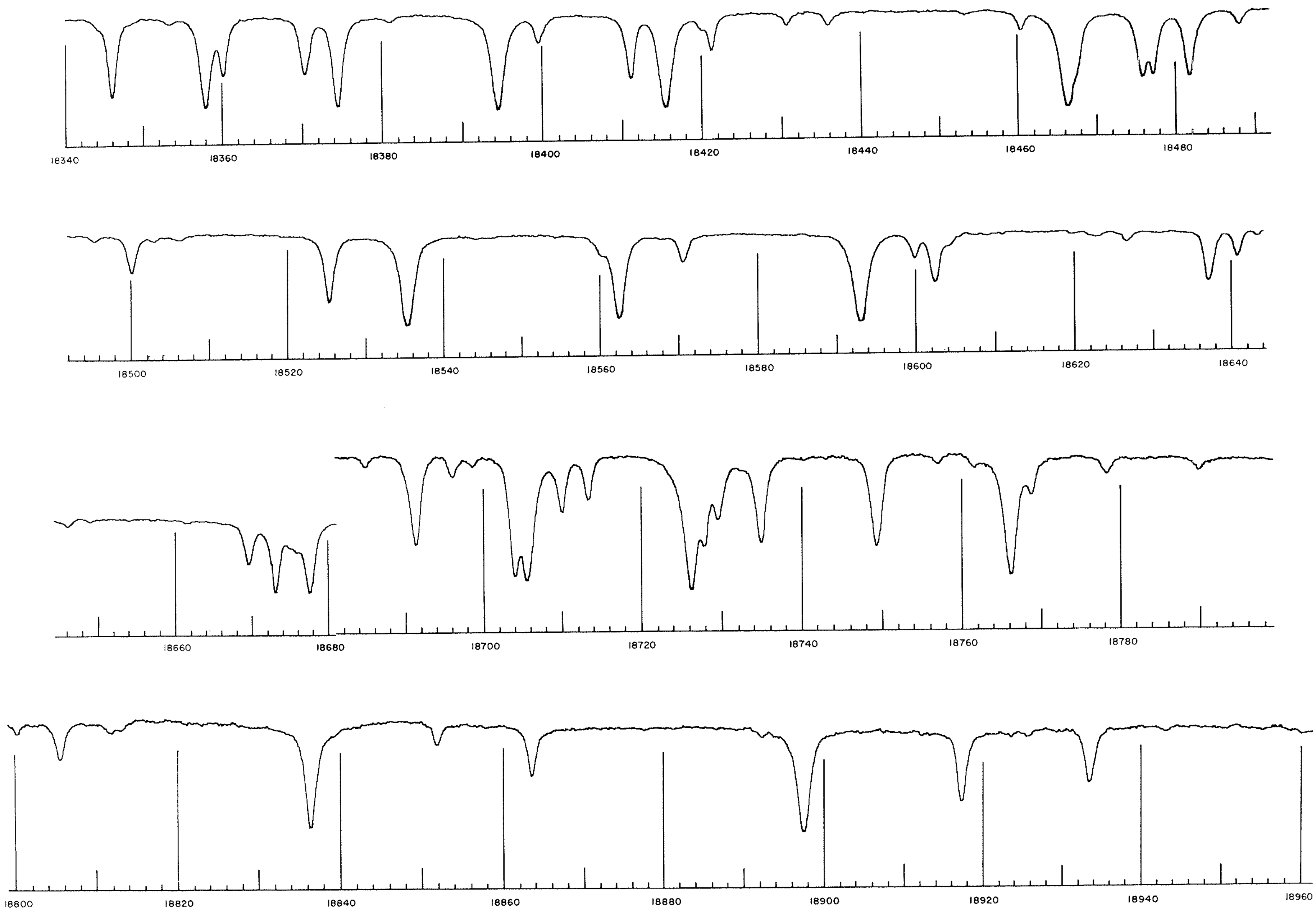

Fig. 12 Laboratory Spectrum of water vapor λλ 18340–18962, that matches the solar spectrum *Figs. 2c, d, 3.*

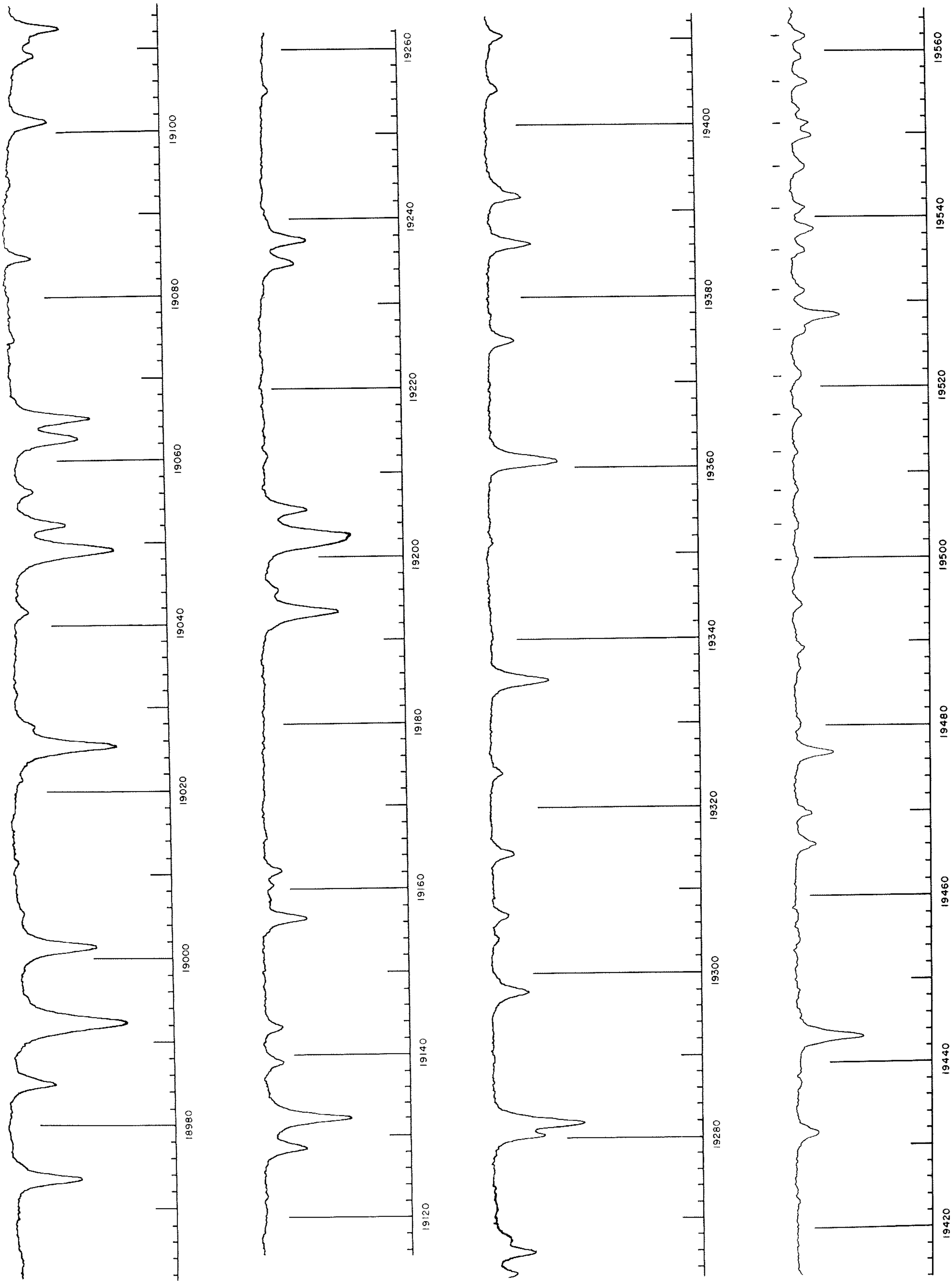

Fig. 13 Laboratory Spectrum of water vapor λλ 18962–19565, that matches the solar spectrum *Fig. 4.*
Strip *a*, *b* and *c*: spectrometer flushed with dry nitrogen.
Strip *d*: Spectrometer not flushed; some CO_2 lines.

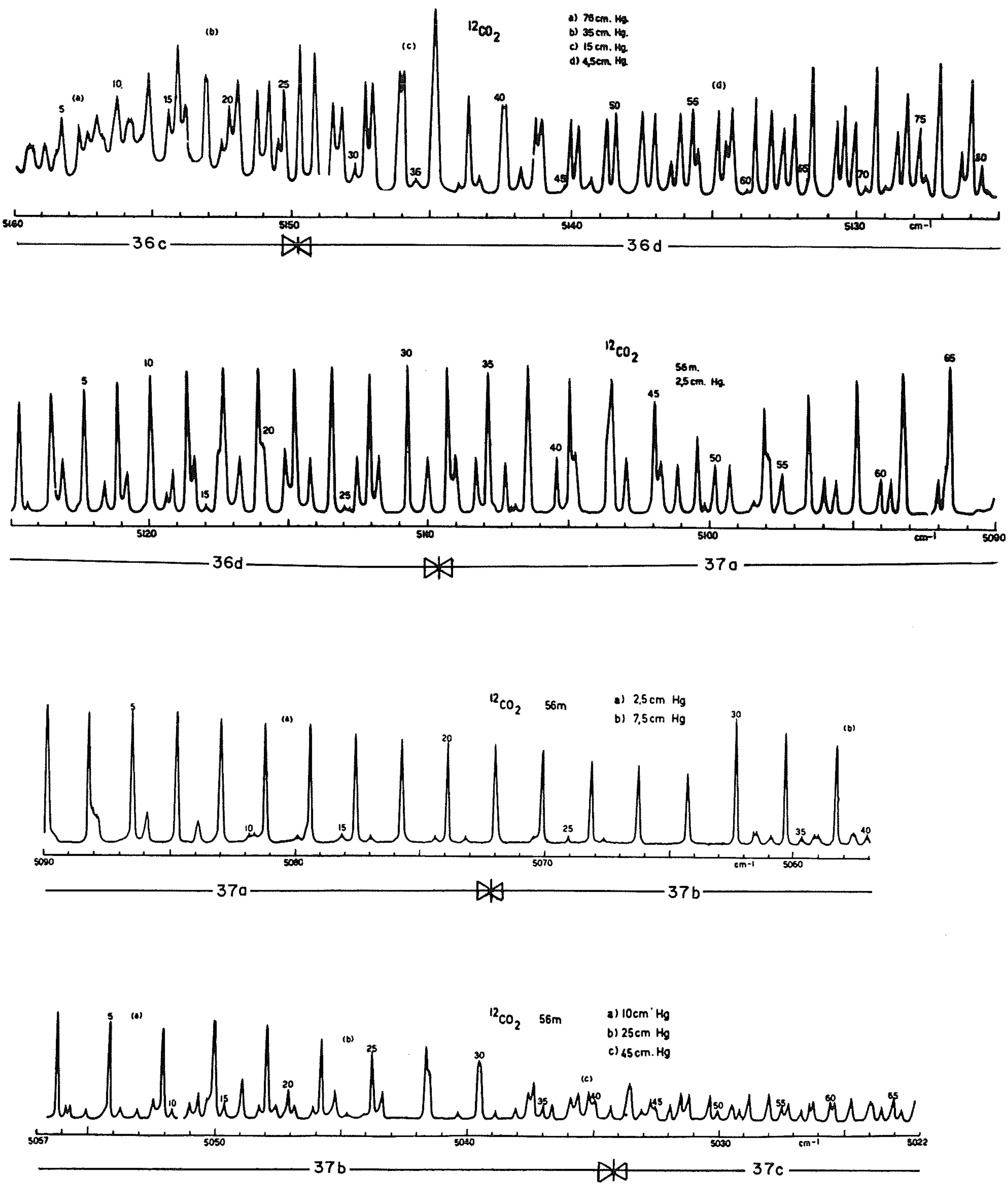

Fig. 14 Courtoy's laboratory spectrum of CO_2, natural isotopic mixture. Scale in wavenumbers. Arrows give chart number of corresponding part of solar spectrum. (Reproduced with permission)

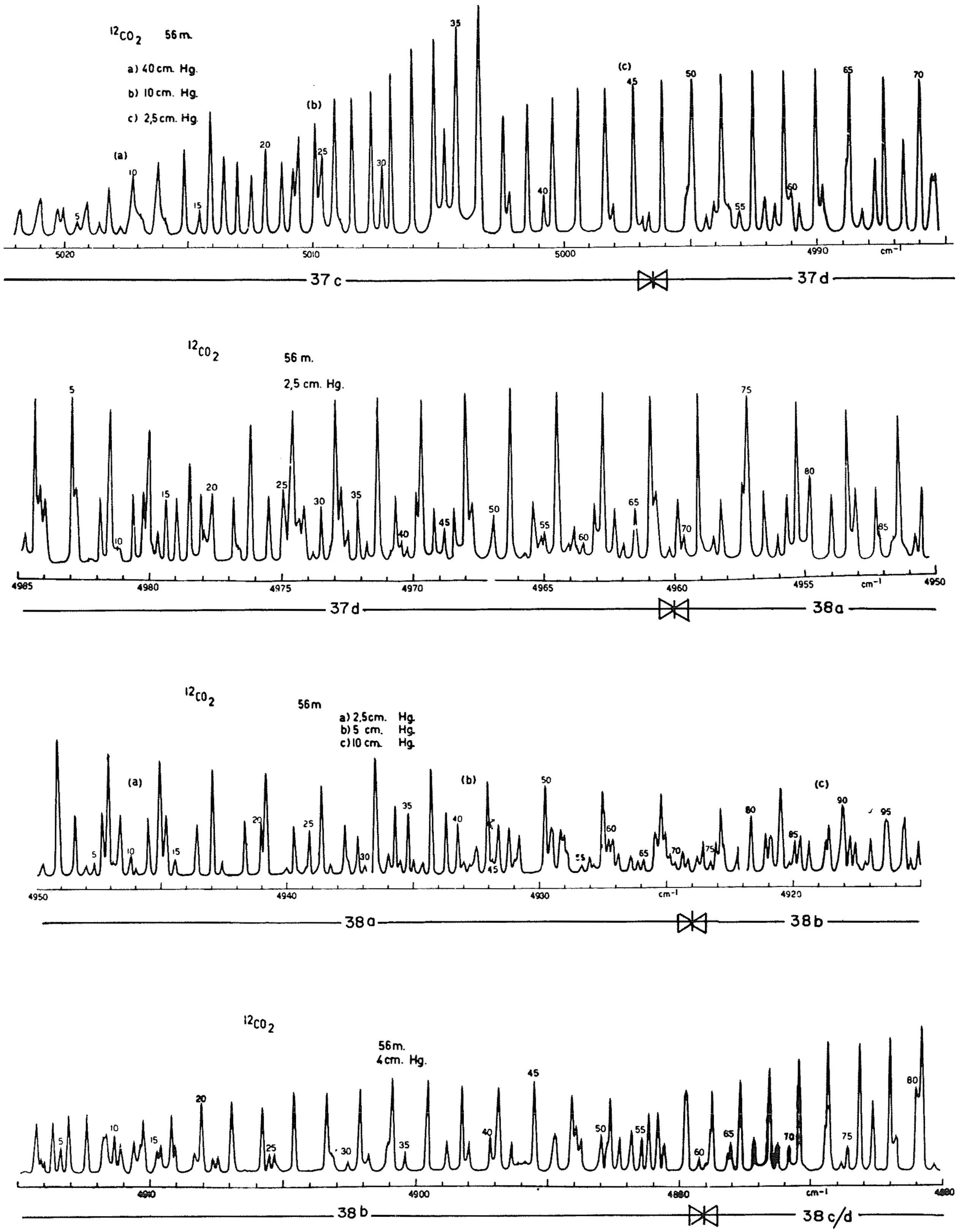

Fig. 15 Courtoy's laboratory spectrum of CO_2, natural isotopic mixture. Scale in wavenumbers. Arrows give chart number of corresponding part of solar spectrum. (Reproduced with permission)

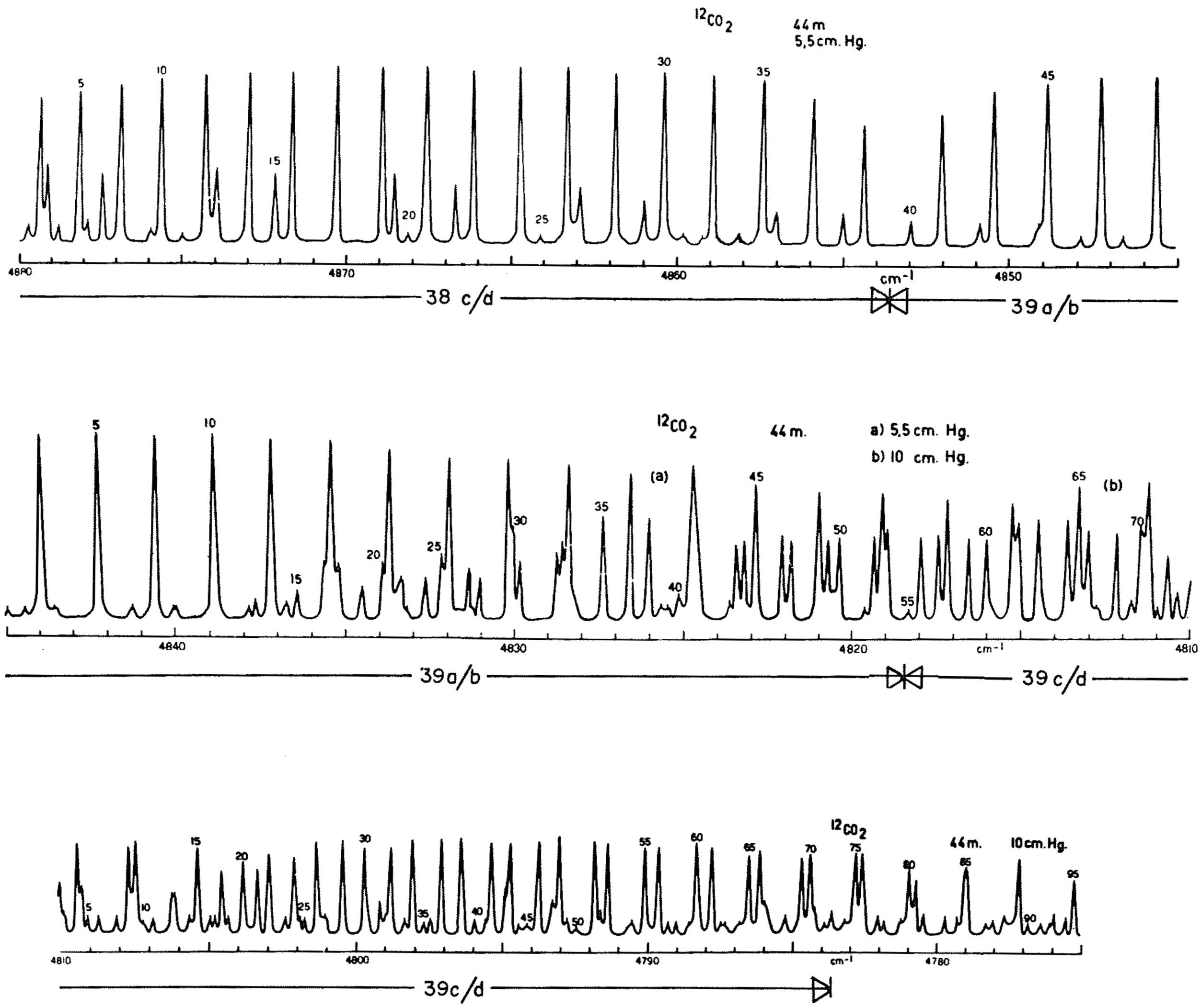

Fig. 16 Courtoy's laboratory spectrum of CO_2, natural isotopic mixture. Scale in wavenumbers. Arrows give chart number of corresponding part of solar spectrum. (Reproduced with permission)

No. 164 ARIZONA-NASA ATLAS OF THE INFRARED SOLAR SPECTRUM, REPORT VIII

by L. A. BIJL, G. P. KUIPER, AND D. P. CRUIKSHANK

July 31, 1969

ABSTRACT

In this paper we reproduce the solar spectrum λλ 21492–25583 Å, as obtained from the NASA CV-990 Jet at high altitude. The paper is a continuation of *Comm. LPL* Nos. 161 and 163. Included are laboratory spectra of the 2.20, 2.32, and 2.37 μ bands of methane and of the wings of the water-vapor bands at 2.7 μ. The 8–6 and 9–7 solar CO bands are found to be present in the spectra.

The solar records reproduced in this paper were obtained on high-altitude flights with the NASA CV-990 Jet, using the LPL 4-m spectrometer with a 600 l/mm grating. They are a continuation of the records in *Comm. LPL* 161 and 163. Observing data are listed in Table 1. The upper wavelength limit in this report was chosen near λ 25578 Å, the upper limit of Mohler's *Table* (1955), which was used in the identification of the lines in the solar spectrum and the construction of the wavelength scale. Additionally, near the end of the *Table,* we consulted the measurements by Plyler and Tidwell (1957) and the line parameters for water vapor at 2.7 μ by Gates *et al.* (1964). For the conversion of wave numbers to wavelengths, we used Coleman's *Table of Wavenumbers* (NBS 1960). As before, we have included the matching parts of the Michigan *Atlas* (1950).

In order to be able to separate the methane absorptions from solar absorptions, we obtained laboratory spectra of the 2.20, 2.32, and 2.37 μ methane bands. To this end, we placed a 10-cm cell in the beam between the light source and entrance slit of the 4-m spectrometer. For the spectra reproduced here (Figs. 10–14), the cell was filled with methane to a pressure of about 4.8 cm Hg, corresponding to 6.3 mm atm. of methane in the path. The 4-m spectrometer was not flushed with dry nitrogen, so that some water-vapor absorptions appear in Fig. 14.

Further included is a laboratory spectrum for the wings of the H_2O bands at 2.7 μ. Because of high humidity in the laboratory, we were unable to reduce the absorptions below the intensities shown (Fig. 15–17), even though the 4-m spectrometer was flushed with dry nitrogen and the light path outside the spectrometer was relatively short.

In his *Table* Mohler gives the line positions of many of the lines in the 2–0, 3–1, 4–2, 5–3, 6–4, 7–5 solar CO bands. Because of the low telluric absorptions in our spectra, these CO bands are shown more completely here. Positions of lines not listed in Mohler's *Table* were interpolated or calculated from the constants for the CO molecule, as given by Goldberg and Müller (1953). In our spectra we also found the 8–6 and 9–7 solar CO bands present, not observed before, of which the positive branch is complete from $J = 22$ to $J = 54$, so that the bandheads at λ 24781 Å and λ 25116 Å are easily recognized. The CO lines are marked with asterisks above the spectral traces. All CO lines recorded are believed to be solar, not telluric, except possibly for lines of the 2–0 CO band with low rotational quantum numbers, which might be telluric in part, though this is not considered likely, in view of the extremely low telluric CO abundance and the high altitude at which the solar spectra were taken.

As before, a dot above the spectral trace indicates a water-vapor absorption; a triangle, a methane absorption. A symbol placed in parentheses indicates that the absorption line is considered only partly telluric.

The water-vapor absorptions in the spectrometer during the flights are not negligible. For an evaluation of their contribution, see *Comm. LPL* 160.

The solar spectra were obtained in the NASA CV-990 by Messrs. Kuiper and Cruikshank. The derivation of the wavelength scale and the identifications were performed by Mr. Bijl, who also obtained the laboratory spectra of the 2.20, 2.32, and 2.37 μ bands of methane and the 2.7 μ bands of H_2O; he further prepared all charts for publication.

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. Mr. D. C. Benner constructed the wavelength scales for the laboratory spectra and assisted in the calculation of the CO line positions. 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.

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SOLAR SPECTRUM RECORDS, 4-M SPECTROMETER NASA CV-990 JET
600 l/mm GRATING; GRATING BLAZE, 1.6 μ, JUL. 18, 19; 2.5 μ, AUG. 1; DETECTOR 0.10 MM
$\tau = 0.12$ SEC., FILTER 1.8 μ

FIG.	CHART			1968 DATE	UT	ALT. (FT)	OUTSIDE TEMP. (°C)	CABIN ALT. (FT)	GAIN	SLIT (MM)
1.	42	a	21492–21639	Aug. 1	20:14	41,800	−58	9300	5–3	0.12
		b	21639–21787	Aug. 1	20:18	41,800	−58	9300	5–3	0.12
		c	21787–21931	Aug. 1	20:21	41,800	−58	9300	5–3	0.12
		d	21931–22075	Aug. 1	20:24	41,800	−58	9300	5–3	0.12
2.	43	a	22075–22223	Aug. 1	20:28	41,800	−58	9300	5–3	0.12
		b	22223–22367	Aug. 1	20:31	41,800	−58	9300	5–3	0.12
		c	22367–22509	Aug. 1	20:34	41,800	−58	9300	5–3	0.12
		d	22509–22653	Aug. 1	20:38	41,800	−57	9300	5–3	0.12
3.	44	a	22653–22798	Aug. 1	20:41	41,800	−56	9300	5–3	0.12
		b	22798–22940	Aug. 1	20:45	41,800	−55	9300	5–3	0.12
		c	22940–23073	Aug. 1	20:48	41,800	−55	9300	5–3	0.12
		d	22940–23073	Jul. 18	20:03	39,000	−54	8500	5–6	0.09
4.	45	a	23073–23204	Aug. 1	20:51	41,800	−54	9300	5–3	0.12
		b	23073–23204	Jul. 18	20:06	39,000	−54	8500	5–6	0.09
		c	23204–23333	Jul. 18	20:09	39,000	−54	8500	5–6	0.09
		d	23204–23271	Aug. 1	20:54	41,800	−55	9300	5–3	0.12
5.	46	a	23333–23465	Jul. 18	20:13	39,000	−54	8500	5–6	0.09
		b	23465–23594	Jul. 18	20:16	39,000	−54	8500	5–6	0.09
		c	23594–23731	Jul. 18	20:19	39,000	−54	8500	5–6	0.09
		d	23594–23731	Jul. 19	18:13	39,000	−53	8500	5–4	0.18
6.	47	a	23731–23871	Jul. 19	18:17	39,000	−53	8500	5–4	0.18
		b	23871–24007	Jul. 19	18:21	39,000	−53	8500	5–4	0.18
		c	24007–24140	Jul. 19	18:24	39,000	−53	8500	5–4	0.18
		d	24140–24276	Jul. 19	18:27	39,000	−53	8500	5–4/5–5	0.18
7.	48	a	24276–24413	Jul. 19	18:31	39,000	−53	8500	5–5	0.18
		b	24413–24543	Jul. 19	18:34	39,000	−53	8500	5–5	0.18
		c	24543–24680	Jul. 19	18:37	39,000	−53	8500	5–5	0.18
		d	24680–24813	Jul. 19	18:41	39,000	−53	8500	5–5	0.18
8.	49	a	24813–24942	Jul. 19	18:44	39,000	−53	8500	5–5	0.18
		b	24942–25072	Jul. 19	18:47	39,000	−53	8500	5–5	0.18
		c	25072–25202	Jul. 19	18:51	39,000	−53	8500	5–5/5–6	0.18
		d	25202–25324	Jul. 19	18:54	39,000	−53	8500	5–6	0.18
9.	50	a	25324–25456	Jul. 19	18:57	39,000	−53	8500	5–6	0.18
		b	25456–25583	Jul. 19	19:01	39,000	−53	8500	5–6	0.18

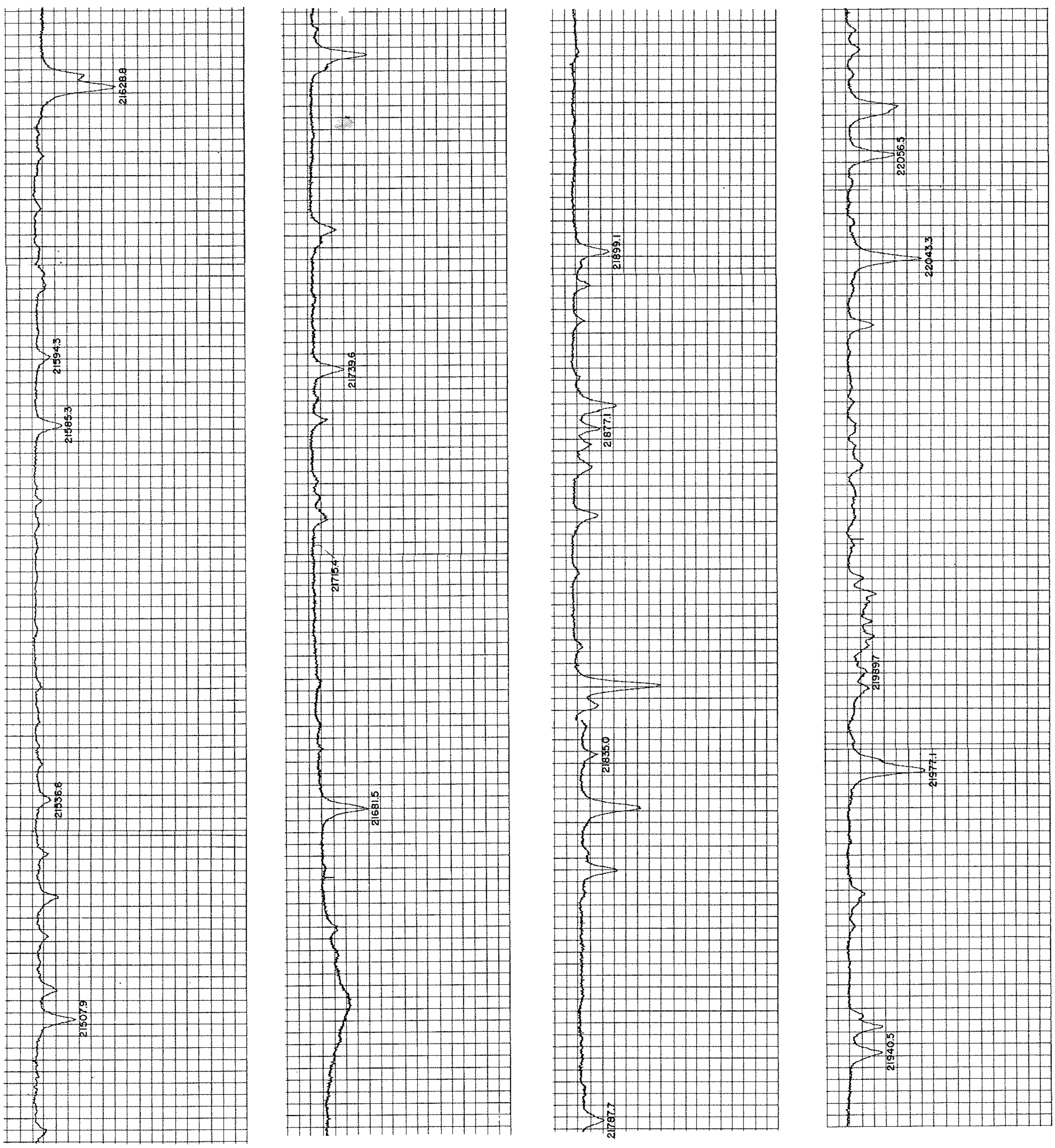

Fig. 1M Part of Michigan Atlas, that matches Fig. 1 (Reproduced with permission).

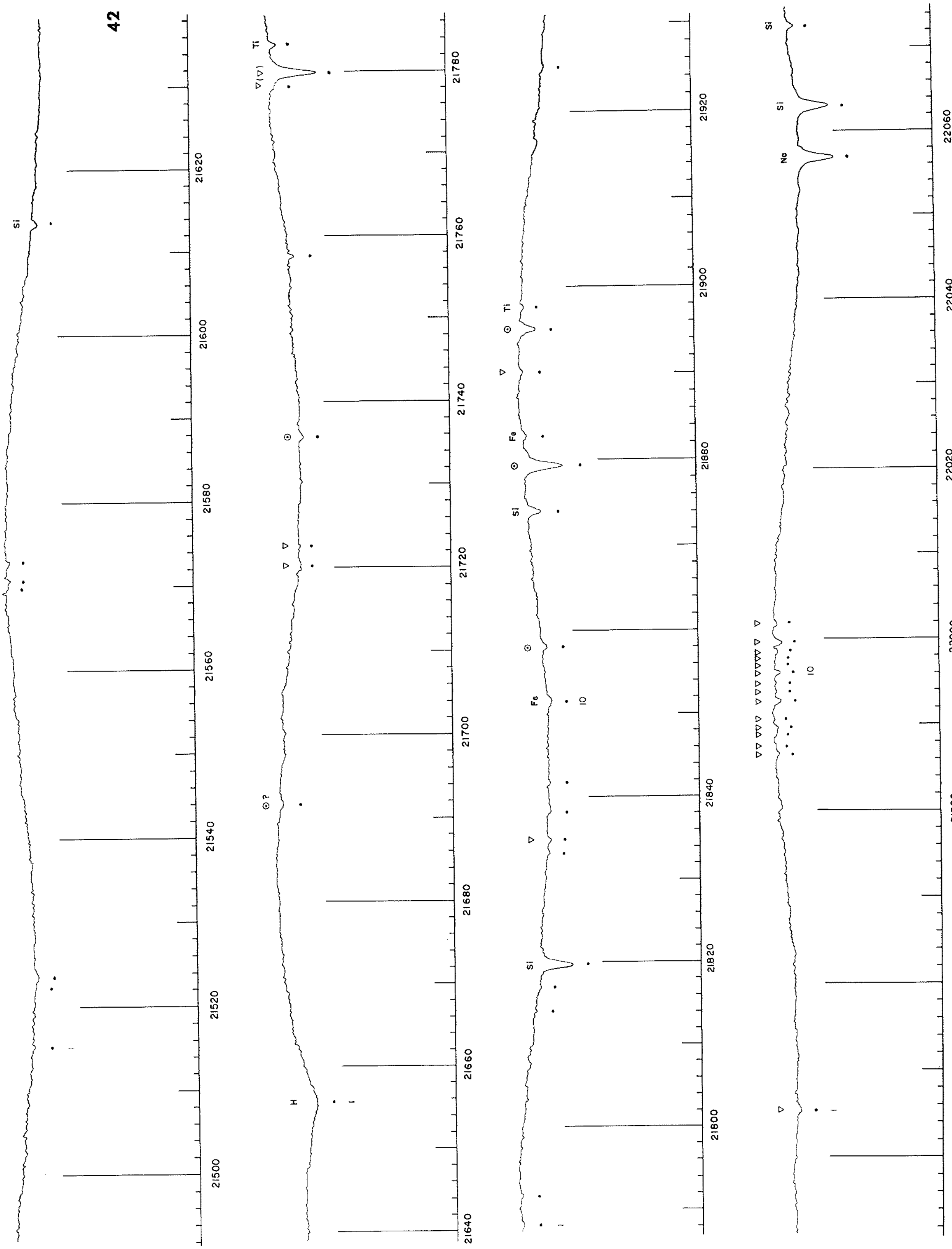

Fig. 1 Solar Spectrum λλ 21492–22075, in four strips (cf. Table 1).

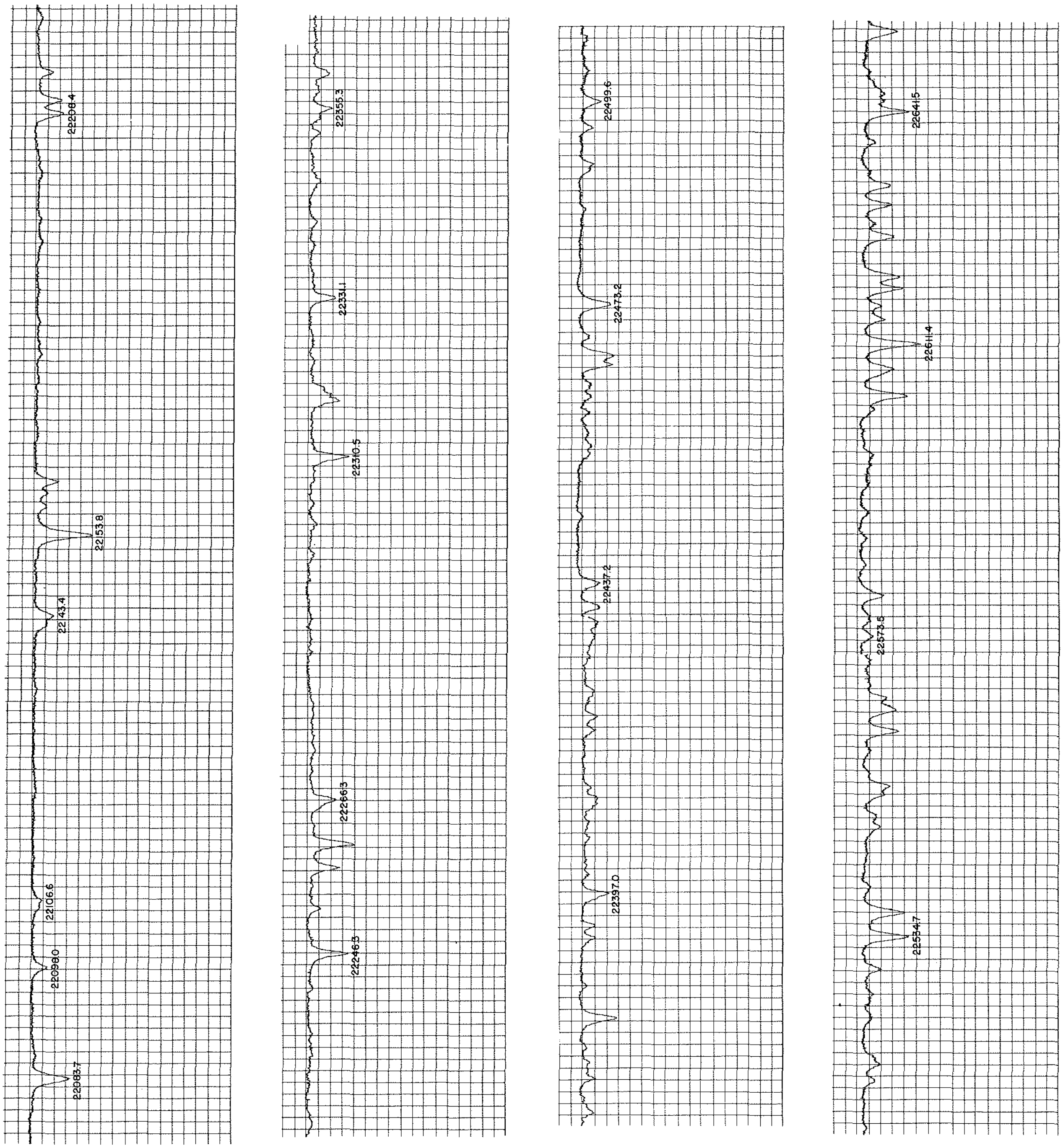

Fig. 2M Part of Michigan Atlas, that matches Fig. 2 (Reproduced with permission).

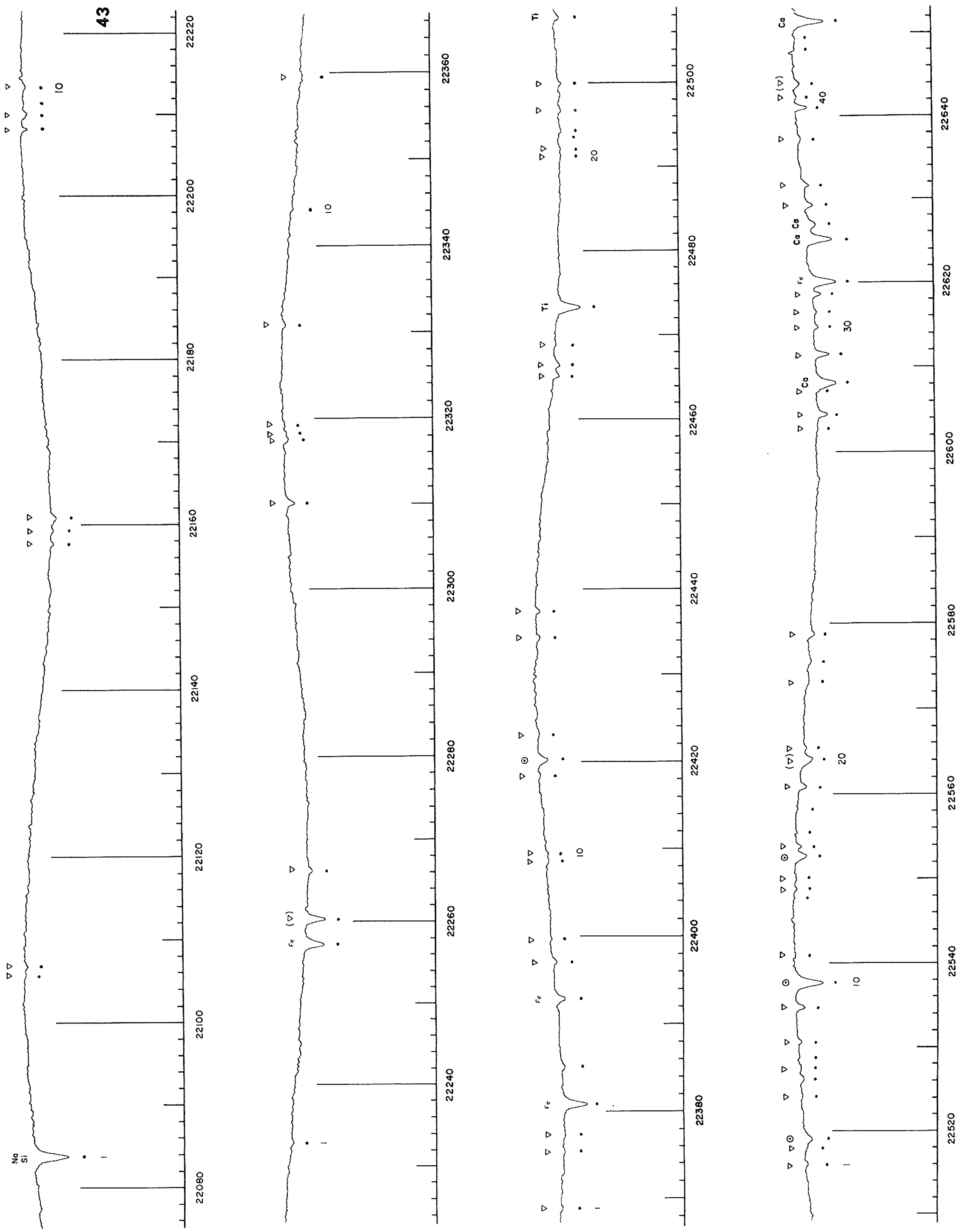

Fig. 2 Solar Spectrum λλ 22075–22653, in four strips (cf. Table 1).

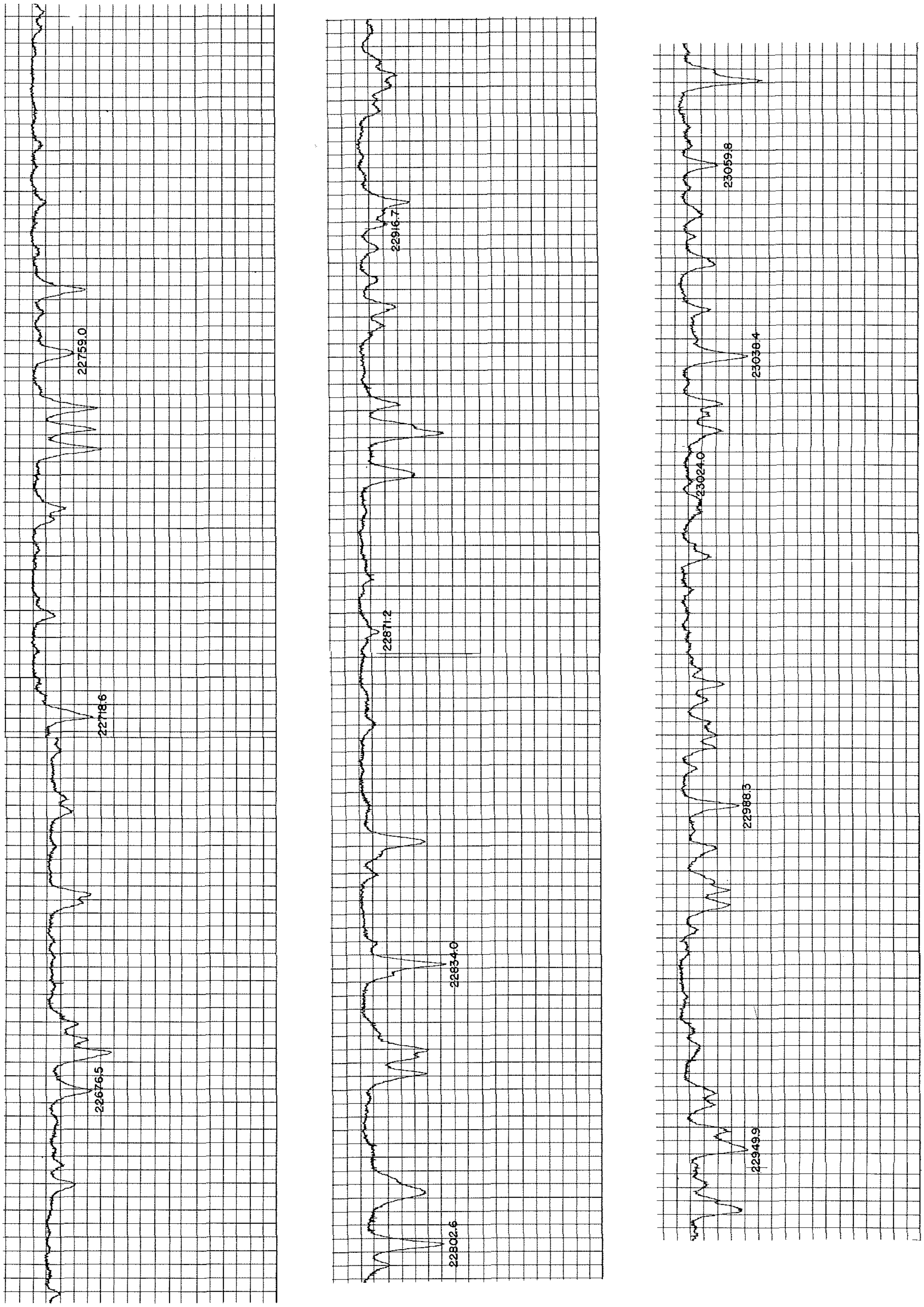

Fig. 3M Part of Michigan Atlas, that matches Fig. 3 (Reproduced with permission).

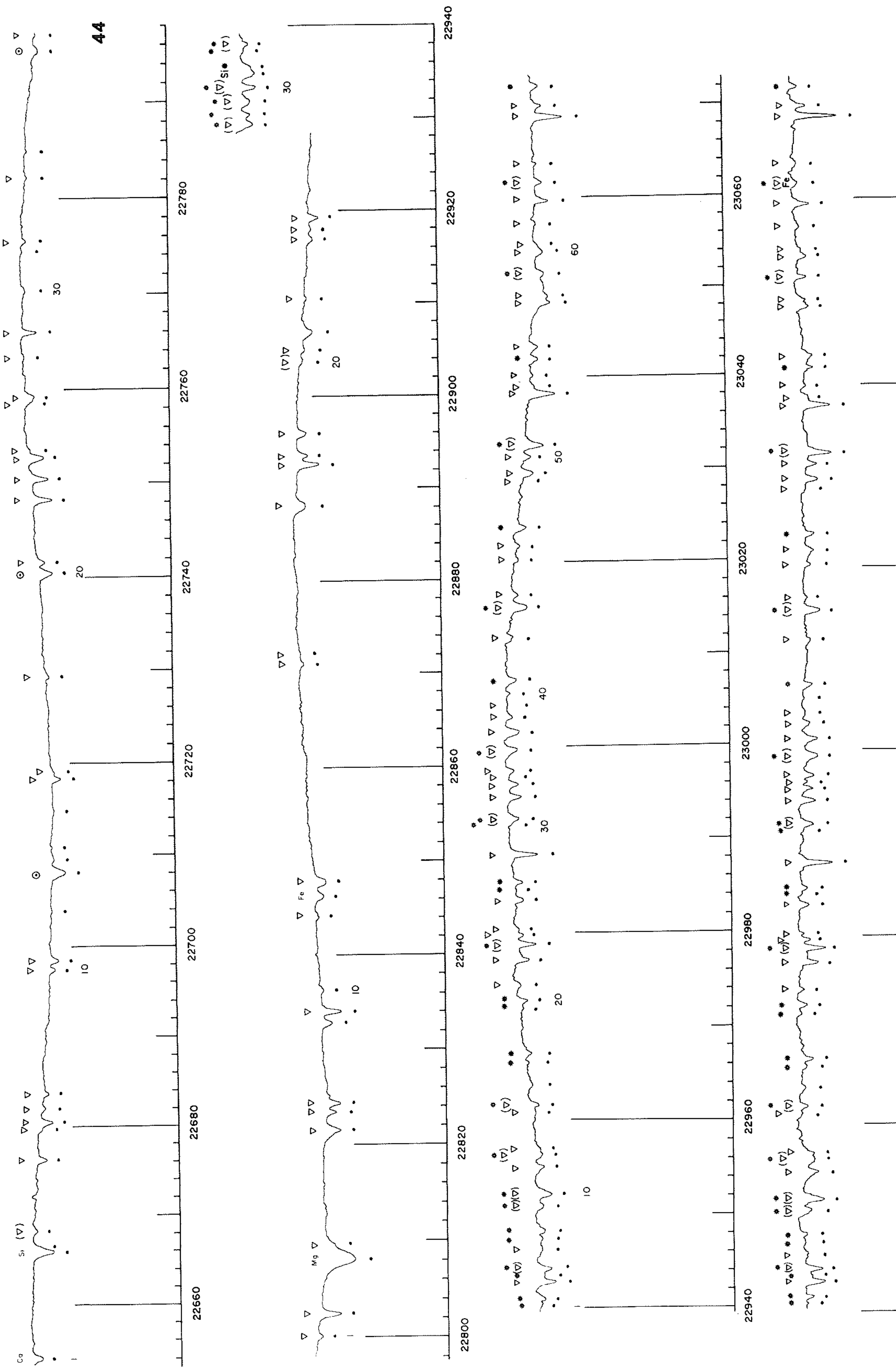

Fig. 3 Solar Spectrum λλ 22653–23073, in four strips (cf. Table 1).

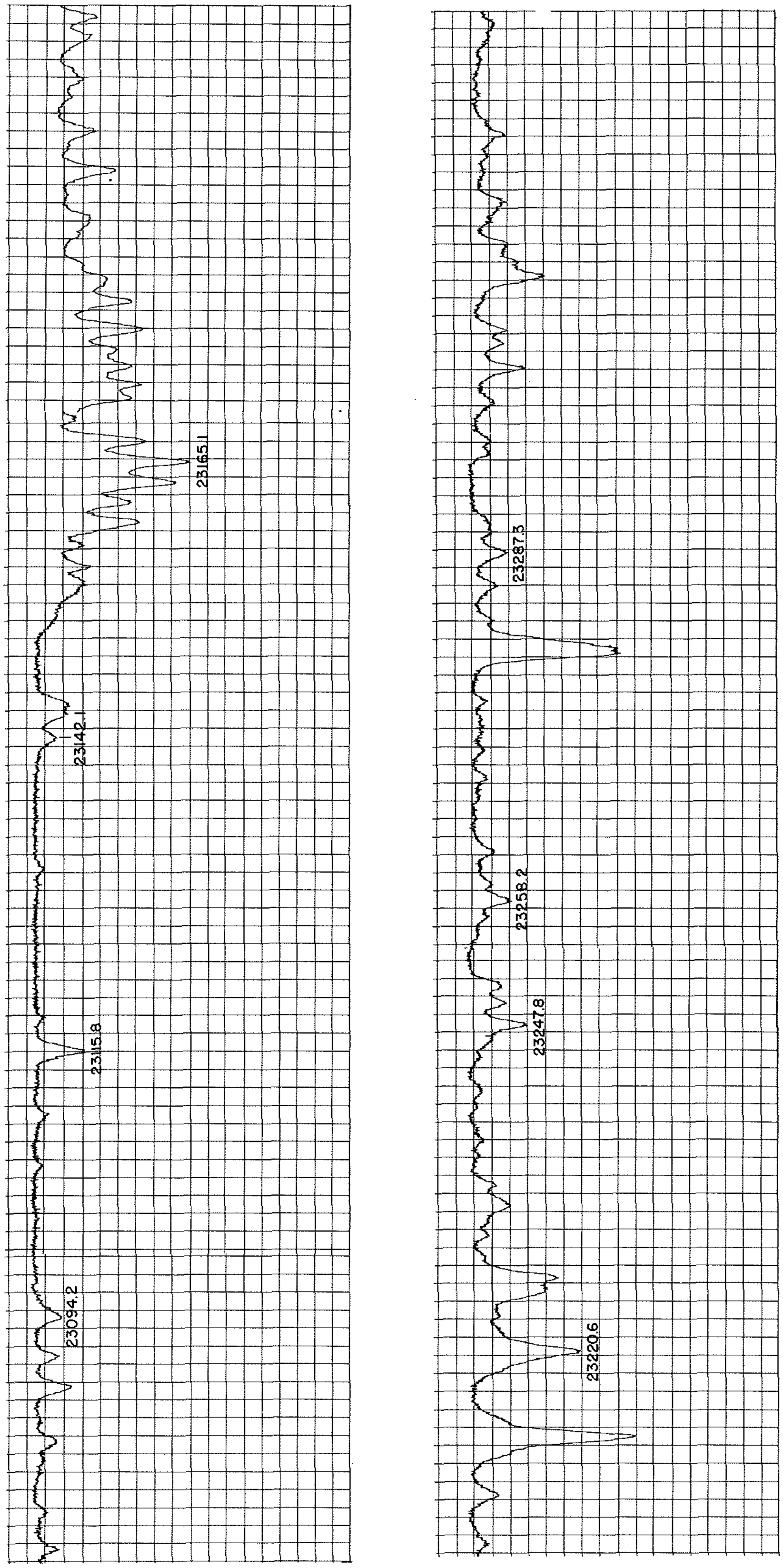

Fig. 4M Part of Michigan Atlas, that matches Fig. 4 (Reproduced with permission).

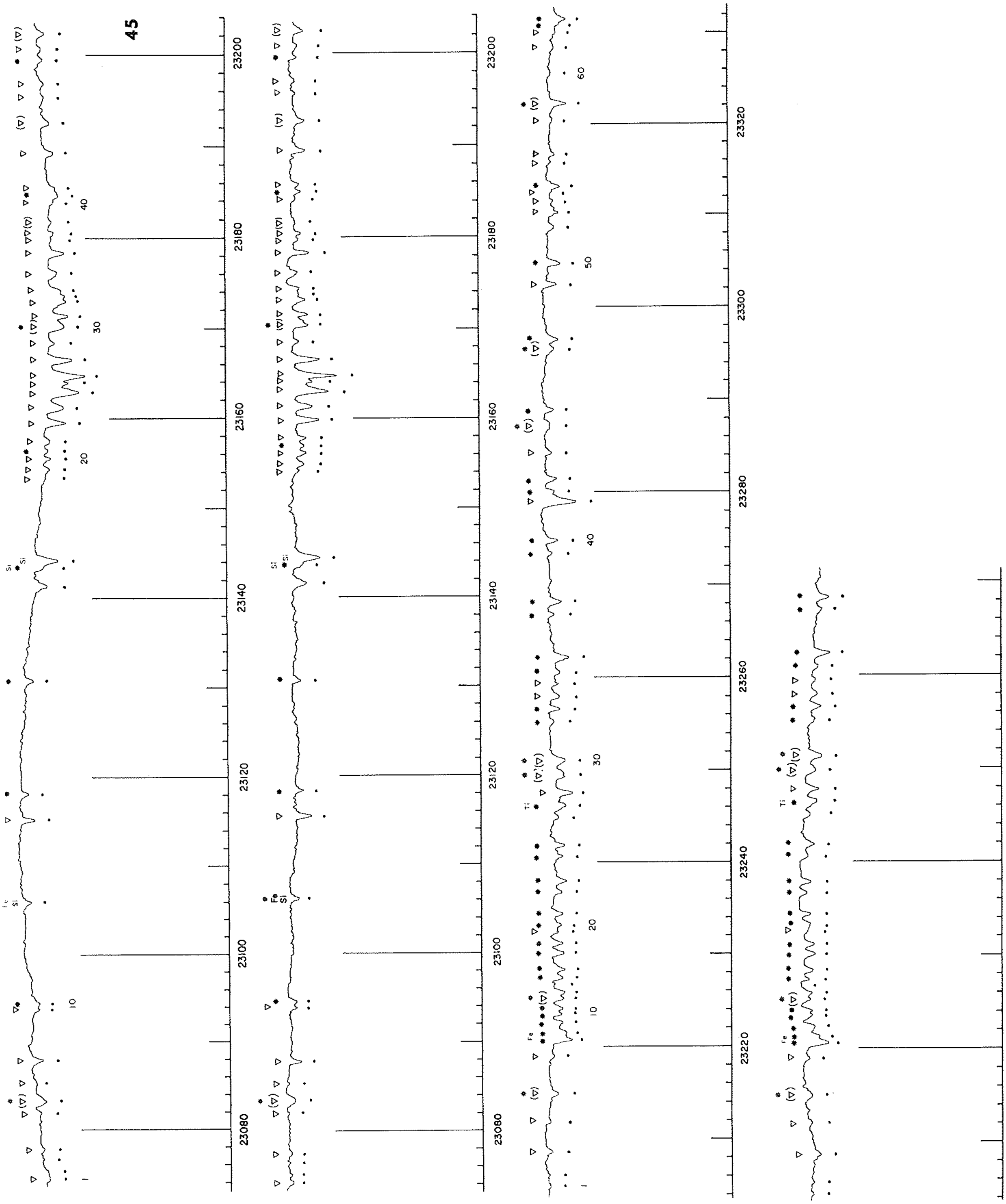

Fig. 4 Solar Spectrum λλ 23073–23333, in four strips (cf. Table 1).

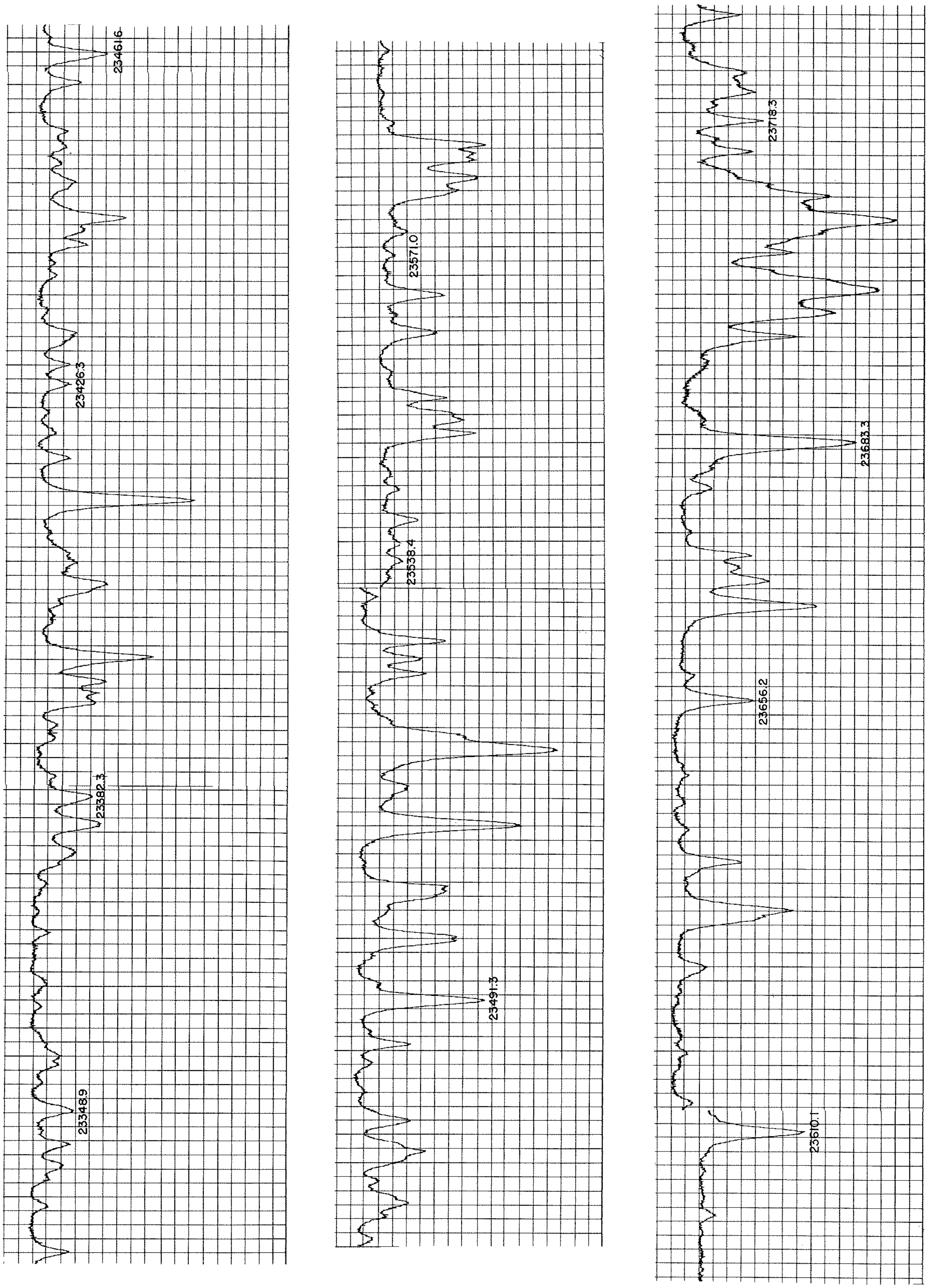

Fig. 5M Part of Michigan Atlas, that matches Fig. 5 (Reproduced with permission).

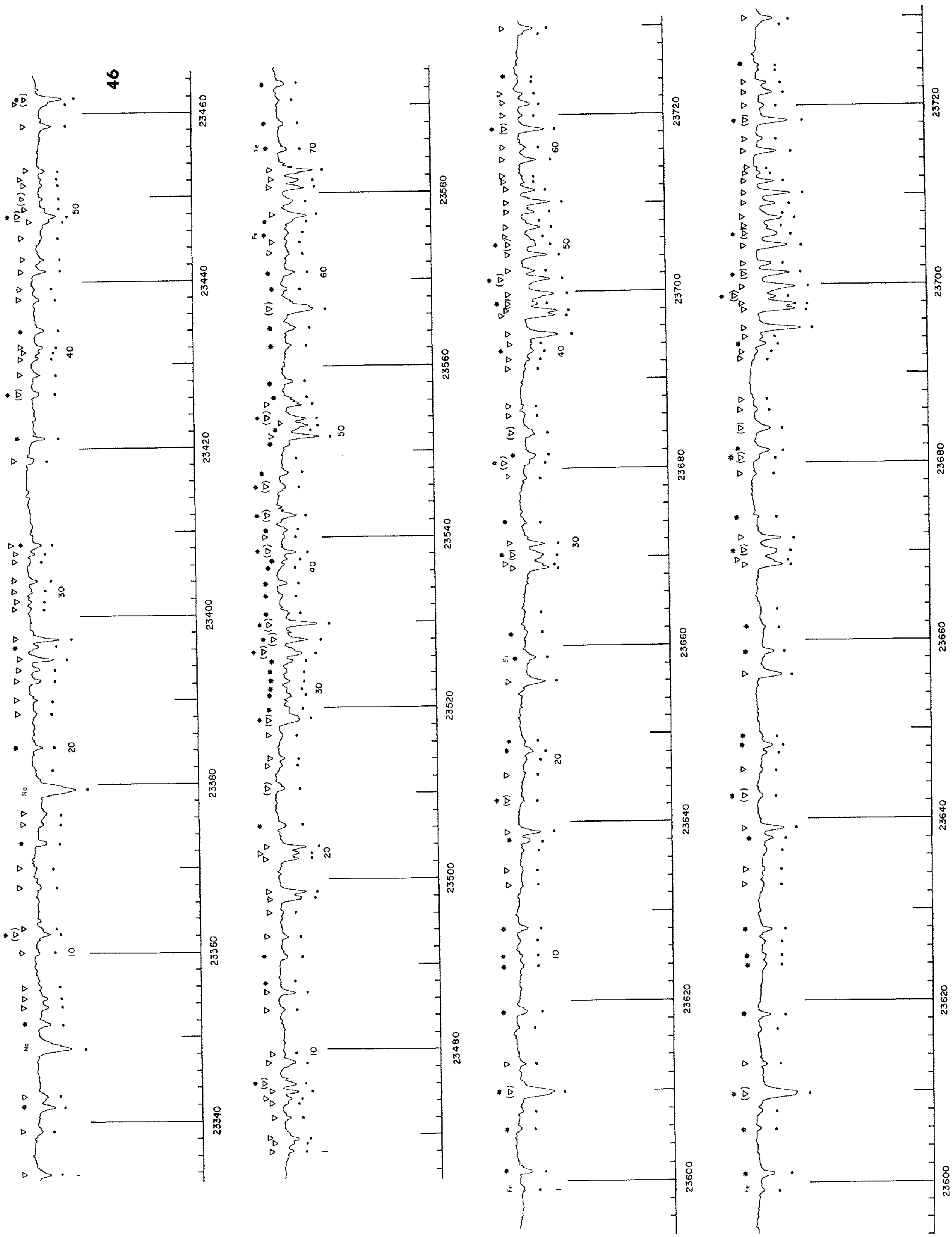

Fig. 5 Solar Spectrum λλ 23333–23731, in four strips (cf. Table 1).

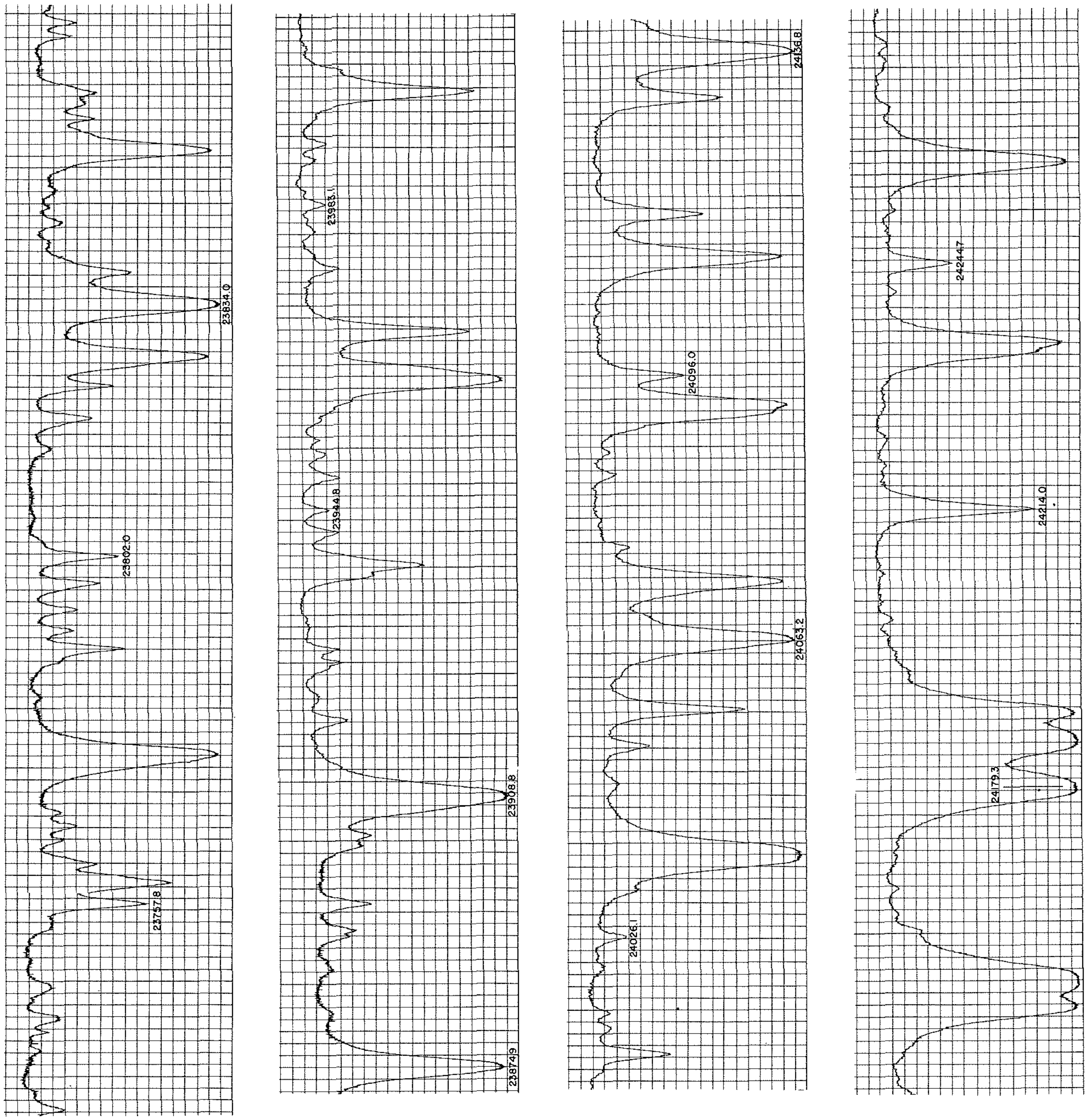

Fig. 6M Part of Michigan Atlas, that matches Fig. 6 (Reproduced with permission).

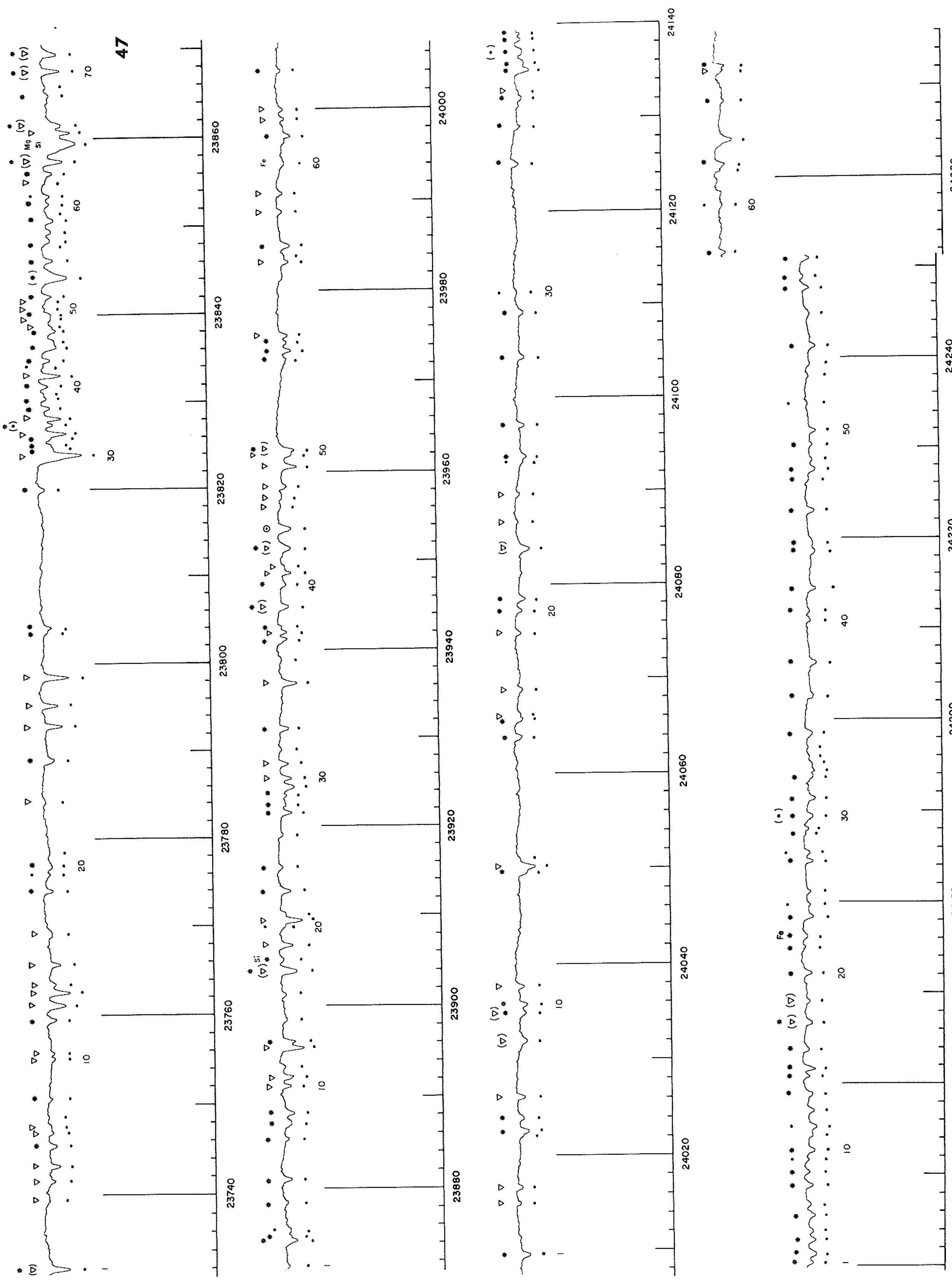

Fig. 6 Solar Spectrum λλ 23731–24276, in four strips (cf. Table 1).

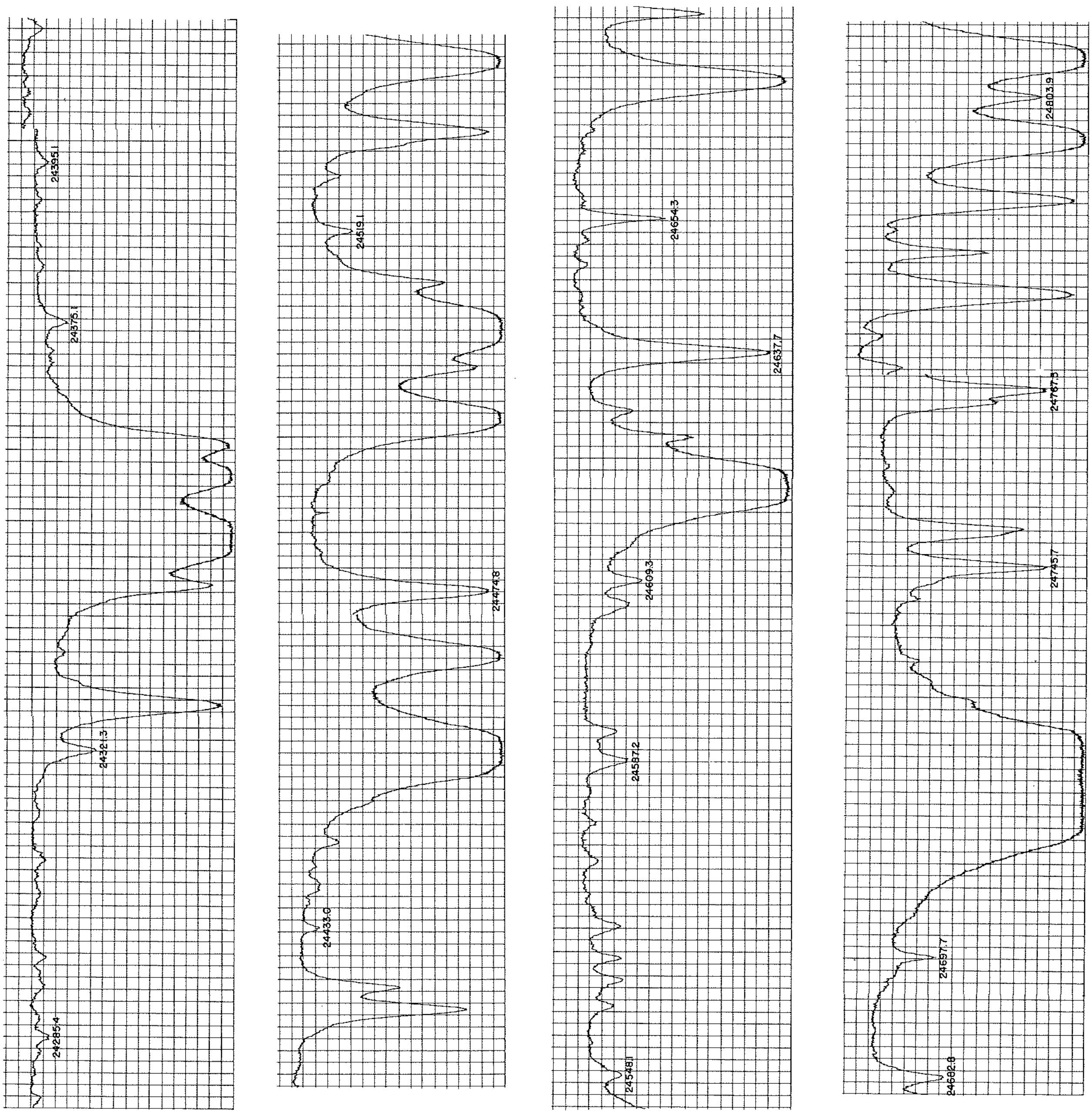

Fig. 7M Part of Michigan Atlas, that matches Fig. 7 (Reproduced with permission).

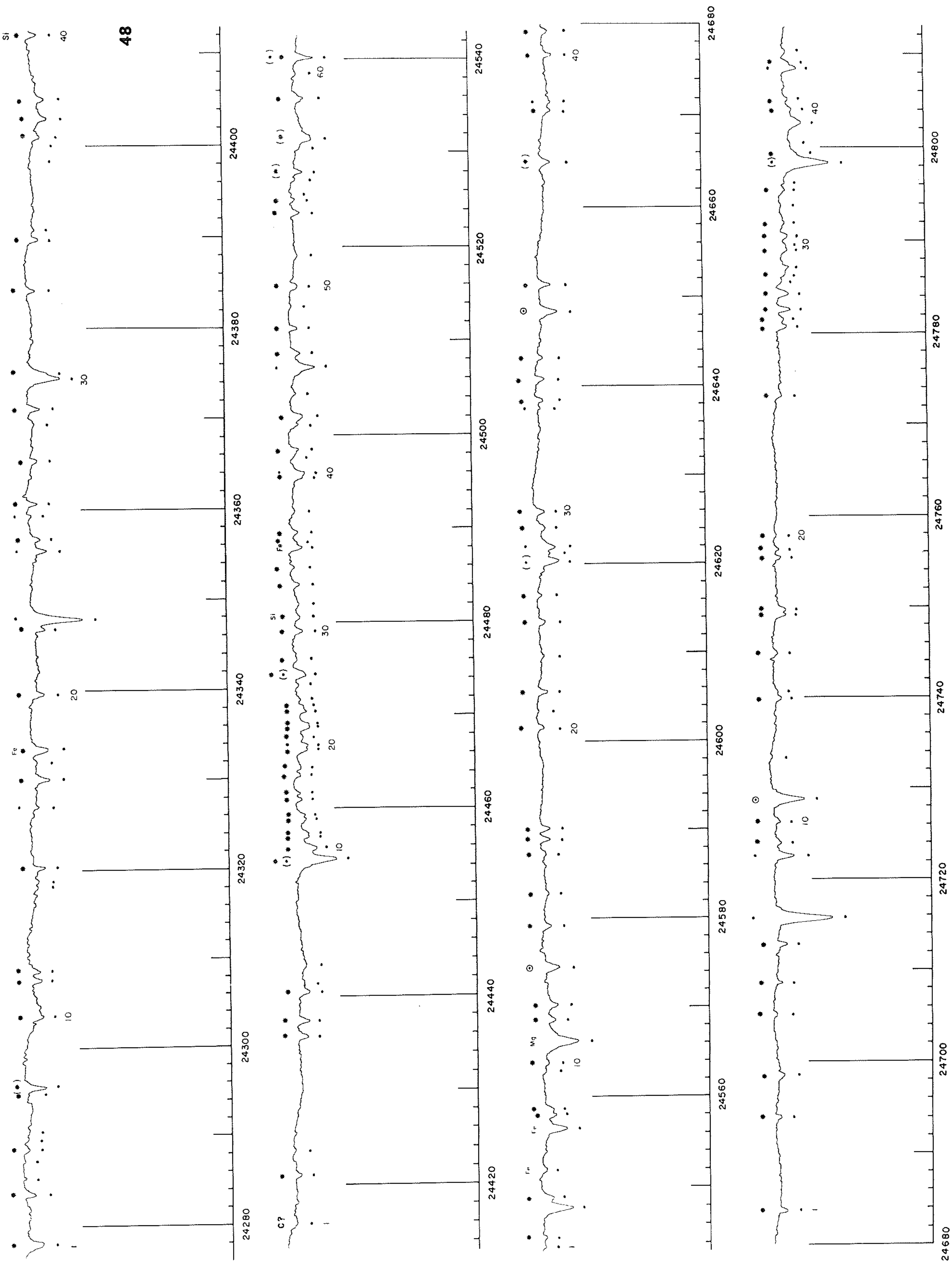

Fig. 7 Solar Spectrum λλ 24276–24813, in four strips (cf. Table 1).

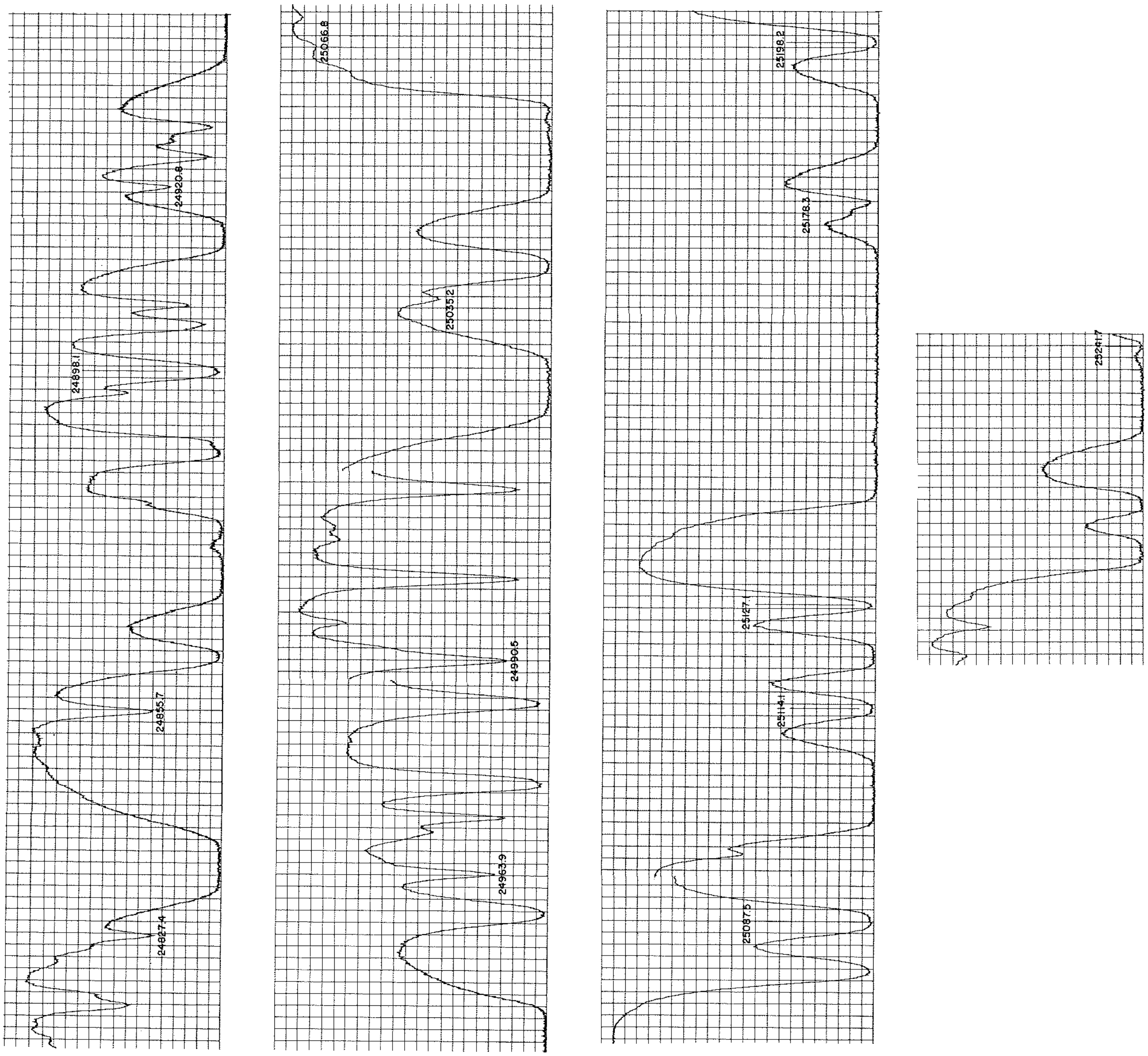

Fig. 8M Part of Michigan Atlas, that matches Fig. 8 (Reproduced with permission).

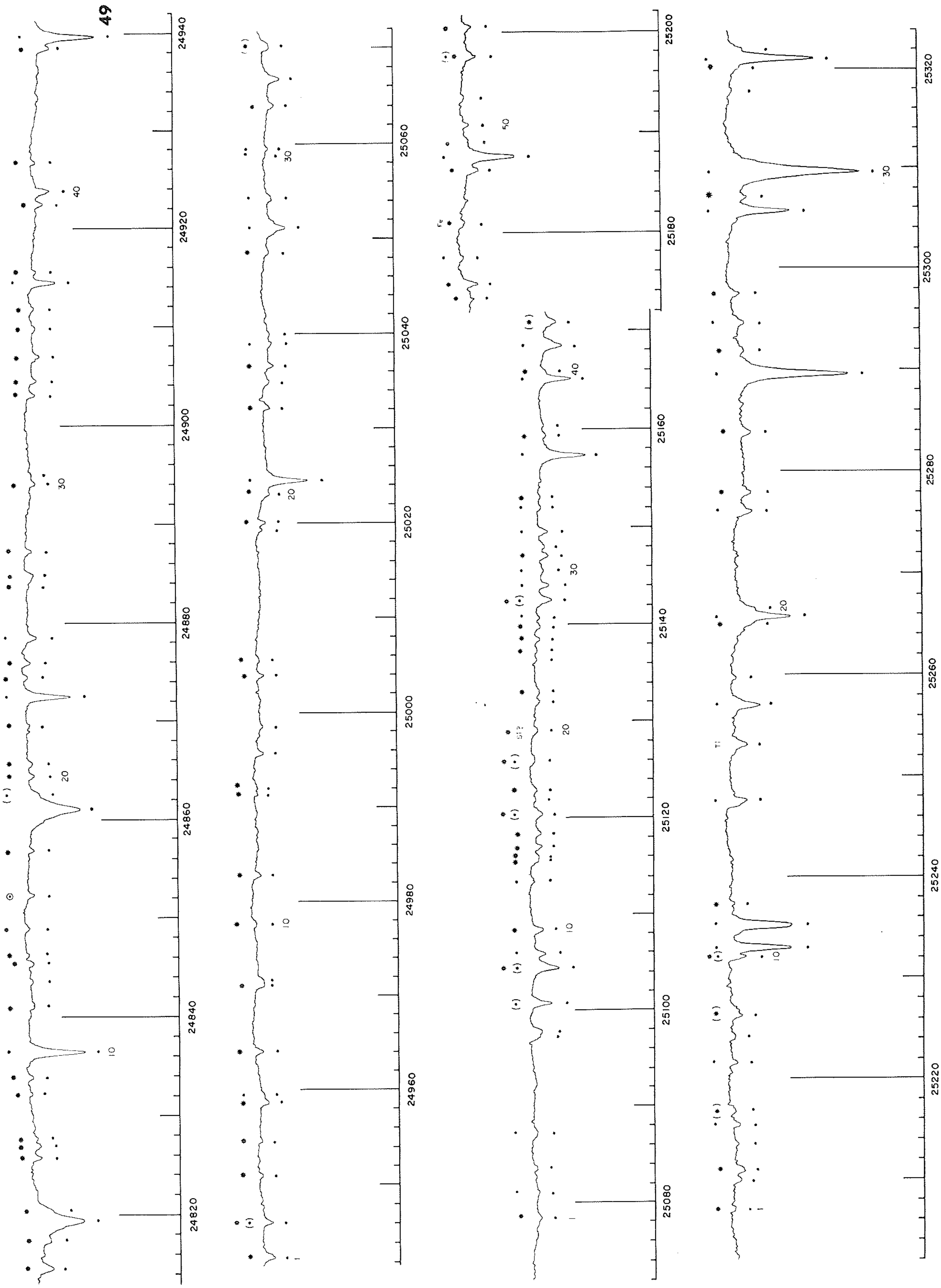

Fig. 8 Solar Spectrum λλ 24813–25324, in four strips (cf. Table 1).

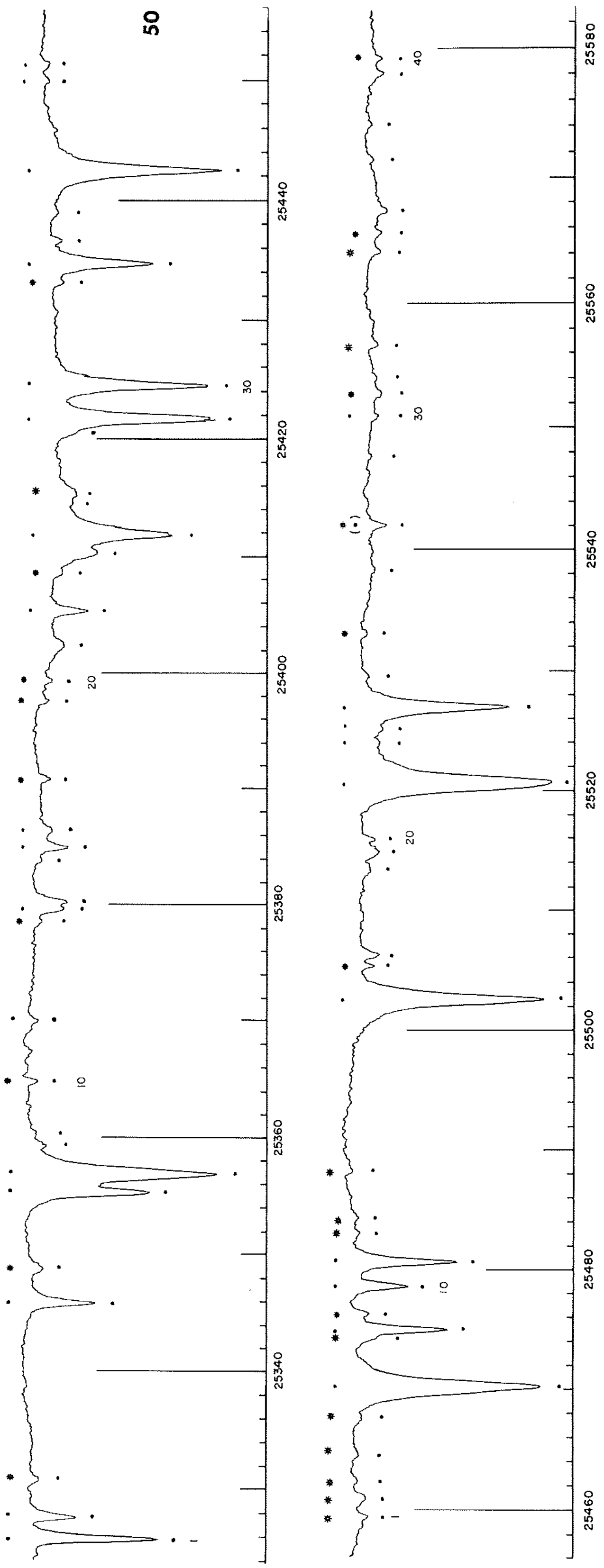

Fig. 9 Solar Spectrum λλ 25324–25583, in two strips (cf. Table 1).

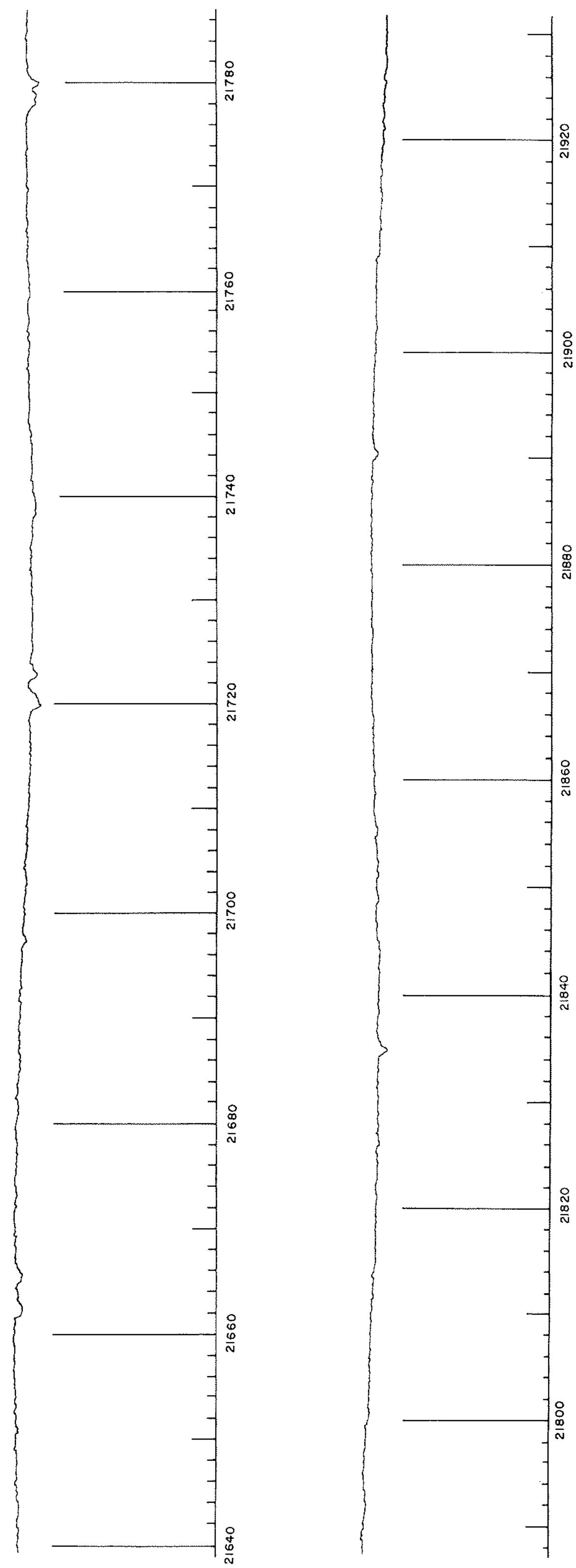

Fig. 10 Laboratory spectrum of methane, covering the same spectral interval as Fig. 1*b*, *c*.

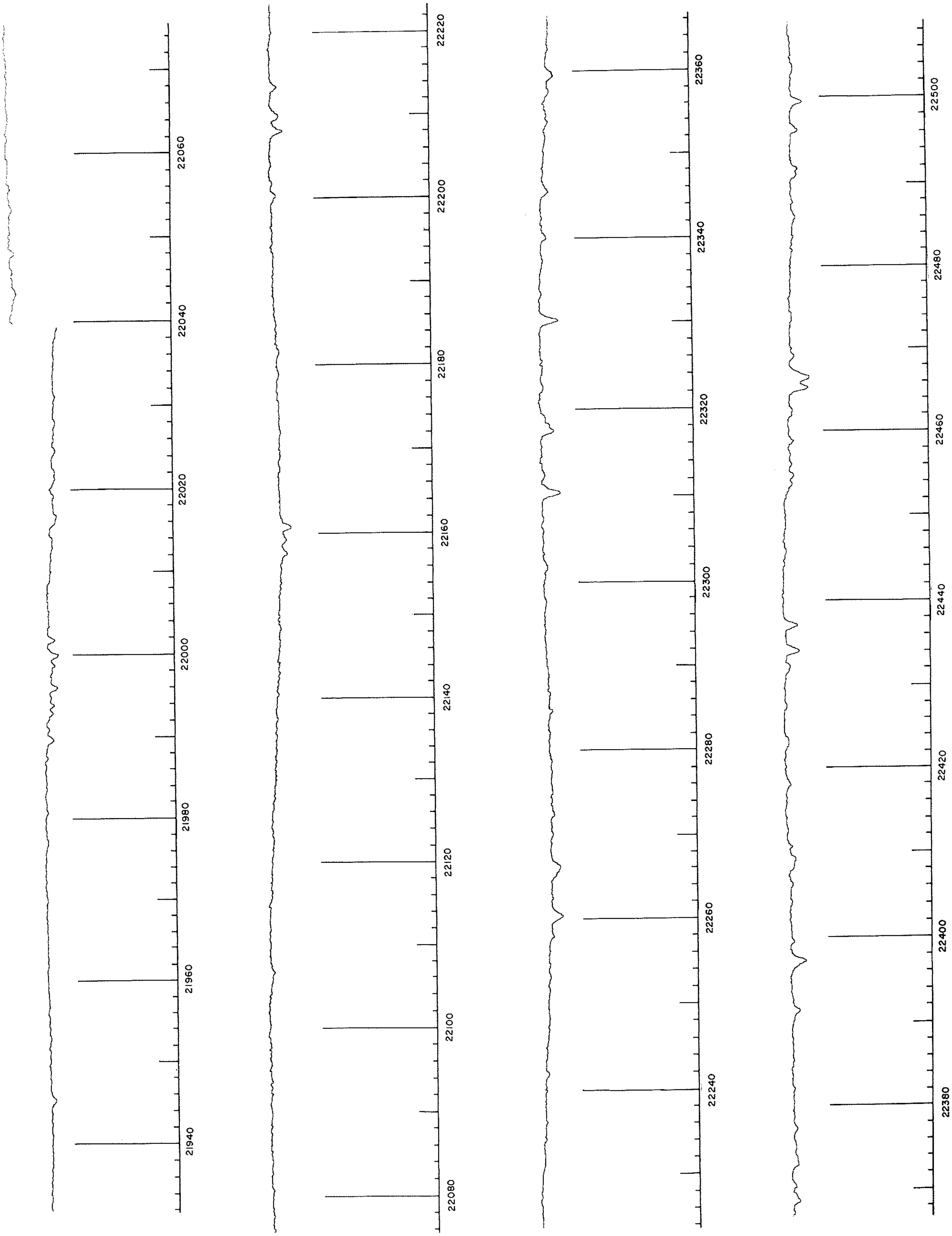

Fig. 11 Laboratory spectrum of methane, covering the same spectral interval as Figs. 1*d*, 2*a*, *b*, *c*.

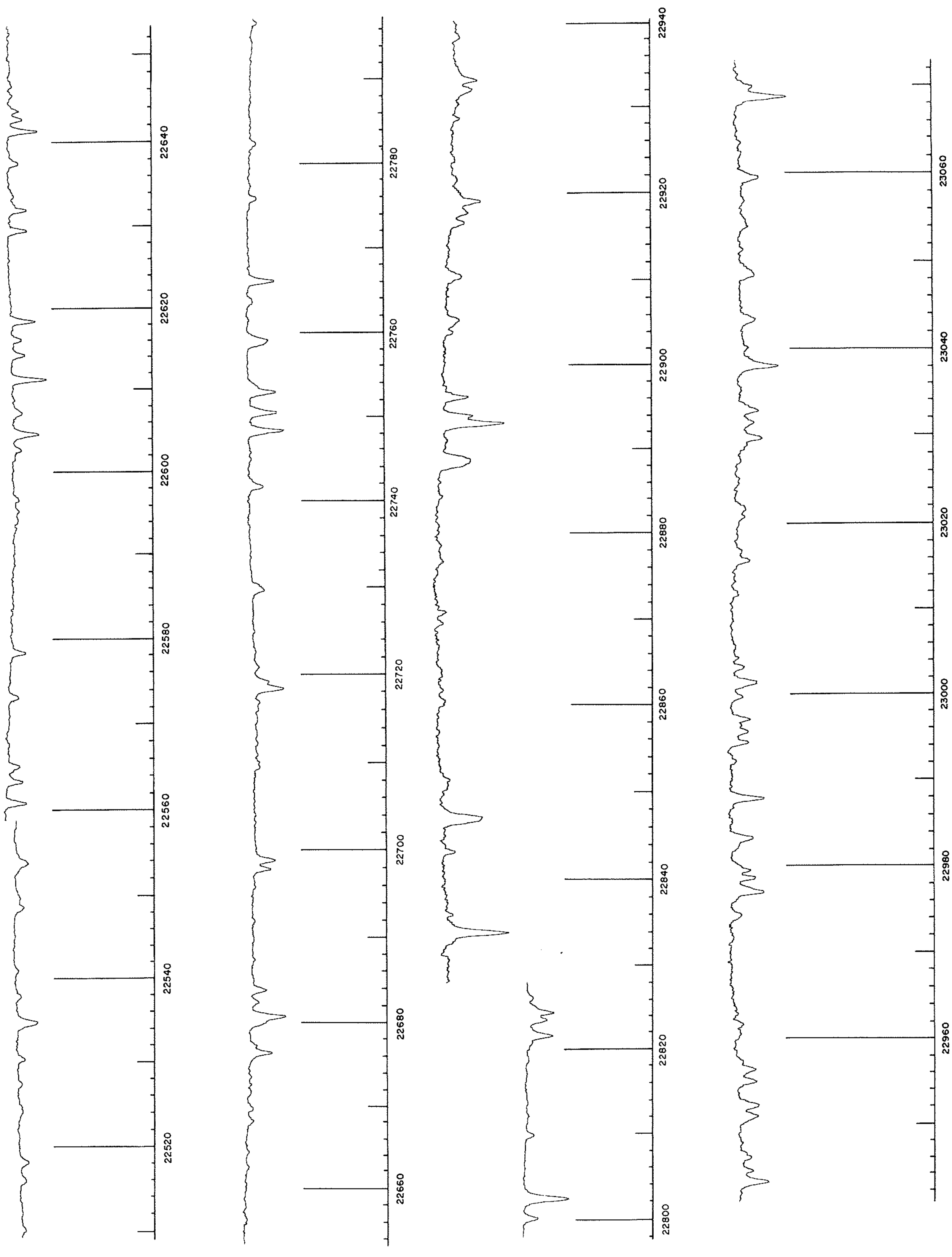

Fig. 12 Laboratory spectrum of methane, covering the same spectral interval as Figs. 2*d*, 3.

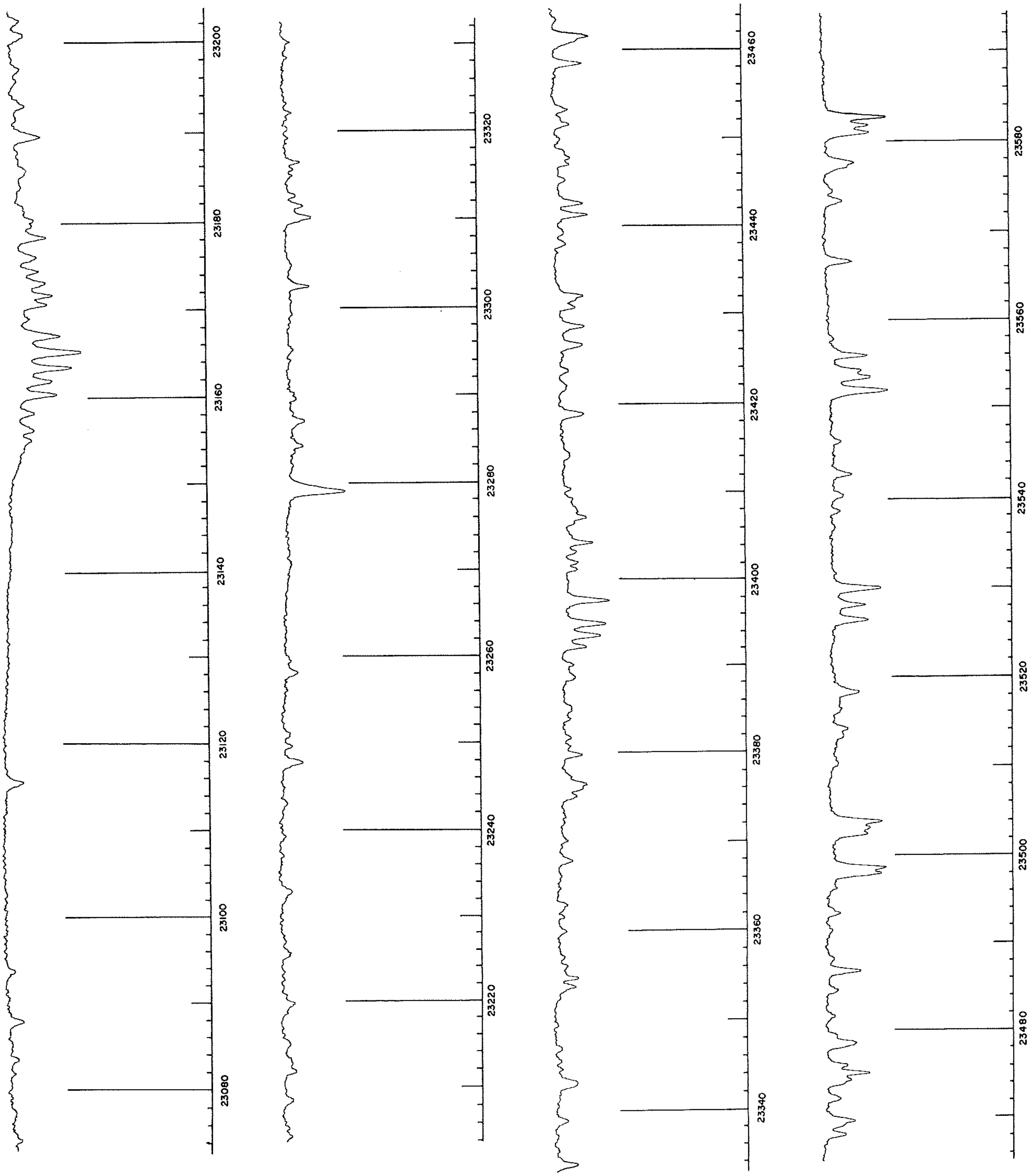

Fig. 13 Laboratory spectrum of methane, covering the same spectral interval as Figs. 4, 5*a*, *b*.

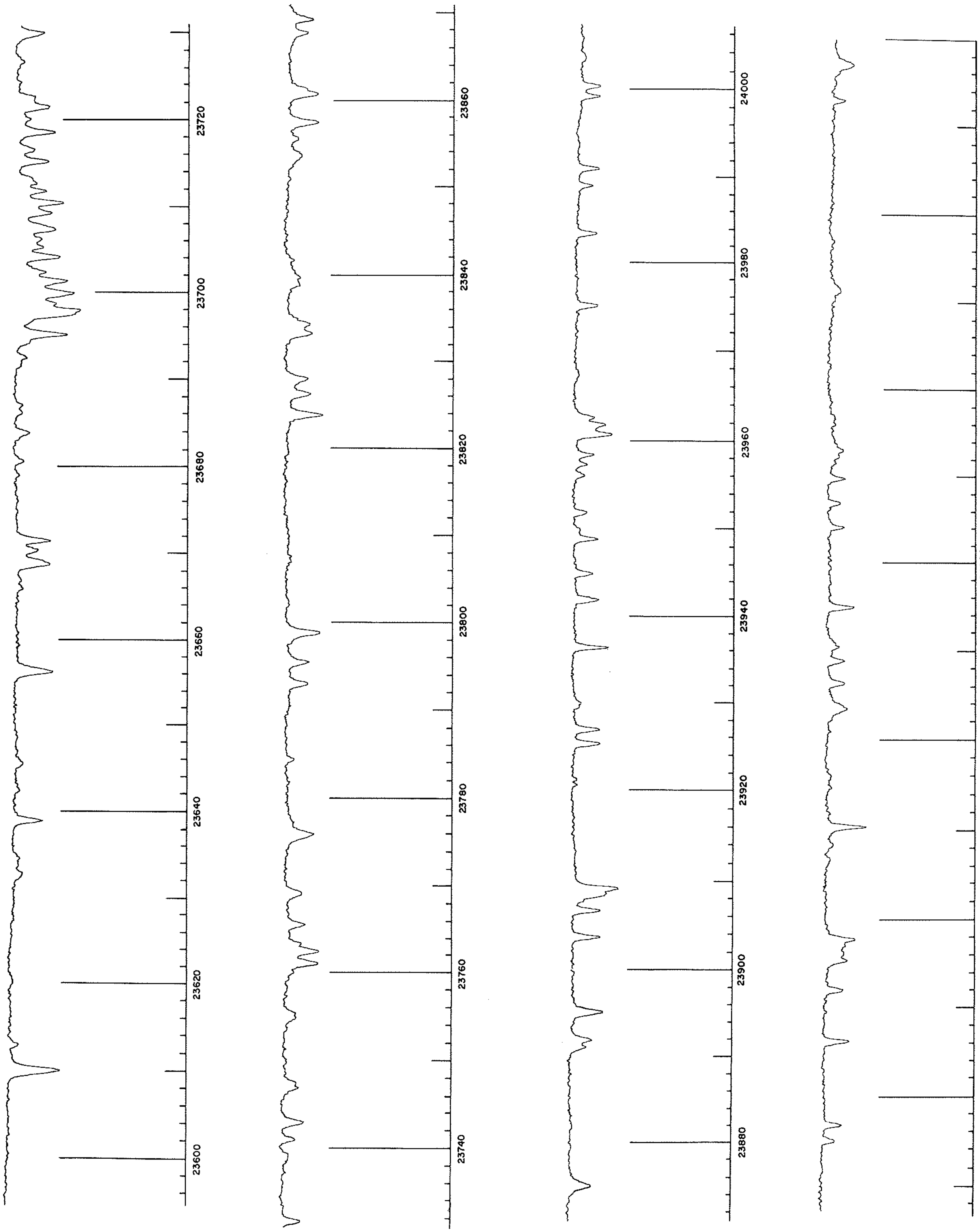

Fig. 14 Laboratory spectrum of methane, covering the same spectral interval as Figs. 5c/d, 6a, b, c.

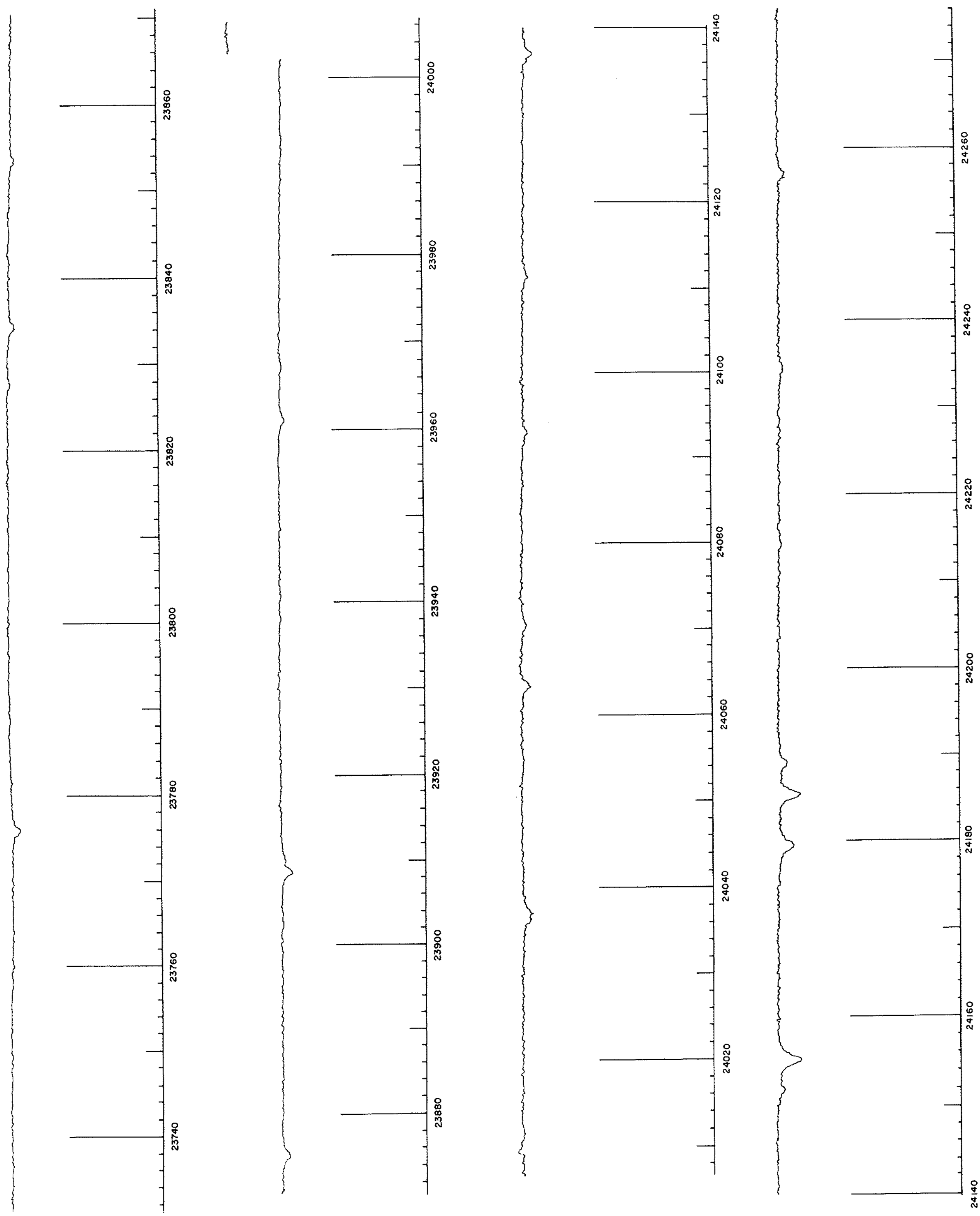

Fig. 15 Laboratory spectrum of water vapor, covering the same spectral interval as Fig. 6.

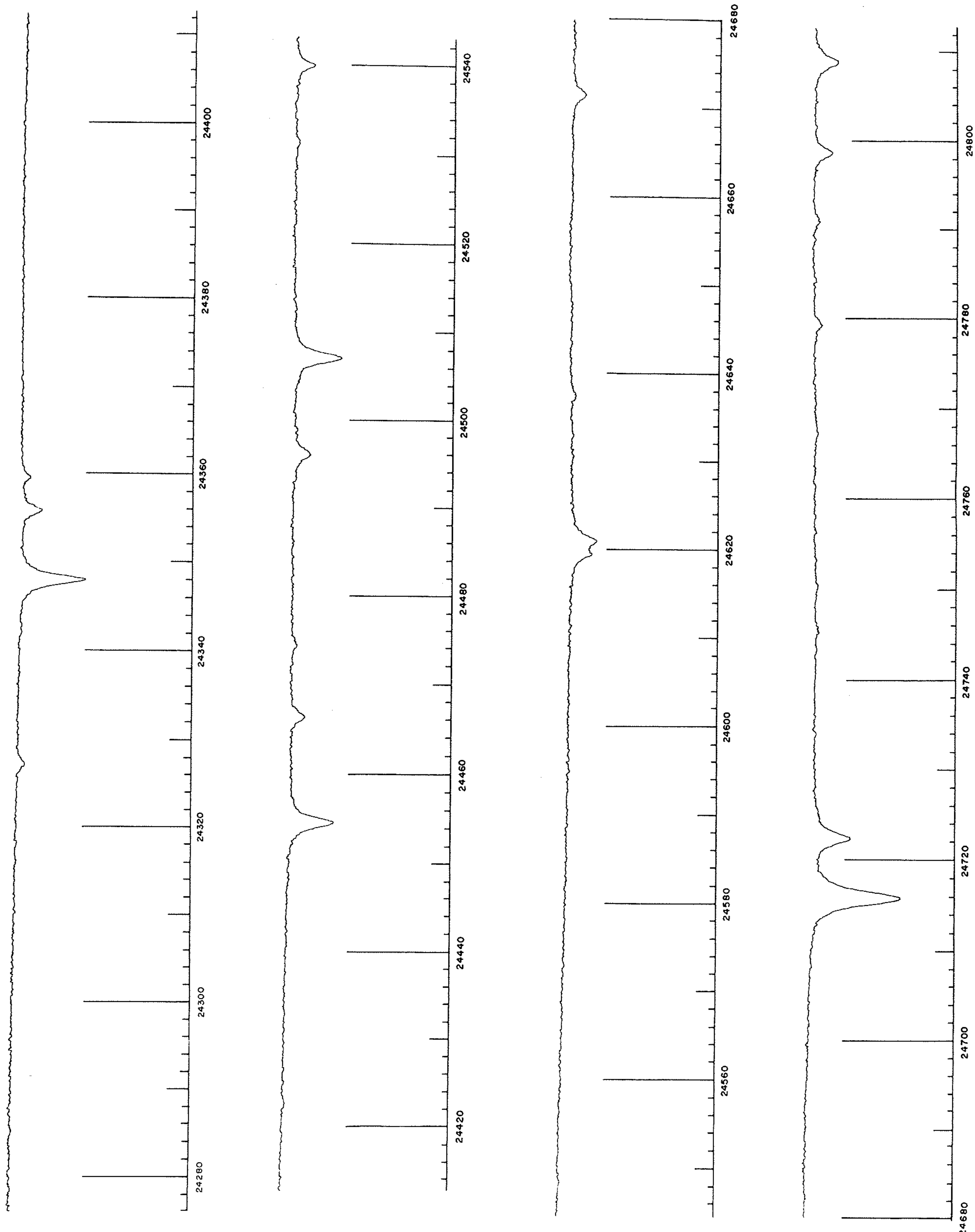

Fig. 16 Laboratory spectrum of water vapor, covering the same spectral interval as Fig. 7.

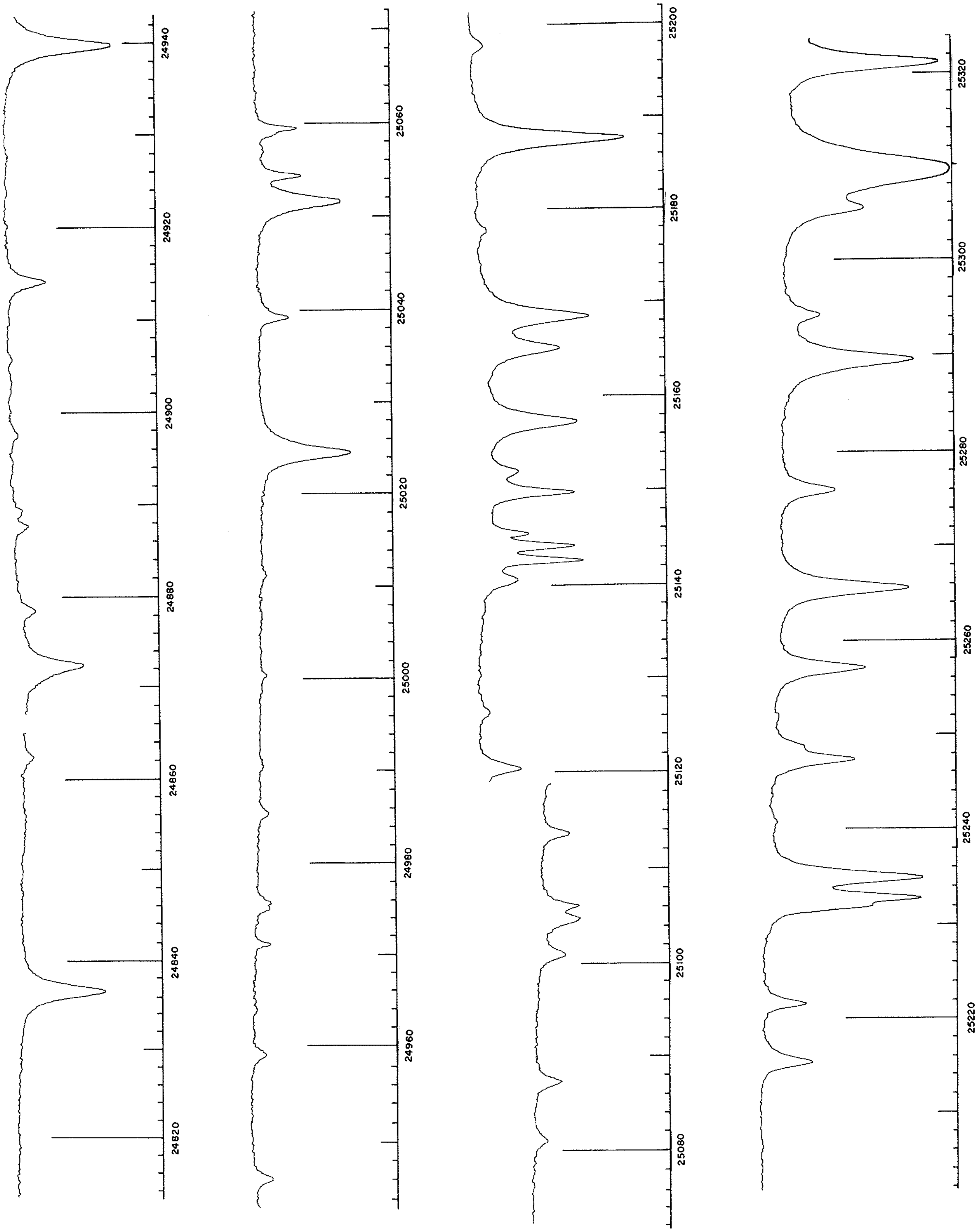

Fig. 17 Laboratory spectrum of water vapor, covering the same spectral interval as Fig. 8.

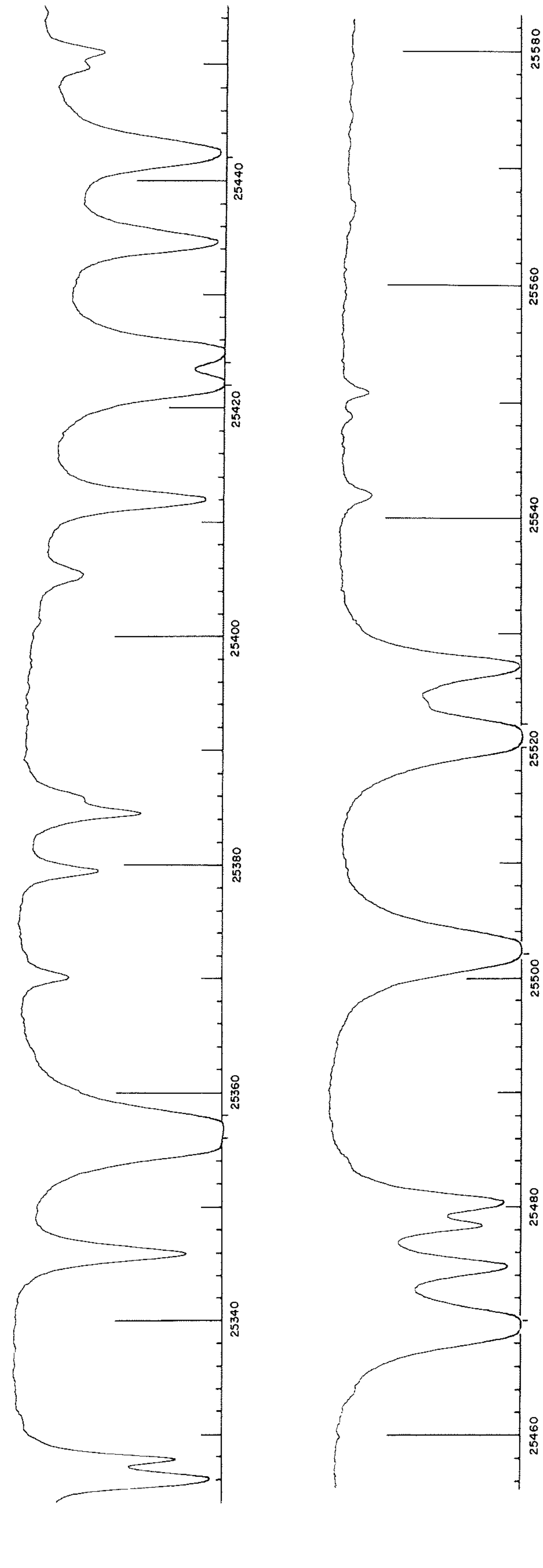

Fig. 18 Laboratory spectrum of water vapor, covering the same spectral interval as Fig. 9.

No. 165 ARIZONA-NASA ATLAS OF THE INFRARED SOLAR SPECTRUM, REPORT IX

by L. A. Bijl, G. P. Kuiper and D. P. Cruikshank

August 25, 1969

ABSTRACT

In this paper we give the solar spectrum λλ 25583–30920 Å as obtained from the NASA CV-990 Jet. A laboratory spectrum of the 2.7 μ H_2O bands is included; Courtoy's laboratory spectrum of the 2.7 μ CO_2 bands is given.

In the summer of 1968 two LPL spectrometers recorded the solar spectrum from the NASA CV 990 Jet at high altitude. This paper concludes the preliminary reports on the solar spectrum as obtained with the LPL 4-m spectrometer. Previous reports were published as *Comm. LPL* Nos. 123, 124, 160, 161, 163, 164. The present report gives the solar spectrum λλ 25583-30920 Å; in a great part of the interval duplicate runs were available. The observing data are listed in Table I, pp. 142–43.

The wavelength scale is based on the wavelengths of water vapor lines as given by Plyler and Tidwell (1957) and by Gates *et al.* (1964); the wavelengths of CO_2 lines as given by Courtoy (1959); the wavelengths of N_2O as given by Tidwell, Plyler and Benedict (1960). For the conversion of wavenumbers to wavelengths, Coleman's *Table of Wavenumbers* (NBS 1960) was used. Inaccuracy in the wavelength scale is caused by a periodic and a small random error in the dispersion, and by small inconsistencies in the above mentioned sources of wavelengths. The wavelength scale of Figs. 18–20 (Charts 67–69) had to be interpolated between the few water vapor absorptions, of which the wavelengths were taken from Gates *et al.* (1964).* The positions of solar CO lines were calculated from the constants given by Goldberg and Müller (1953). The CO lines are indicated with an asterisk above the spectral traces. Atmospheric absorptions by H_2O, N_2O, and CO_2 are indicated by a dot, the symbol ✧, and a vertical line, respectively, all above the spectral trace. We tried to separate the several CO_2 bands in this region by placing the vertical lines at different levels and giving them a different appearance. In doing this we consulted Courtoy's spectrum of CO_2, herein reproduced in Figs. 29 and 30.

Several runs of the water vapor spectrum at 2.7 μ were made, with different amounts of gas. In Figs. 21–28 we reproduce a spectrum with medium-strong absorptions. It shows the weak lines while the strong lines are saturated and their fine structure is not visible, contrary to the solar spectra. Some unidentified lines in the solar spectra may still be telluric.

*Identification of solar lines on these charts were obtained from Migeotte, *et al* (1956).

The solar spectra were obtained in the NASA CV-990 by Messrs. Kuiper and Cruikshank. The derivation of the wavelength scale and the identifications were all performed by Mr. Bijl, who also obtained the laboratory spectra of the 2.7 μ H_2O bands and prepared the charts for publication.

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. Mr. D. C. Benner constructed the wavelength scales for the laboratory spectra and assisted in the calculation of the CO line positions. 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.

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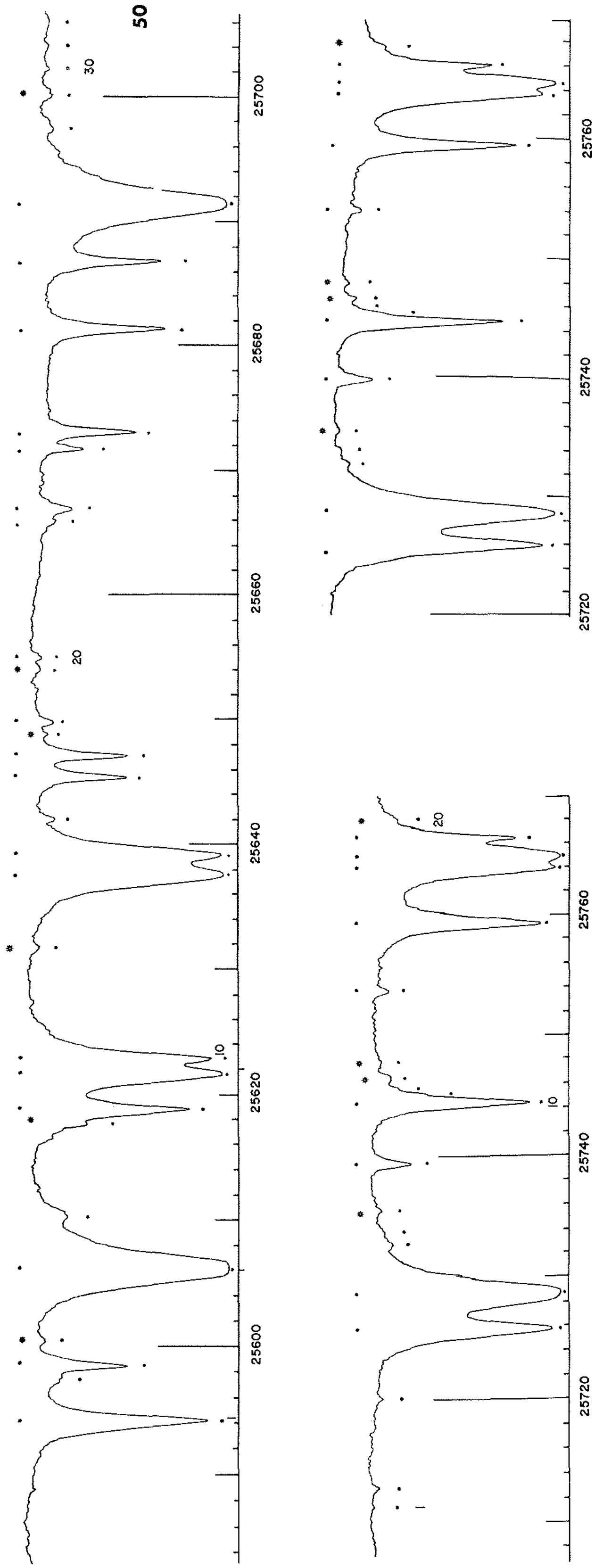


Fig. 1 Solar Spectrum λλ 25583–25770, in two strips (cf. Table 1).

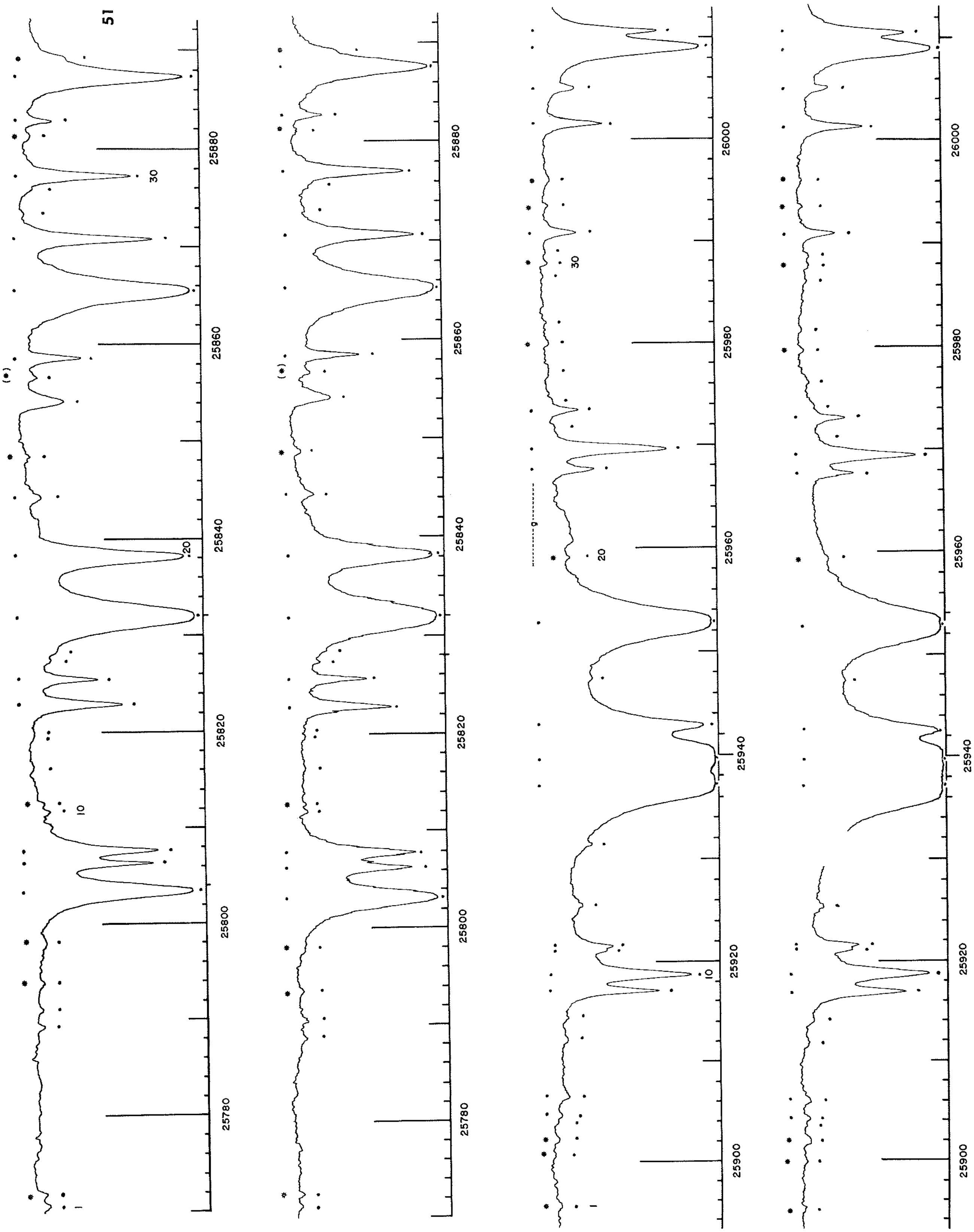


Fig. 2 Solar Spectrum λλ 25770–26013, in four strips (cf. Table 1).

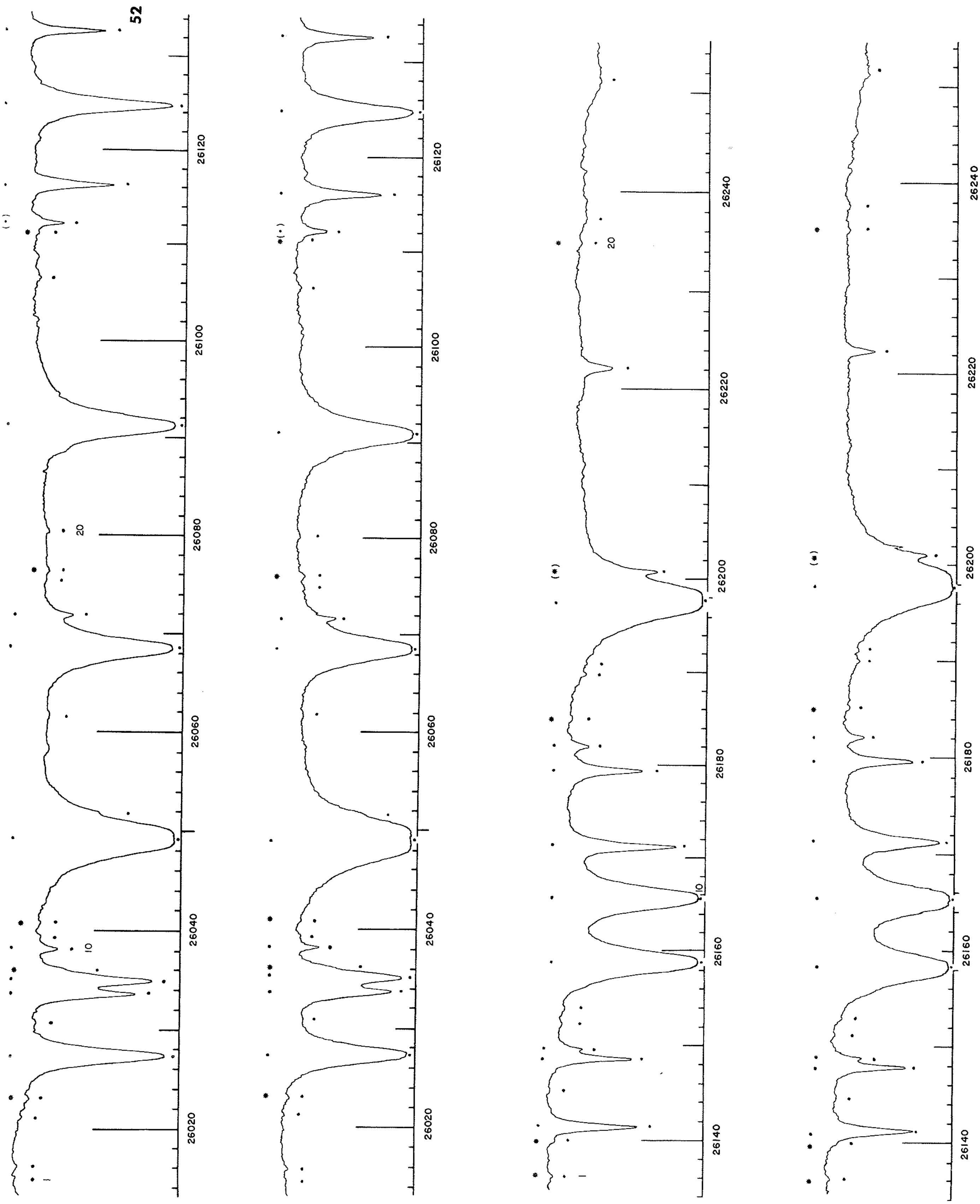


Fig. 3. Solar Spectrum λλ 26012–26255, in four strips (cf. Table 1).

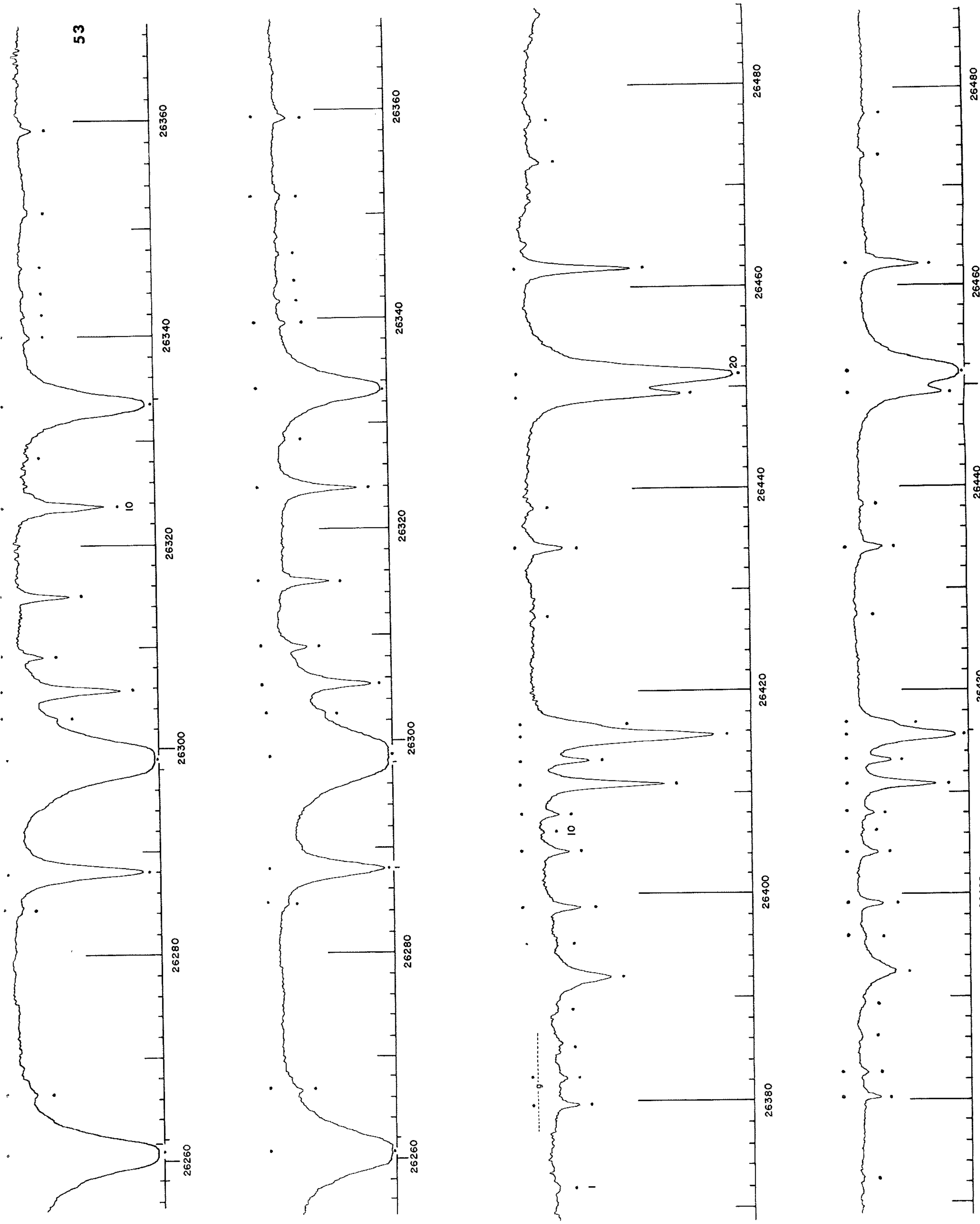


Fig. 4 Solar Spectrum λλ 26255–26488, in four strips (cf. Table 1).

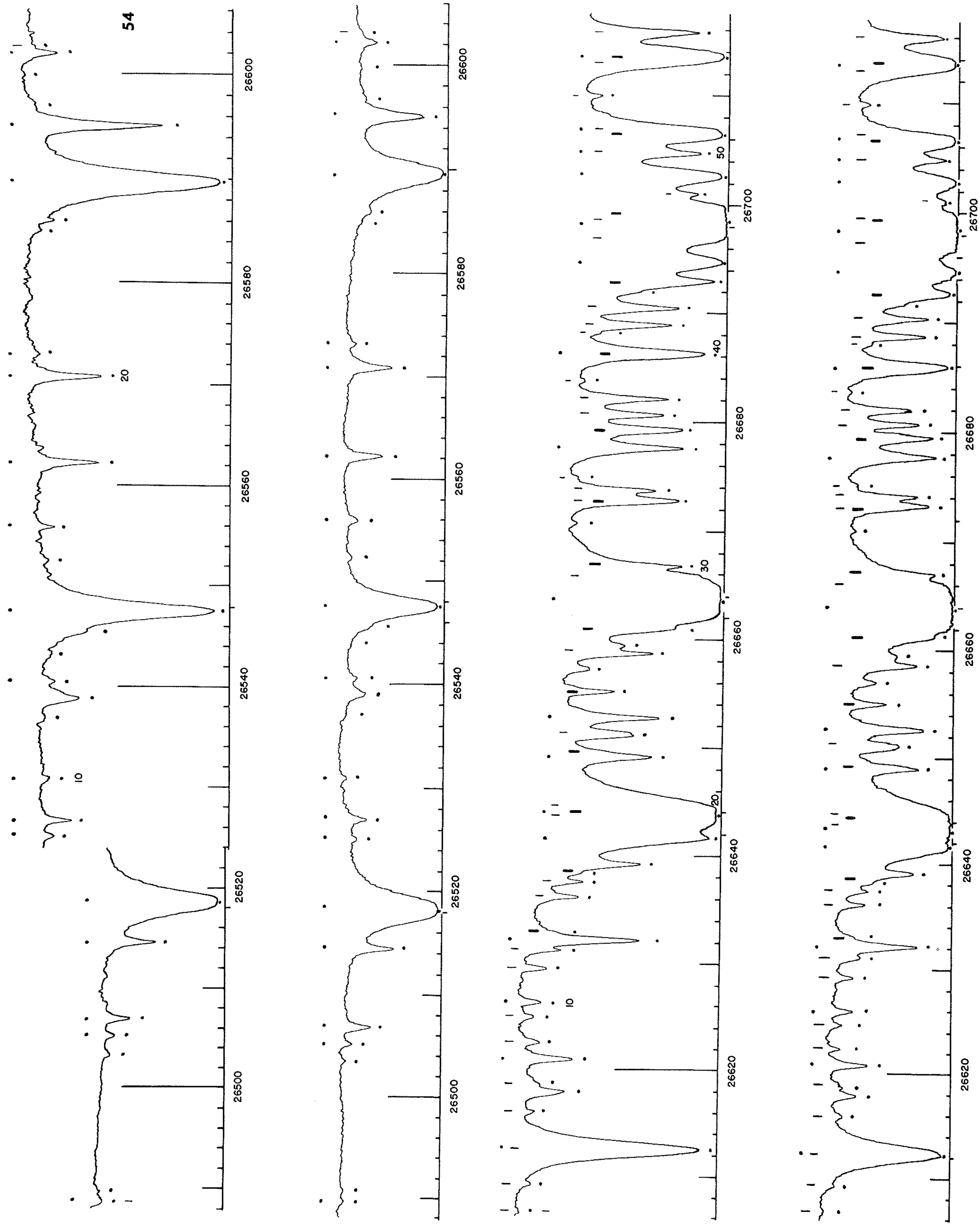


Fig. 5 Solar Spectrum λλ 26488–26718, in four strips (cf. Table 1).

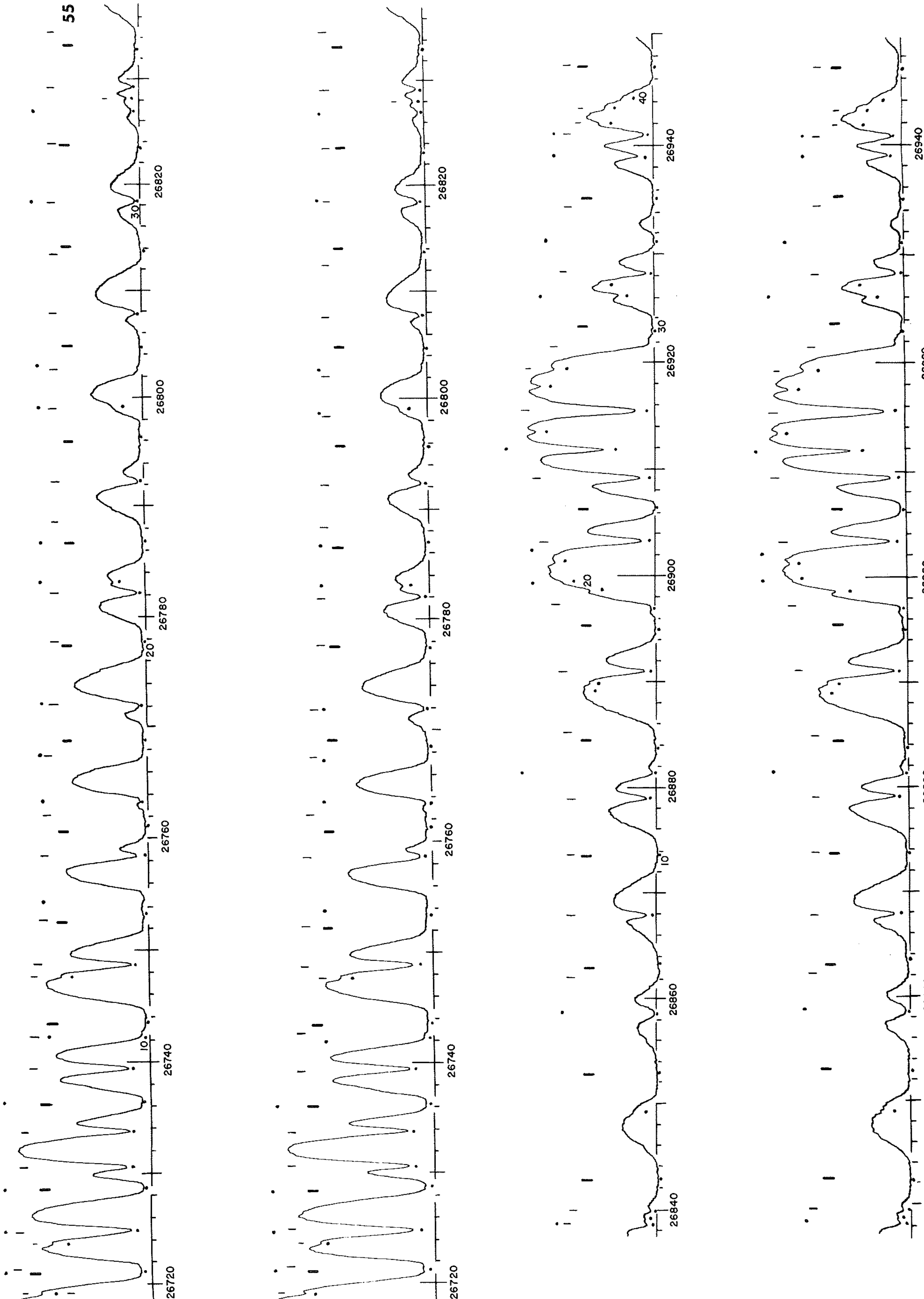


Fig. 6 Solar Spectrum λλ 26718–26950, in four strips (cf. Table 1).

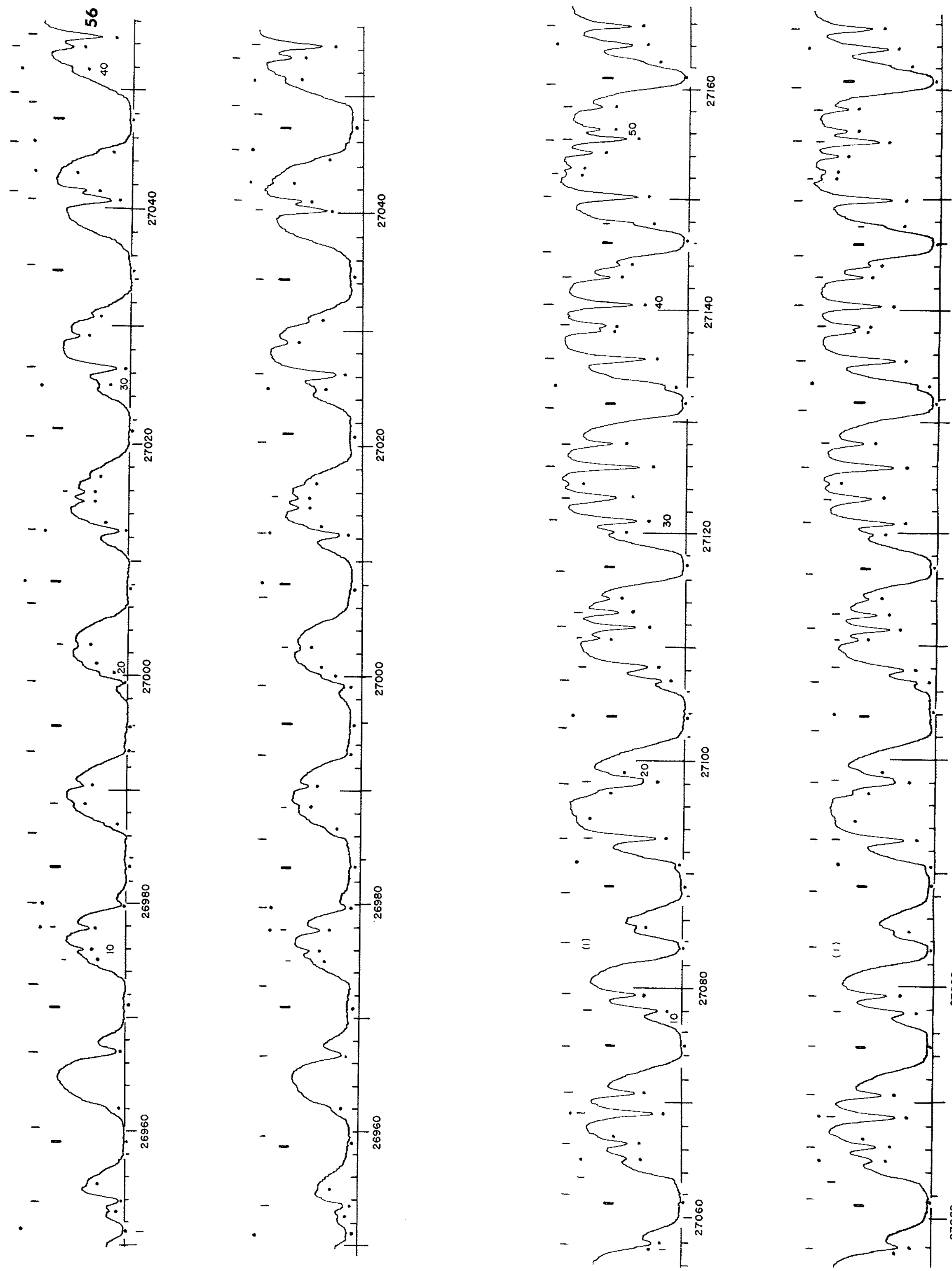


Fig. 7 Solar Spectrum λλ 26950–27167, in four strips (cf. Table 1).

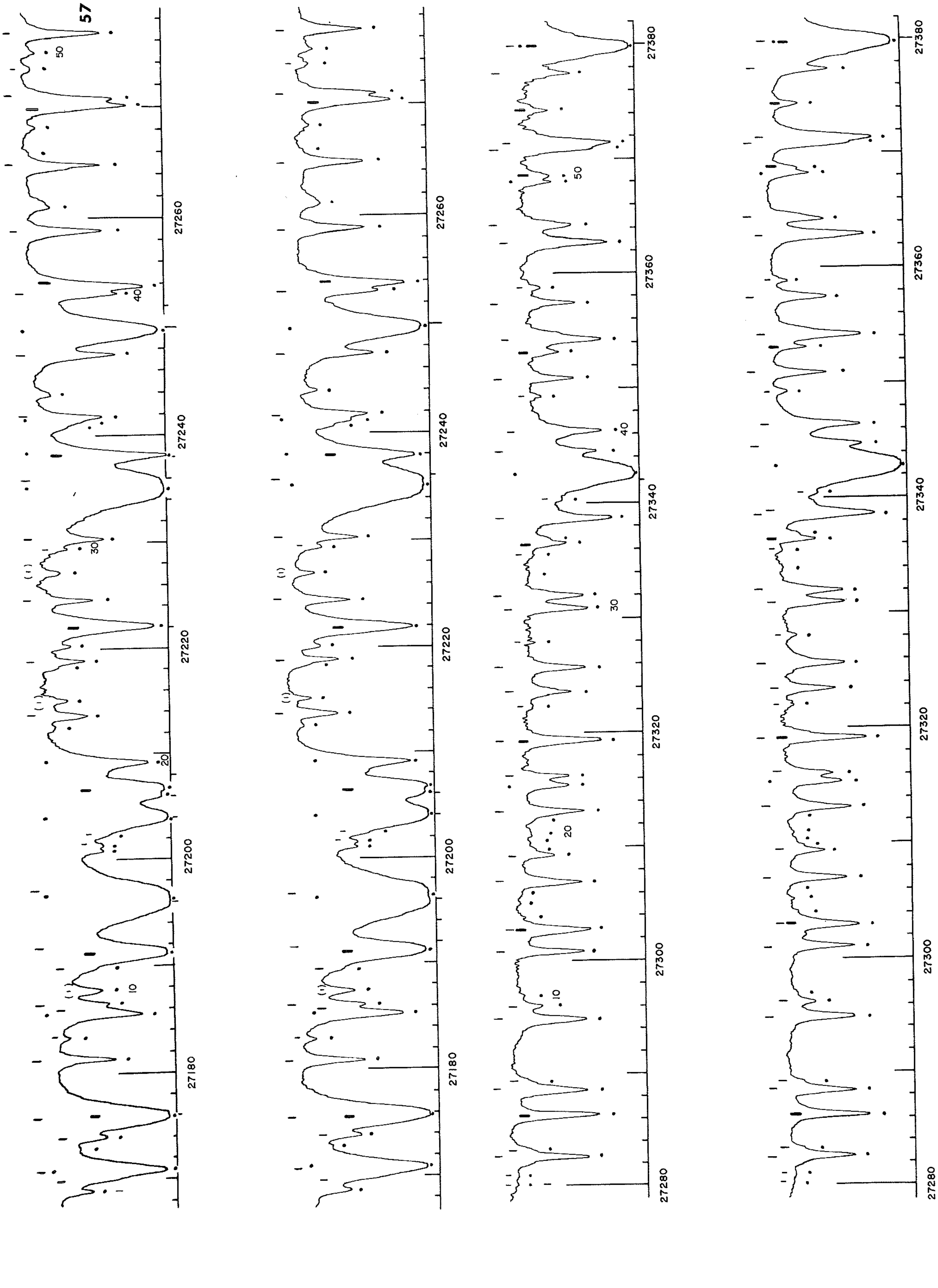


Fig. 8 Solar Spectrum λλ 27167–27382, in four strips (cf. Table 1).

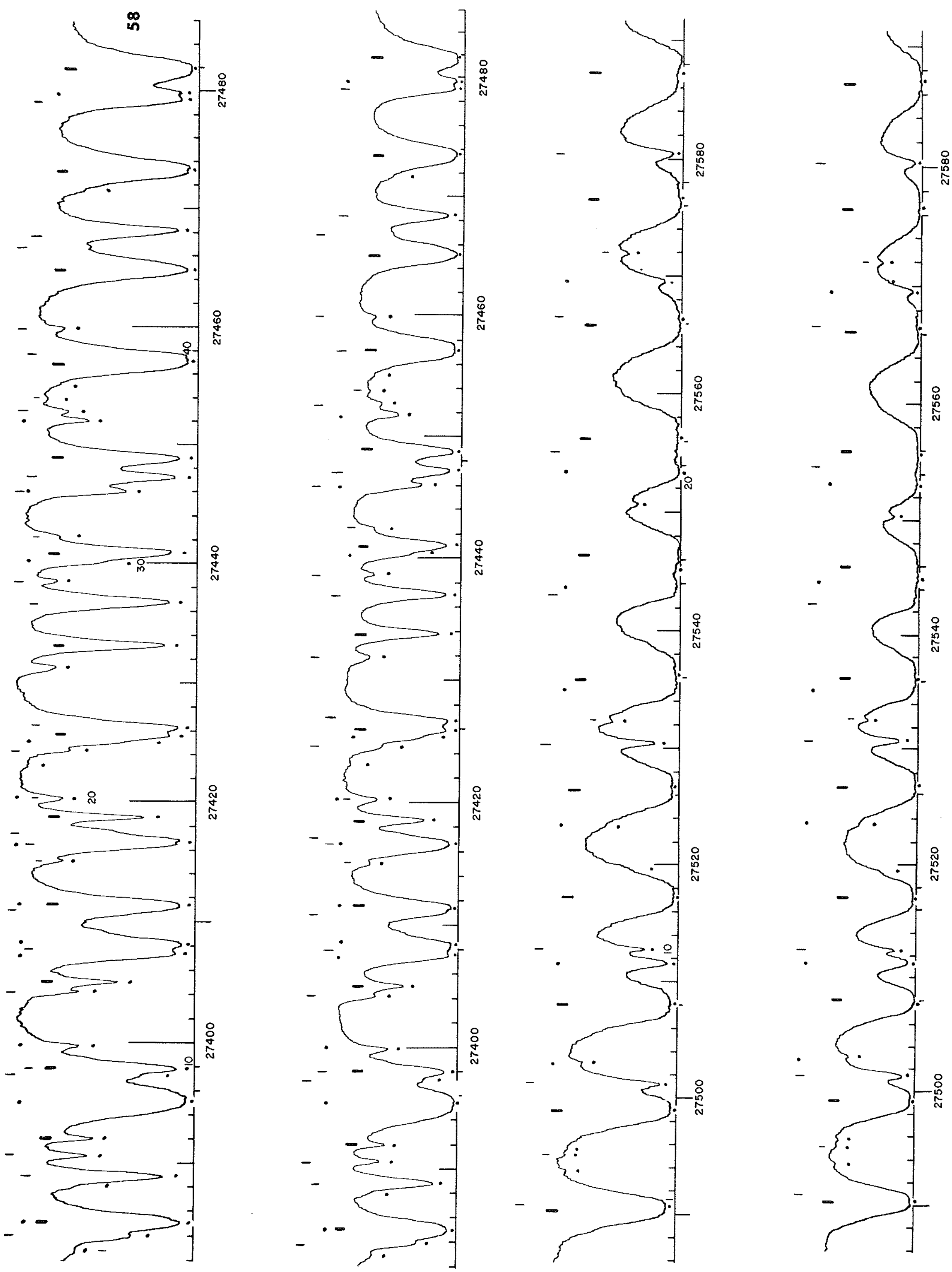


Fig. 9 Solar Spectrum λλ 27382–27592, in four strips (cf. Table 1).

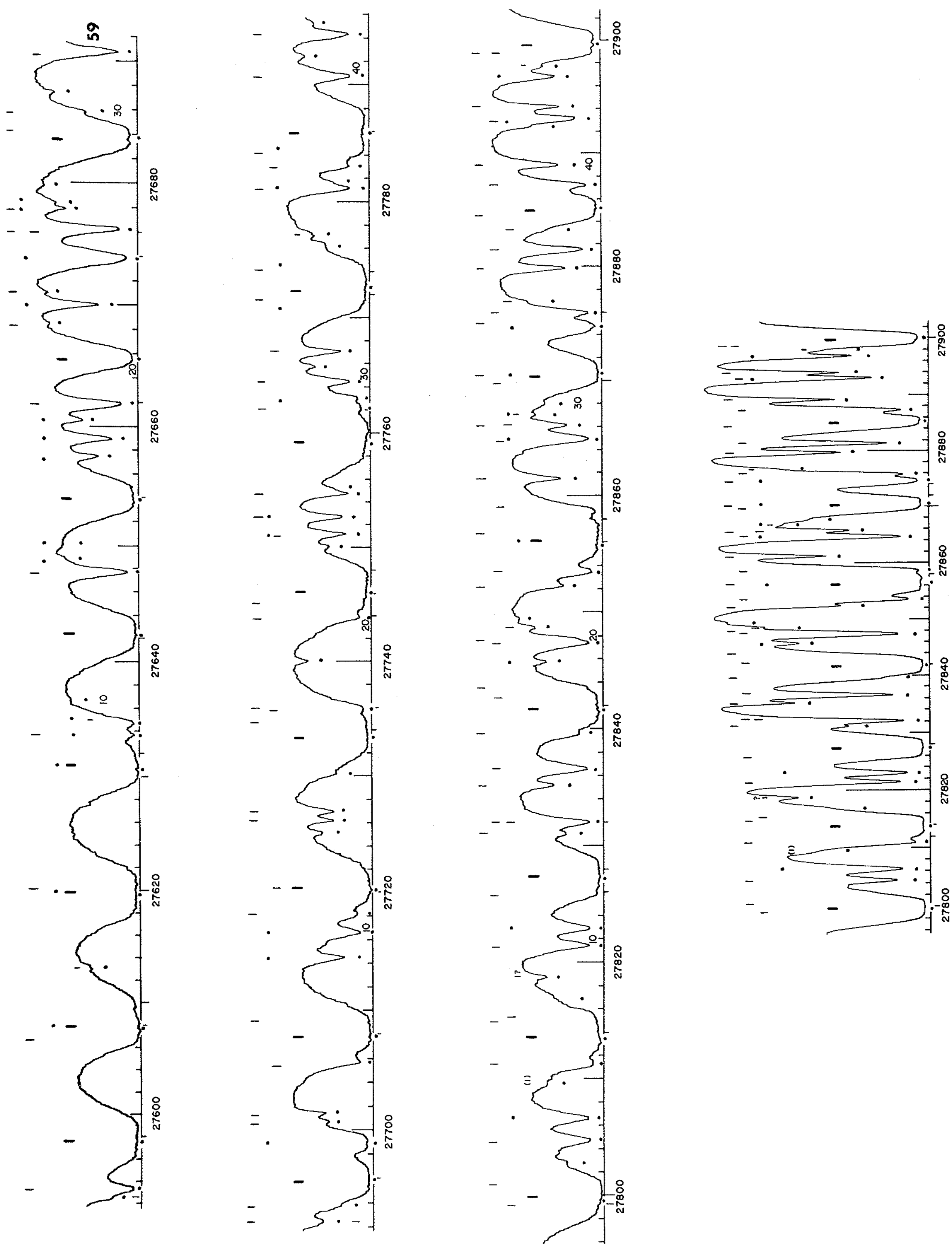


Fig. 10 Solar Spectrum λλ 27592–27903, in four strips (cf. Table 1).

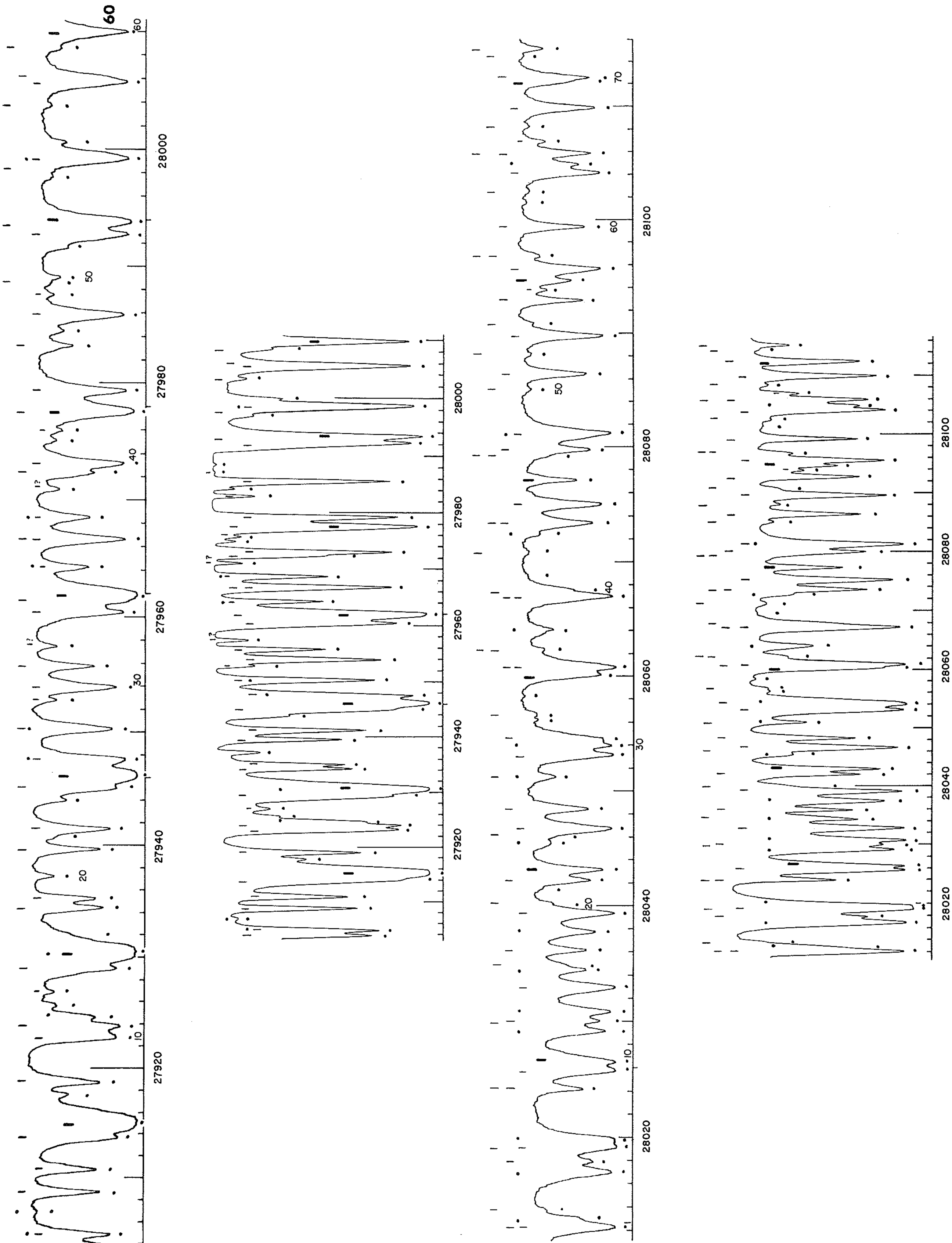


Fig. 11 Solar Spectrum λλ 27903–28116, in four strips (cf. Table 1).

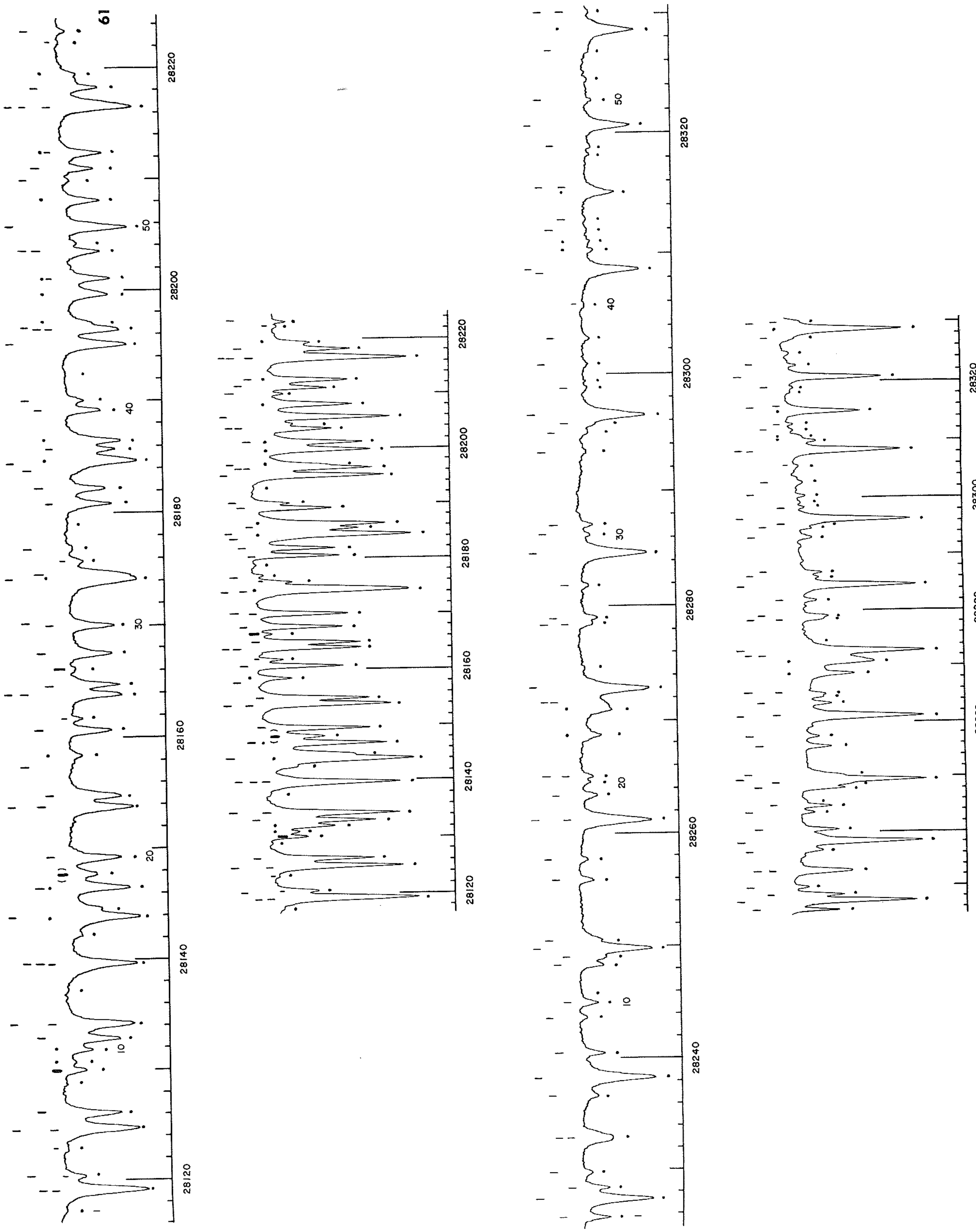


Fig. 12 Solar Spectrum λλ 28116–28331, in four strips (cf. Table 1).

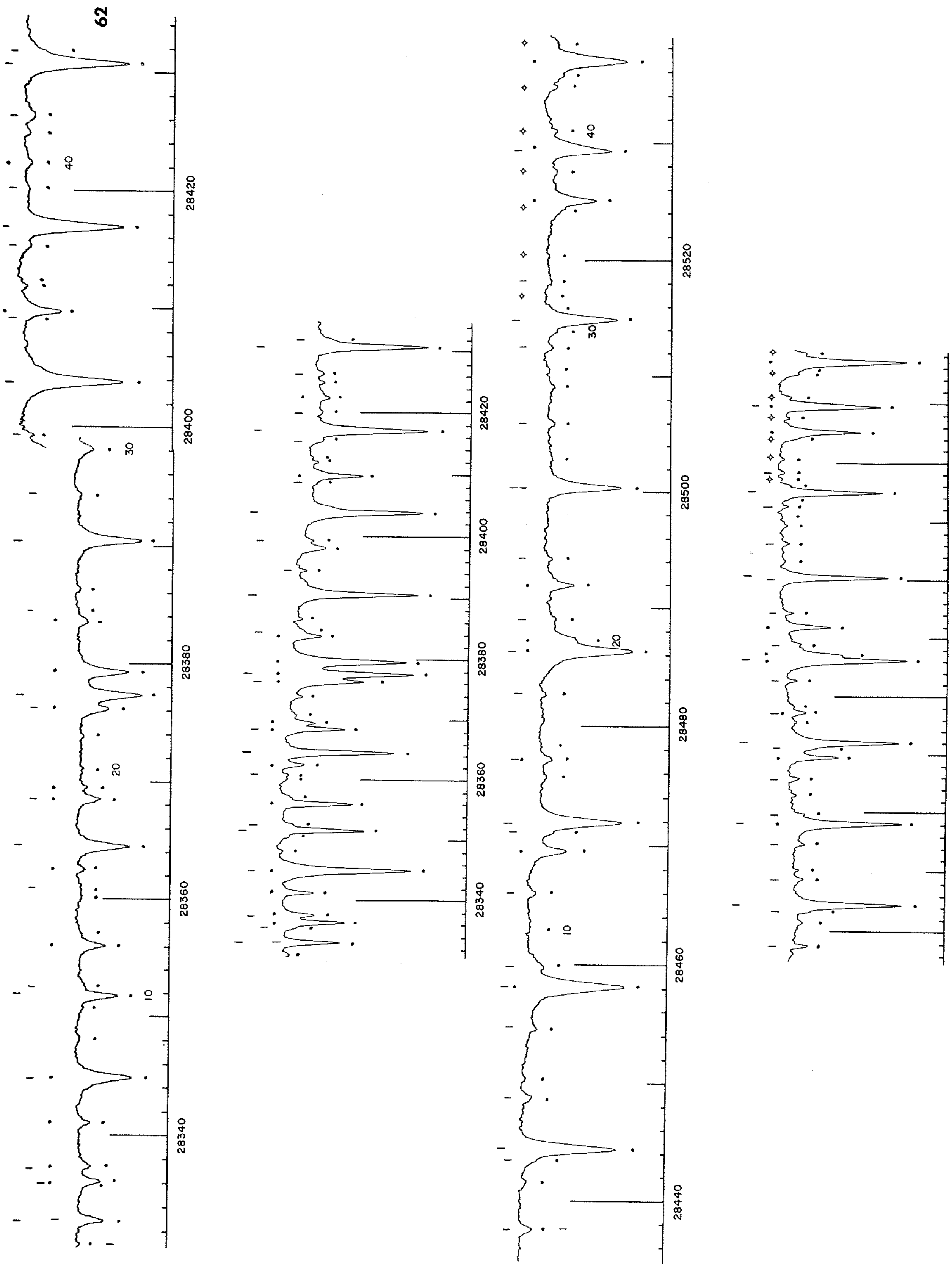


Fig. 13 Solar Spectrum λλ 28331–28539, in four strips (cf. Table 1).

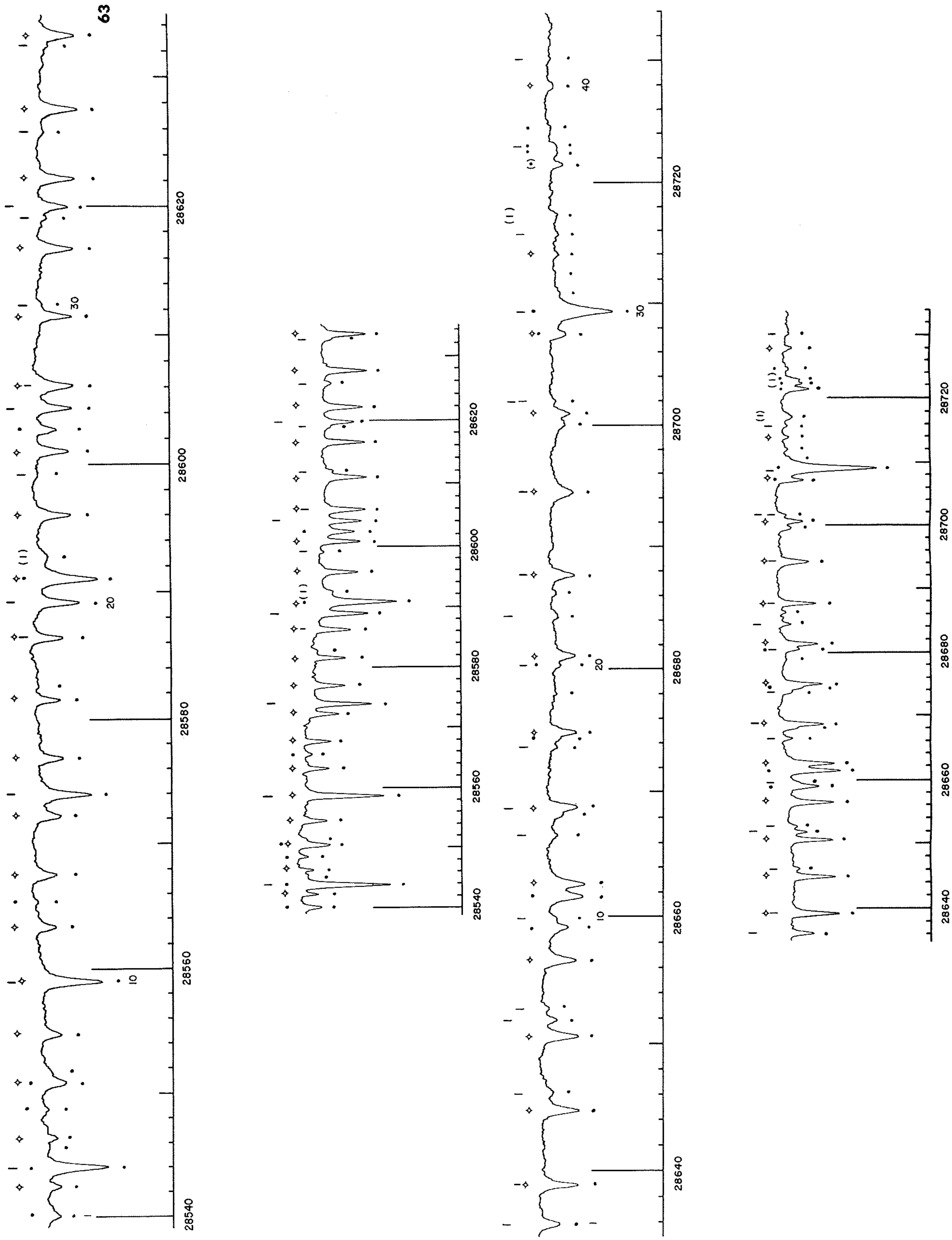


Fig. 14 Solar Spectrum λλ 28539–28734, in four strips (cf. Table 1).

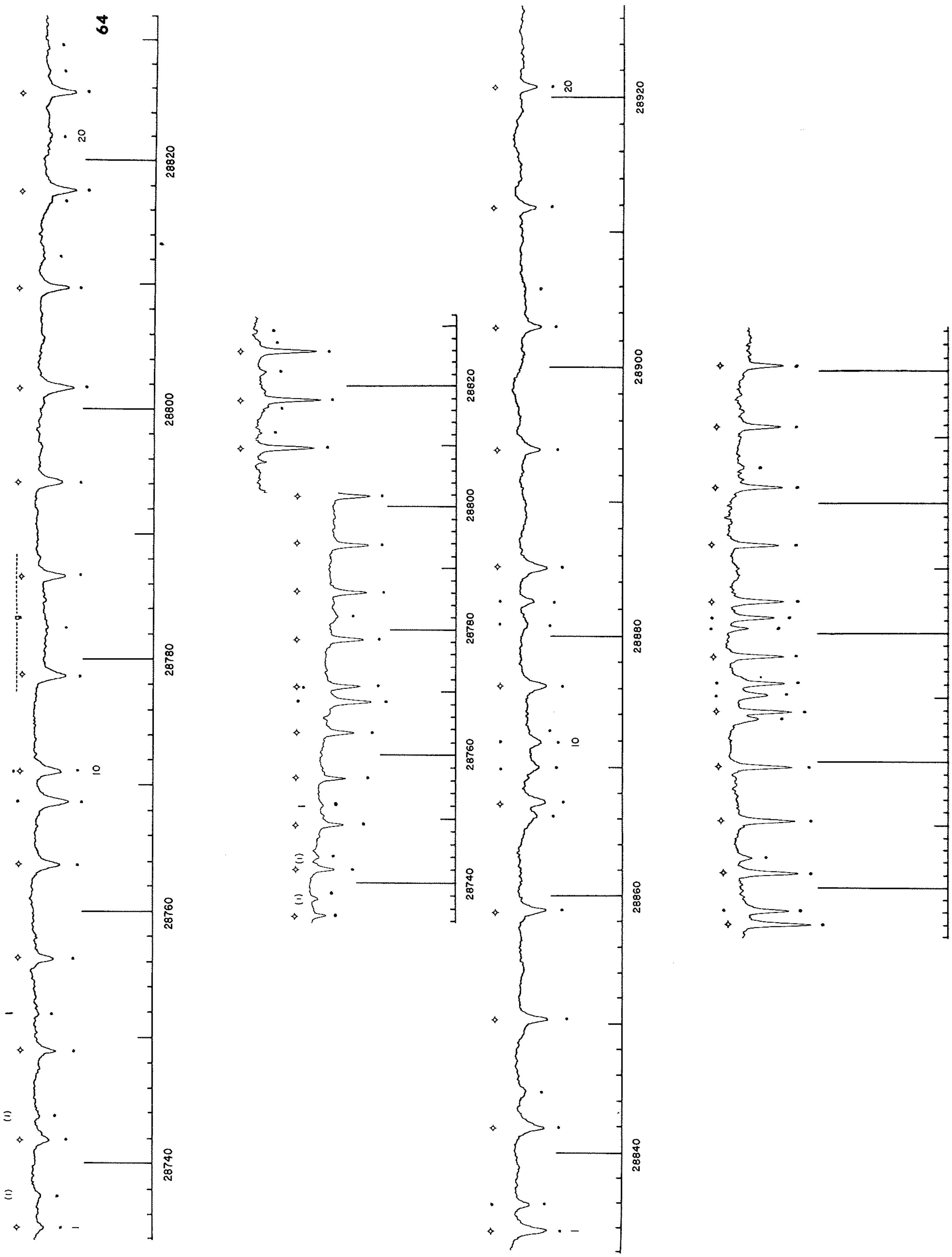


Fig. 15 Solar Spectrum λλ 28734–28927, in four strips (cf. Table 1).

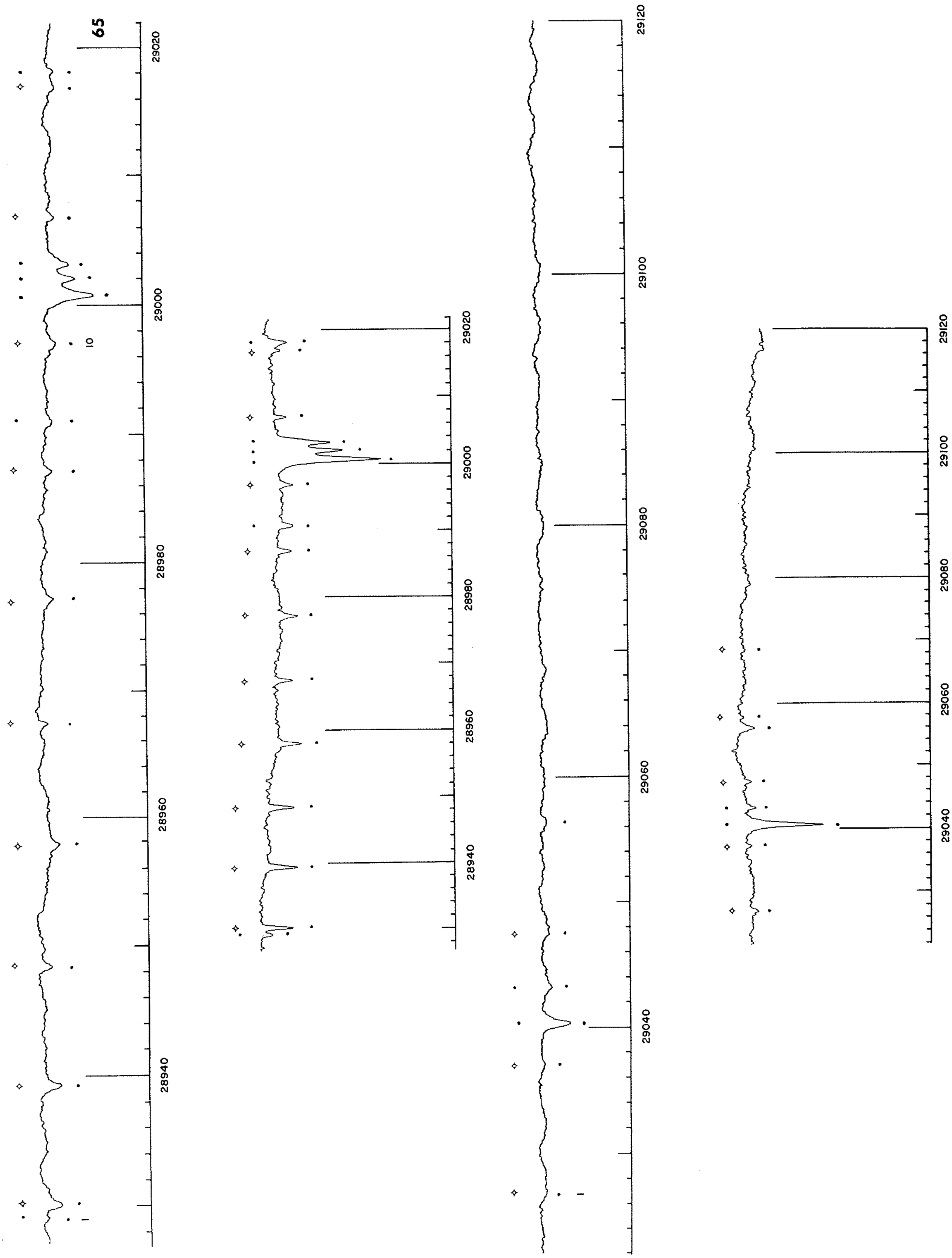
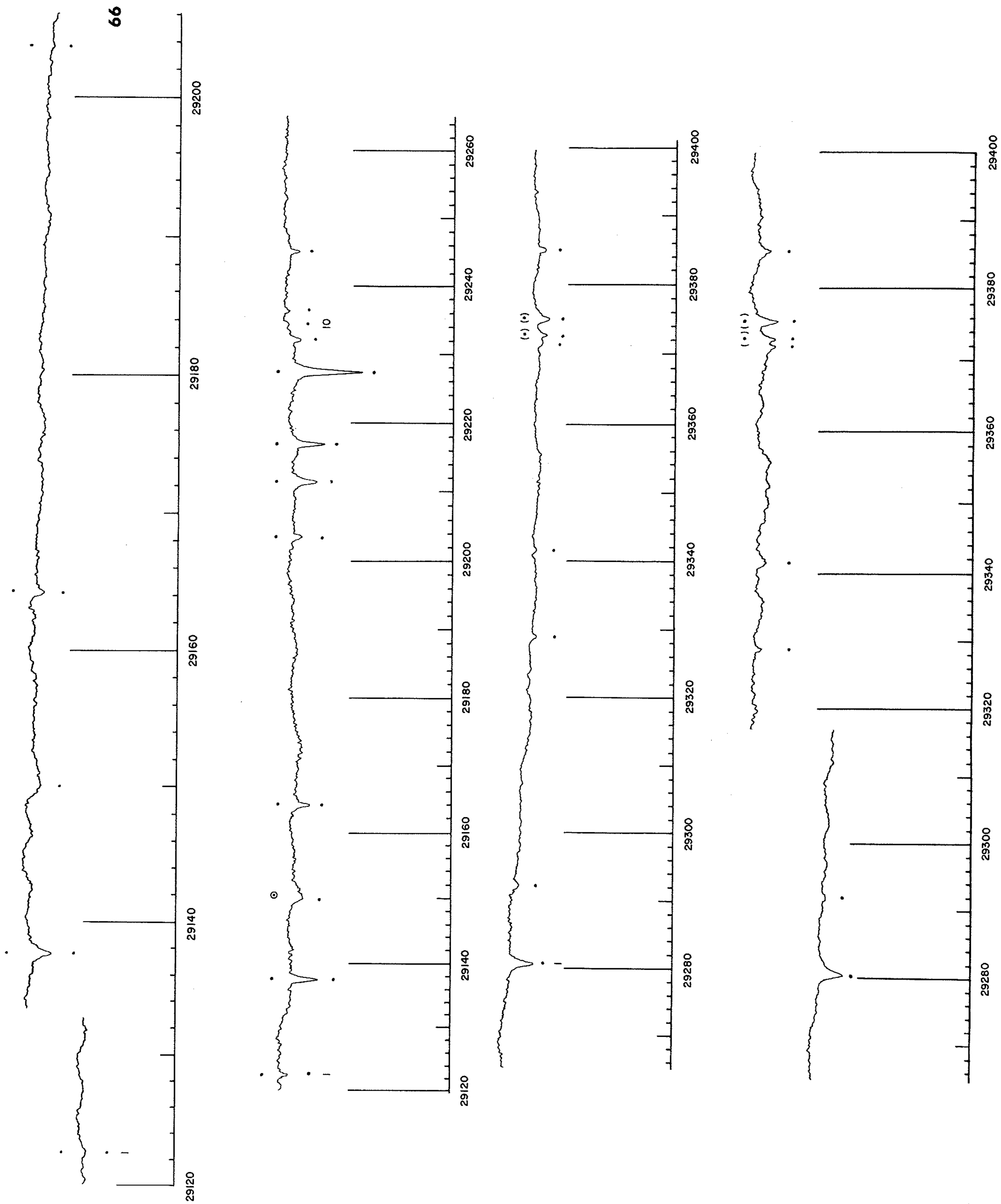


Fig. 16 Solar Spectrum λλ 28927–29120, in four strips (cf. Table 1).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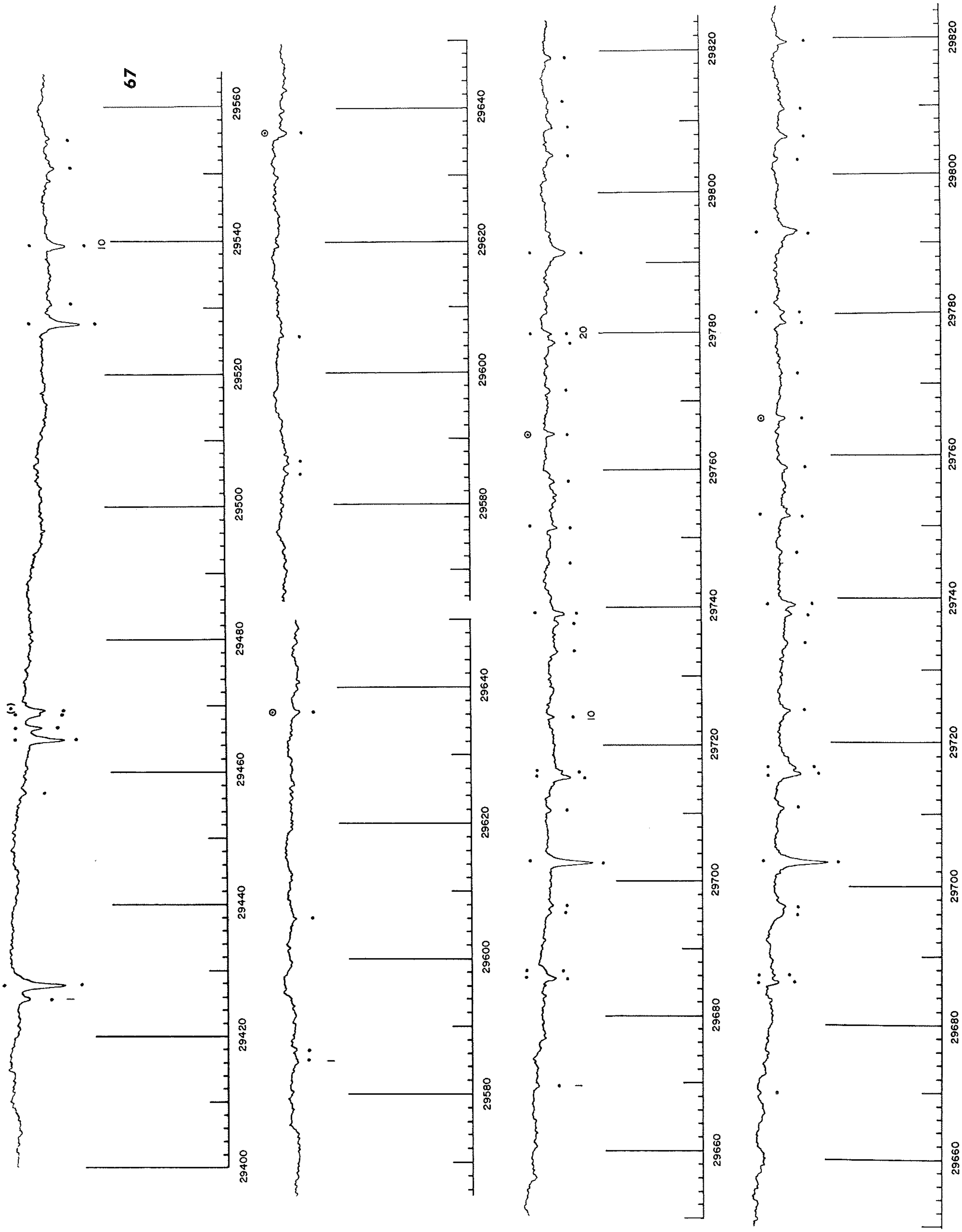

Fig. 18 Solar Spectrum λλ 29400–29825, in four strips (cf. Table 1).

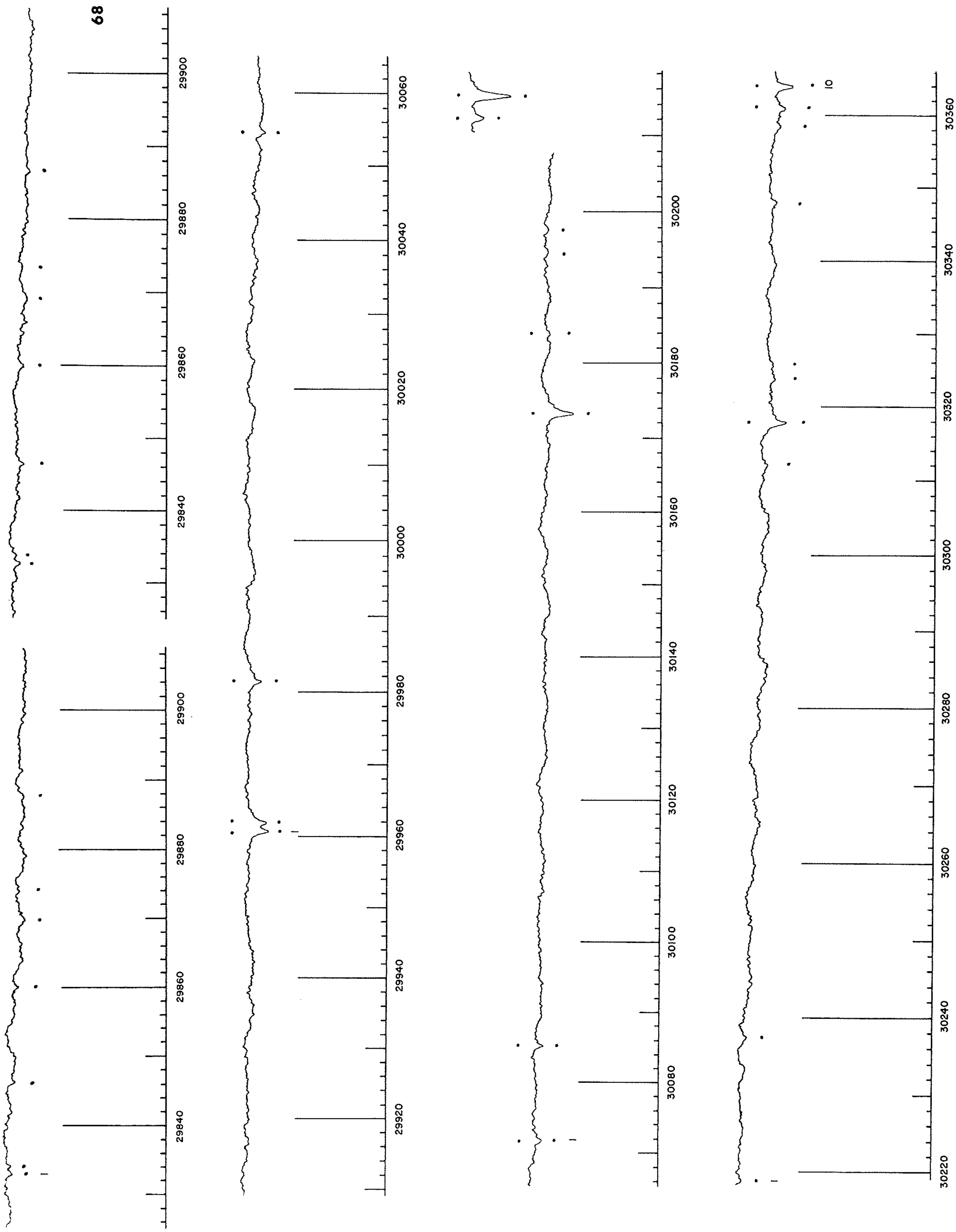

Fig. 19 Solar Spectrum λλ 29825–30366, in four strips (cf. Table 1).

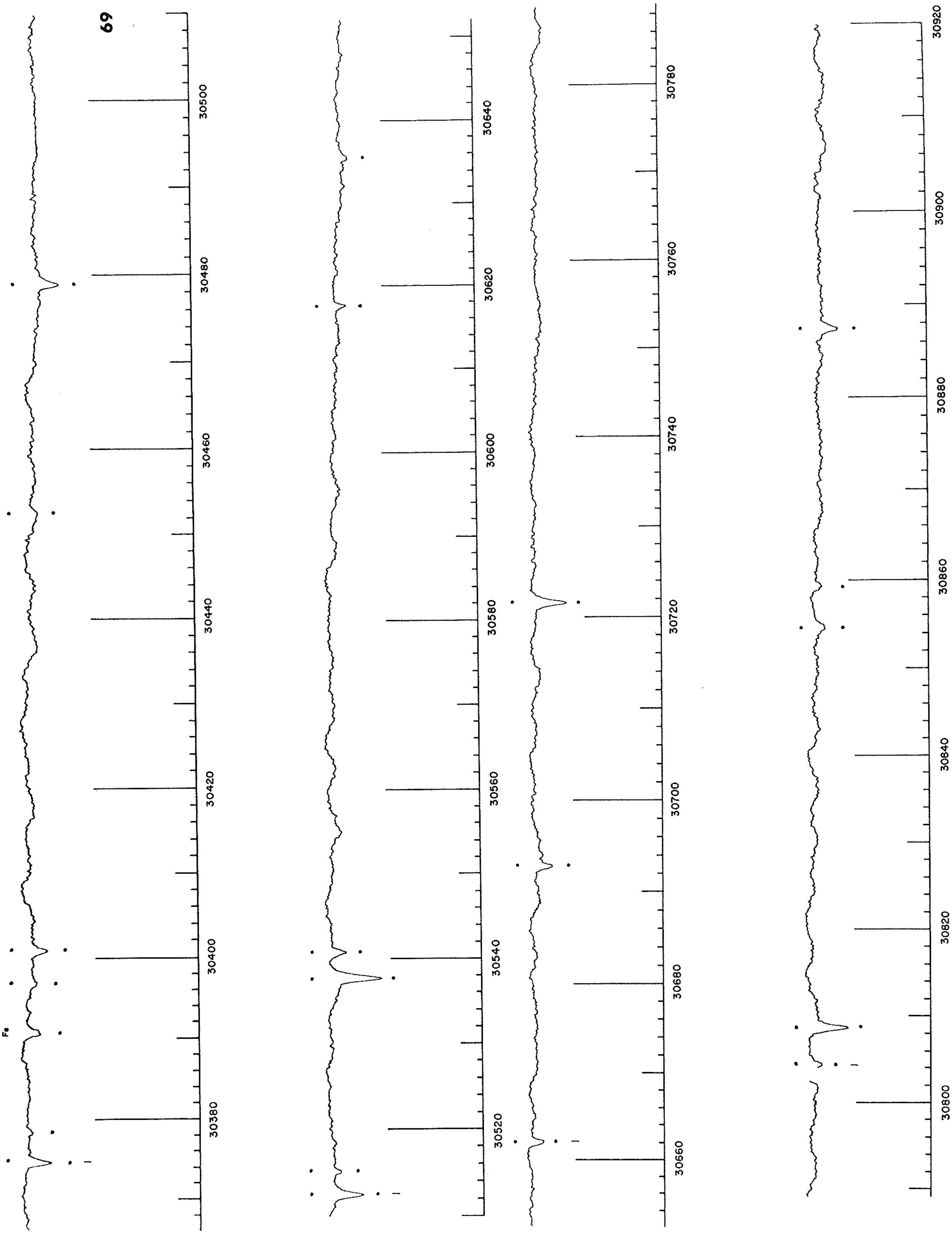

Fig. 20 Solar Spectrum λλ 30366–30920, in four strips (cf. Table 1).

TABLE I

SOLAR SPECTRUM RECORDS, 4-m SPECTROMETER, NASA CV-900 JET
GRATING 600 l/mm: GRATING BLAZE, JULY 19: 1.6 μ, JULY 30, AUG. 1: 2.5 μ
FILTER 1.8 μ; DETECTOR 0.10 mm

FIG.	CHART		1968 DATE	UT	ALT. (FT.)	OUTSIDE TEMP. (°C)	CABIN ALT. (FT.)	GAIN	SLIT (mm)	τ (SEC.)
1	50 c	25583-25707	July 19	19:04	39,000	—52	8500	5-6	0.18	0.12
	d	25707-25770	July 19/30	19:07/18:26	39,000/40,800	—52/—55	8500/8900	5-5	0.18/0.15	0.12
2	51 a	25770-25893	July 30	18:29	41,000	—55	8900	5-5	0.15	0.12
	b	25770-25893	July 19	19:09	39,000	—52	8500	5-6	0.18	0.12
	c	25893-26013	July 30	18:32	41,100	—55	8900	5-5	0.15	0.12
	d	25893-26013	July 19	19:12	39,000	—52	8500	5-6	0.18	0.12
3	52 a	26013-26134	July 30	18:35	41,200	—55	8900	5-5	0.15	0.12
	b	26013-26134	July 19	19:16	39,000	—52	8500	5-6	0.18	0.12
	c	26134-26255	July 30	18:38	41,300	—55	8900	5-5	0.15	0.12
	d	26134-26255	July 19	19:19	39,000	—52	8500	5-6	0.18	0.12
4	53 a	26255-26369	July 30	18:41	41,400	—55	8900	5-5	0.15	0.12
	b	26255-26369	July 19	19:22	39,000	—52	8500	5-6	0.18	0.12
	c	26369-26488	July 30	19:25	41,500	—59	8900	5-6	0.15	0.12
	d	26369-26488	July 19	19:25	39,000	—52	8500	5-6	0.18	0.12
5	54 a	26488-26606	July 30	18:47/19:28	41,500	—55/—59	8900	5-5/5-6	0.15	0.12
	b	26488-26606	July 19	19:29	39,000	—52	8500	5-6	0.18	0.12
	c	26606-26718	July 30	19:31	41,500	—59	8900	5-6	0.15	0.12
	d	26606-26718	July 19	19:37	39,000	—52	8500	6-2	0.18	0.12
6	55 a	26718-26837	July 30	19:34	61,500	—59	8900	5-6	0.15	0.12
	b	26718-26837	July 30	18:55	41,700	—55	8900	5-6	0.15	0.12
	c	26837-26950	July 30	19:38	41,500	—59	8900	5-6	0.15	0.12
	d	26837-26950	July 30	18:58	41,600	—56	8900	5-6	0.15	0.12
7	56 a	26950-27056	July 30	19:42	41,500	—60	8900	5-6	0.15	0.12
	b	26950-27056	July 30	19:01	41,600	—57	8900	5-6	0.15	0.12
	c	27056-27167	July 30	19:45	41,500	—60	8900	5-6	0.15	0.12
	d	27056-27167	July 30	19:05	41,500	—58	8900	5-6	0.15	0.12
8	57 a	27167-27279	July 30	19:48	41,500	—60	8900	5-6	0.15	0.12
	b	27167-27279	July 30	19:08	41,500	—58	8900	5-6	0.15	0.12
	c	27279-27382	July 30	19:51	41,500	—60	8900	5-6	0.15	0.12
	d	27279-27382	July 30	19:11	41,500	—59	8900	5-6	0.15	0.12
9	58 a	27382-27486	July 30	19:57	41,500	—60	8900	6-2	0.15	0.12
	b	27382-27486	July 30	19:14	41,500	—59	8900	5-6	0.15	0.12
	c	27486-27592	July 30	20:00	41,500	—59	8900	6-2	0.15	0.12
	d	27486-27592	July 30	19:17	41,500	—59	8900	5-6	0.15	0.12

10	59 a	27592-27692	July 30	20:03	41,500	—59	8900	6-2	0.15	0.12
	b	27692-27796	July 30	20:06	41,500	—59	8900	6-2	0.15	0.12
	c	27796-27903	July 30	20:10	41,500	—59	8900	6-2	0.14	0.12
	d*	27796-27903	Aug. 1	18:19	39,000	—54	9300	6-1	0.30	0.12
11	60 a	27903-28011	July 30	20:13	41,500	—59	8900	6-2	0.14	0.12
	b*	27903-28011	Aug. 1	18:20	39,000	—54	9300	6-1	0.30/0.24	0.12
	c	28011-28116	July 30	20:16	41,500	—58	8900	6-2	0.14	0.12
	d*	28011-28116	Aug. 1	18:22	39,200	—54	9300	6-1	0.24	0.12
12	61 a	28116-28225	July 30	20:20	41,500	—58	8900	6-2	0.14	0.12
	b*	28116-28225	Aug. 1	18:24	39,400	—56	9300	6-1	0.24	0.12
	c	28225-28331	July 30	20:23	41,500	—58	8900	6-2	0.14	0.12
	d*	28225-28331	Aug. 1	18:26	39,600	—54	9300	6-1	0.24	0.12
13	62 a	28331-28435	July 30	20:26	41,500	—58	8900	6-2/6-3	0.14	0.12/0.24
	b*	28331-28435	Aug. 1	18:27	39,800	—54	9300	6-1	0.24	0.12
	c	28435-28539	July 30	20:30	41,500	—58	8900	6-3	0.14	0.24
	d*	28435-28539	Aug. 1	18:29	40,000	—54	9300	6-1	0.24	0.12
14	63 a	28539-28635	July 30	20:33	41,500	—58	8900	6-3	0.14	0.24
	b*	28539-28635	Aug. 1	18:31	40,200	—53	9300	6-1	0.24	0.12
	c	28635-28734	July 30	20:37	41,500	—58	8900	6-3	0.14	0.24
	d*	28635-28734	Aug. 1	18:32	40,400	—53	9300	6-1	0.24	0.12
15	64 a	28734-28832	July 30	20:40	41,500	—58	8900	6-3	0.24	0.24
	b*	28734-28832	Aug. 1	18:34	40,500	—53	9300	6-1/6-2	0.24	0.12
	c	28832-28927	July 30	20:43	41,500	—58	8900	6-3	0.14	0.24
	d*	28832-28927	Aug. 1	18:36	40,500	—53	9300	6-2	0.24	0.12
16	65 a	28927-29022	July 30	20:46	41,500	—58	8900	6-3	0.14	0.24
	b*	28927-29022	Aug. 1	18:37	40,500	—53	9300	6-2	0.24	0.12
	c	29022-29120	July 30	20:49	41,500	—58	8900	6-3	0.14	0.24
	d*	29022-29120	Aug. 1	18:39	40,500	—53	9300	6-2	0.24	0.12
17	66 a	29120-29206	July 30	20:52	41,500	—58	8900	6-3	0.14/0.20	0.24
	b*	29120-29265	Aug. 1	18:41	40,500	—53	9300	6-2	0.24	0.12
	c*	29265-29400	Aug. 1	18:44	40,300	—53	9300	6-2	0.24	0.12/0.24
	d*	29265-29400	Aug. 1	18:48	40,500	—53	9300	6-2/6-3	0.24	0.24
18	67 a*	29400-29565	Aug. 1	18:50	40,500	—53	9300	6-3	0.24	0.24
	b*	29565-29650	Aug. 1	18:53/19:21	40,800/41,500	—55/—58	9300	6-3	0.24	0.24
	c*	29650-29825	Aug. 1	18:55	41,200	—58	9300	6-3	0.24	0.24
	d*	29650-29825	Aug. 1	19:23	41,500	—58	9300	6-3	0.24	0.24
19	68 a*	29825-29909	Aug. 1	18:58/19:26	41,800/41,500	—59/—60	9300	6-3	0.24	0.24
	b*	29909-30065	Aug. 1	19:28	41,500	—60	9300	6-3	0.24	0.24
	c*	30065-30218	Aug. 1	19:31	41,500	—60	9300	6-3	0.24/0.38	0.24
	d*	30218-30366	Aug. 1	19:34	41,500	—60	9300	6-3	0.38	0.24
20	69 a*	30366-30510	Aug. 1	19:37	41,500	—60	9300	6-3	0.38	0.24
	b*	20510-30652	Aug. 1	19:40	41,500	—60	9300	6-3	0.38	0.24
	c*	30652-30789	Aug. 1	19:43	41,500	—60	9300	6-3	0.38	0.24
	d*	30789-30920	Aug. 1	19:47	41,500	—60	9300	6-3	0.38	0.24

*Grating turned at double rate.

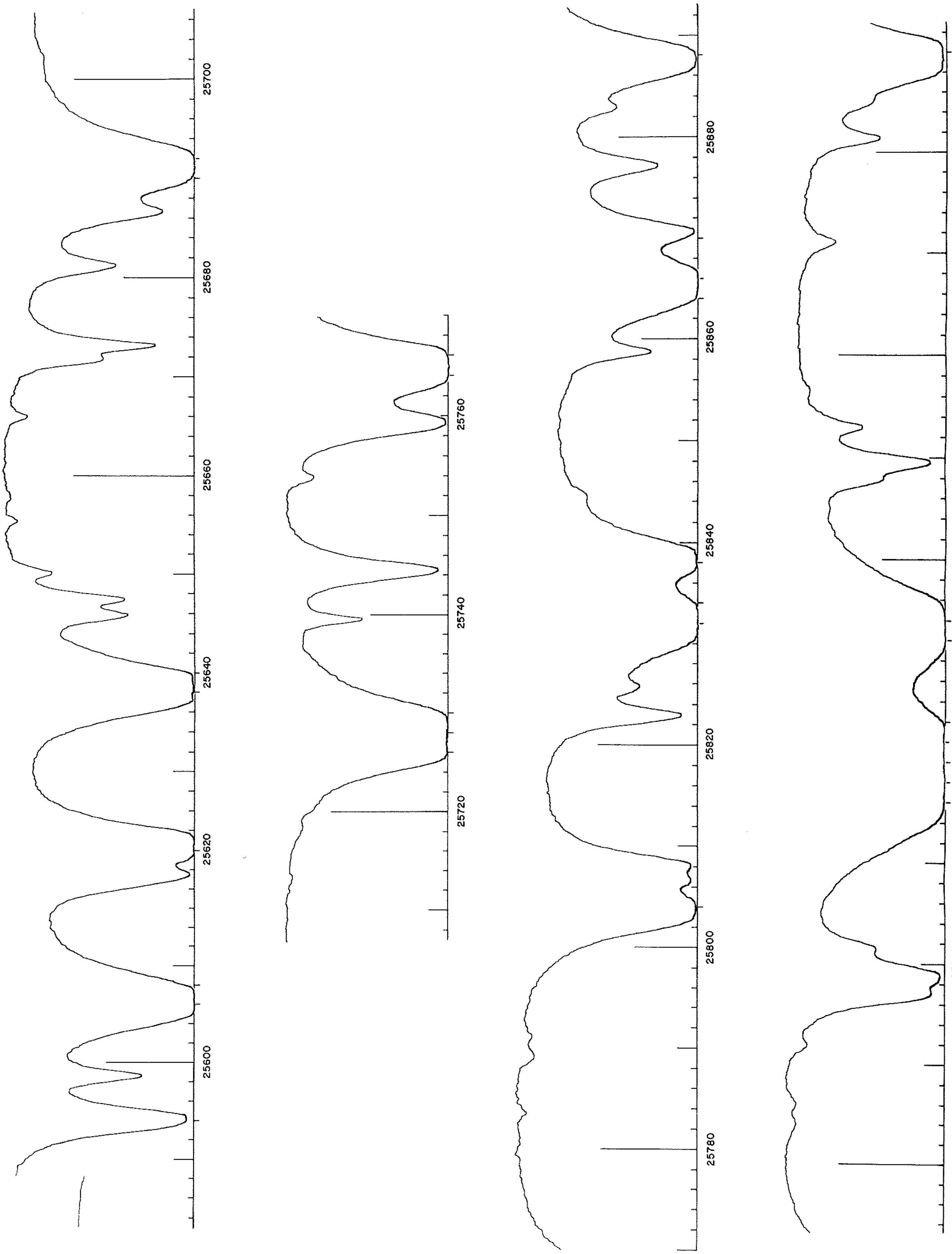

Fig. 21 Laboratory Spectrum of water vapor λλ 25583–26013, matching the solar spectrum Figs. 1, 2.

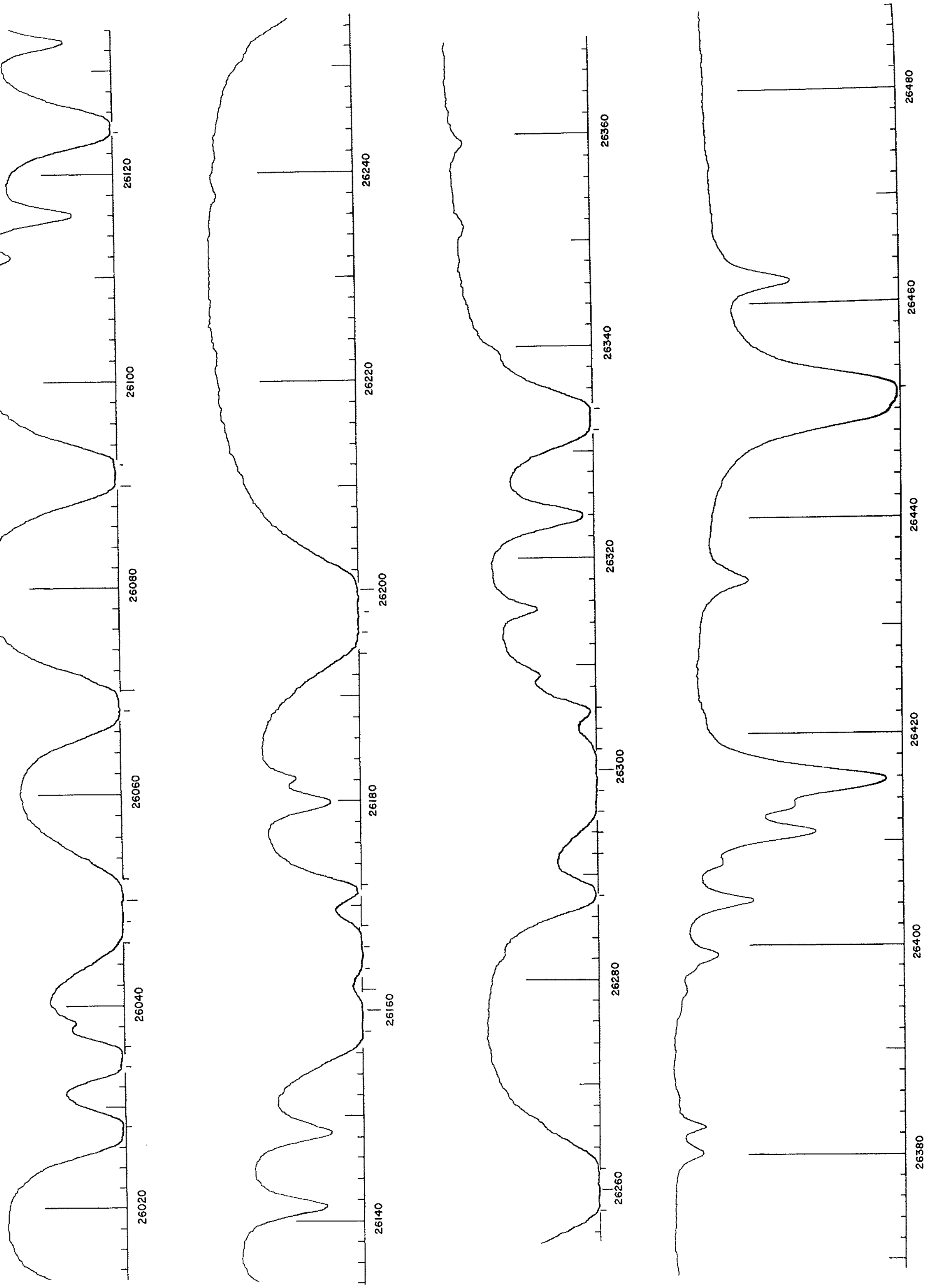

Fig. 22 Laboratory Spectrum of water vapor λλ 26013–26488, matching the solar spectrum Figs. 3, 4.

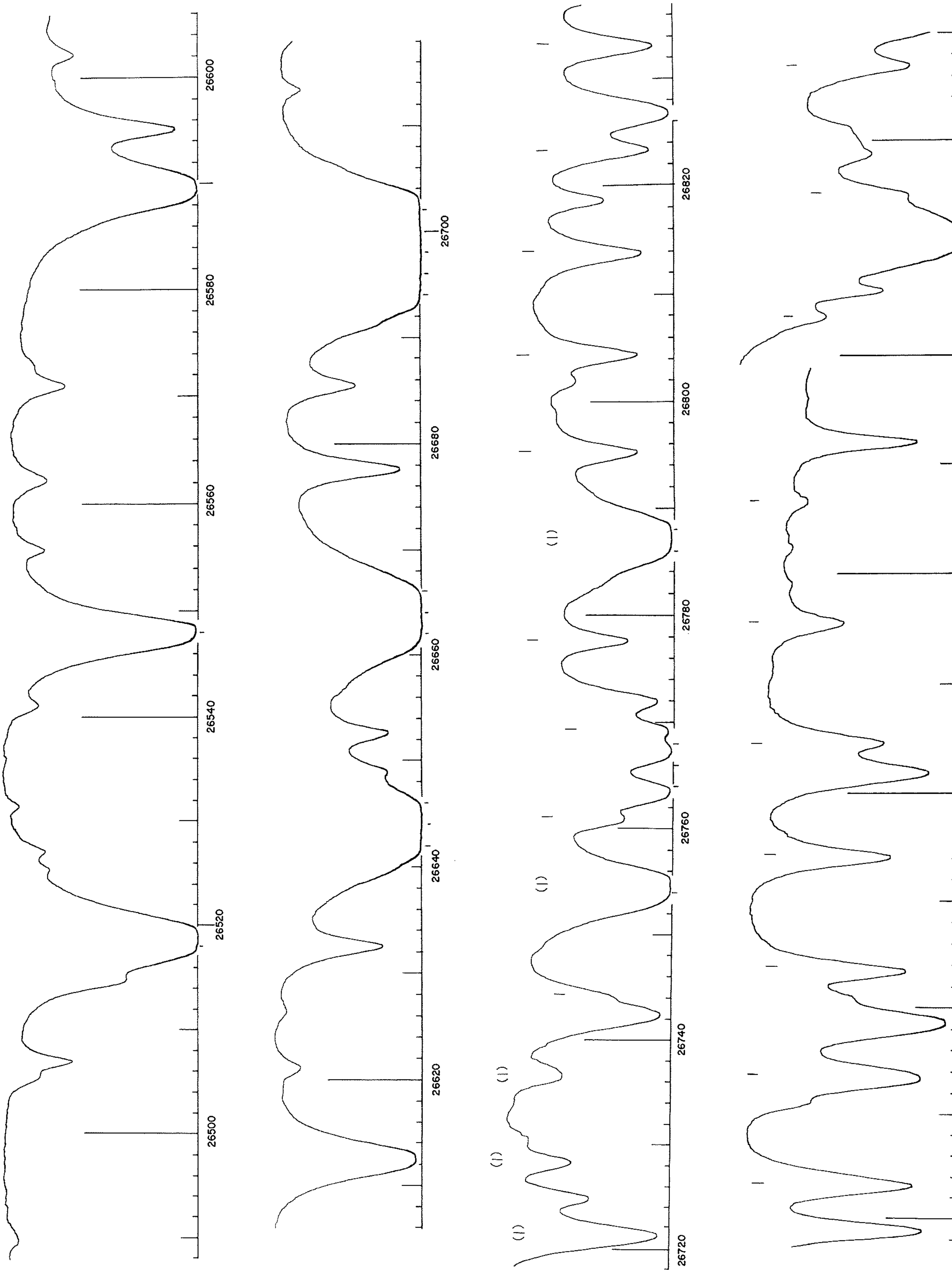

Fig. 23 Laboratory Spectrum of water vapor λλ 26488–26950, matching the solar spectrum Figs. 5, 6.

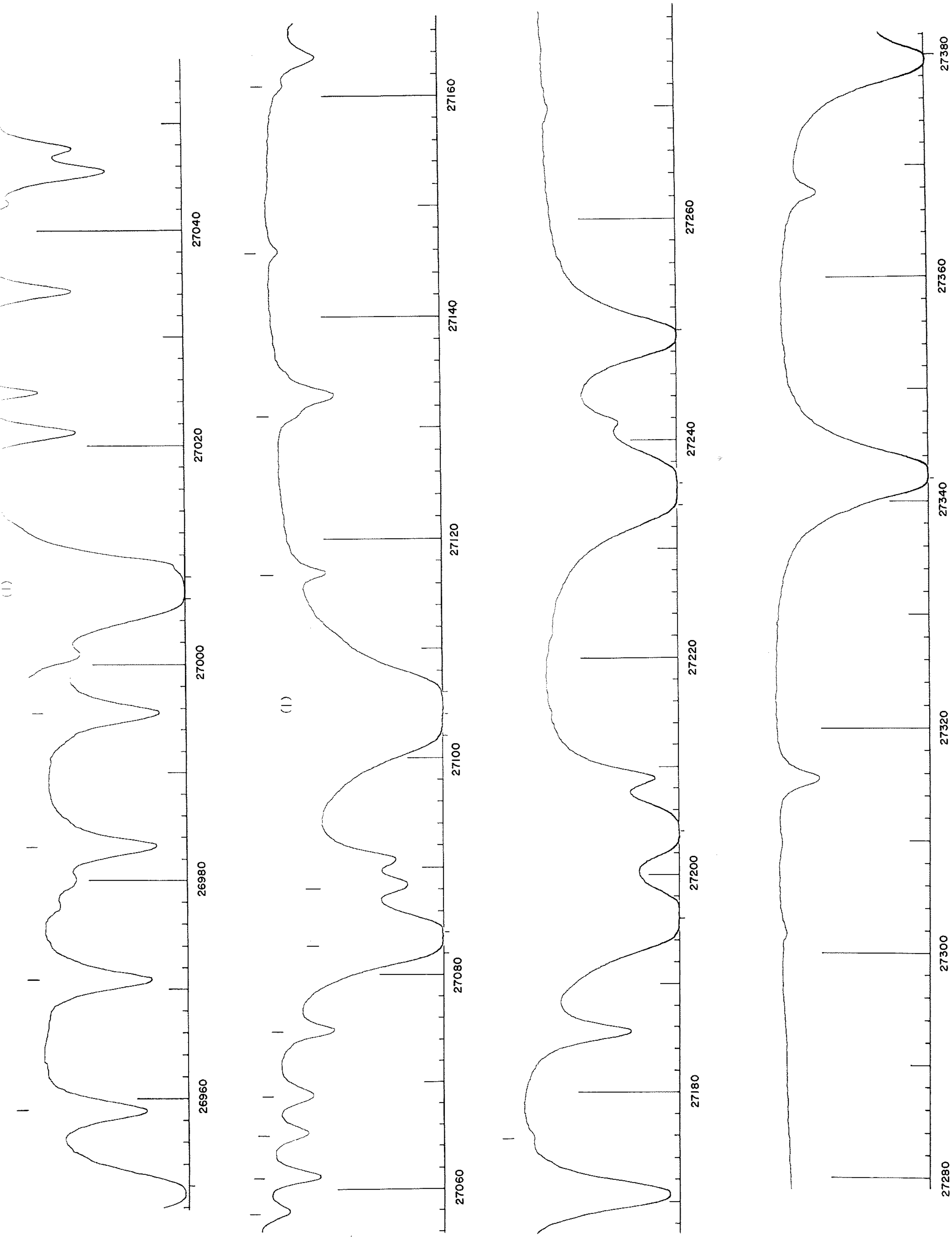

Fig. 24 Laboratory Spectrum of water vapor λλ 26950–27382, matching the solar spectrum Figs. 7, 8.

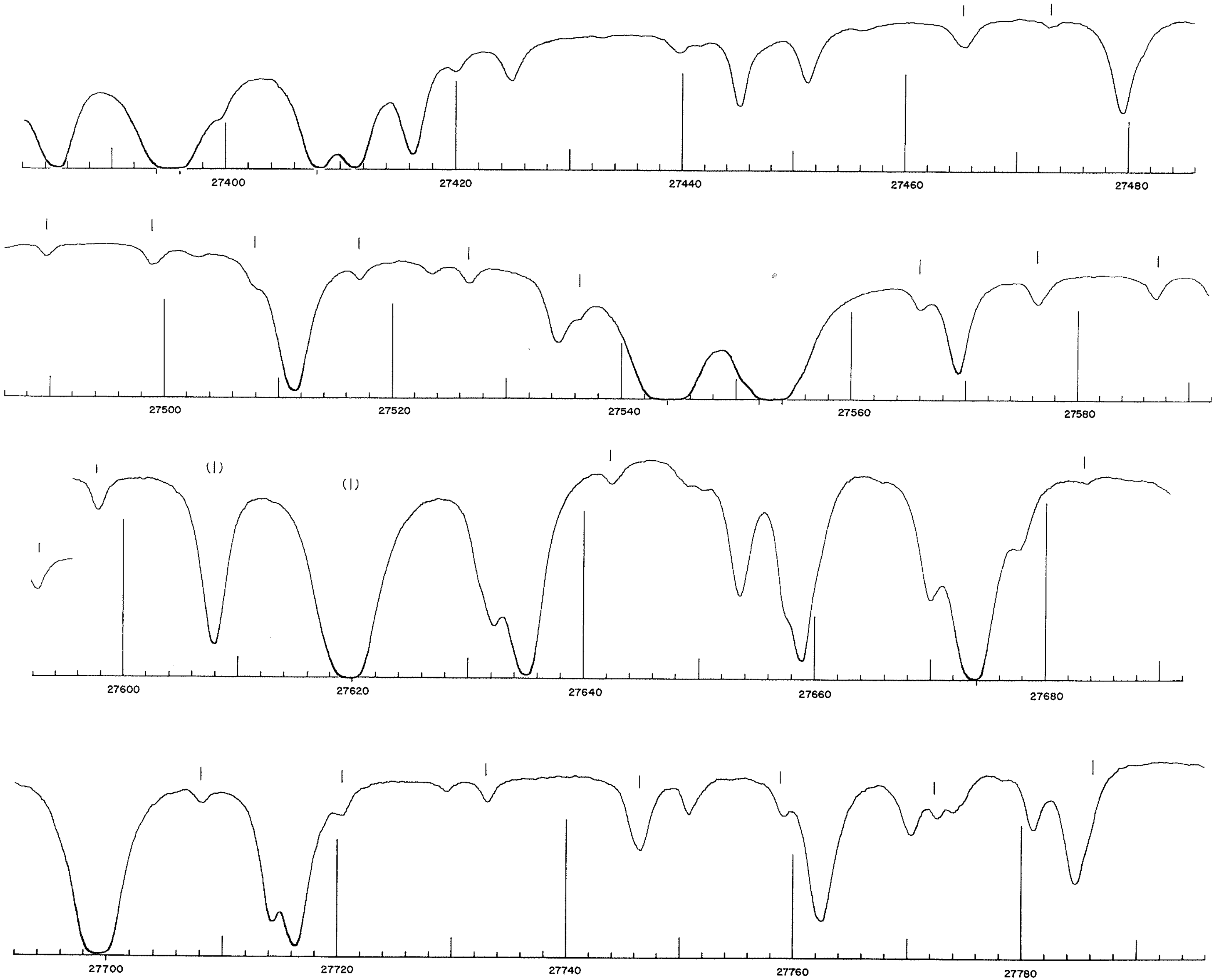

Fig. 25 Laboratory Spectrum of water vapor λλ 27382–27796, matching the solar spectrum Figs. 9, 10*a*, *b*.

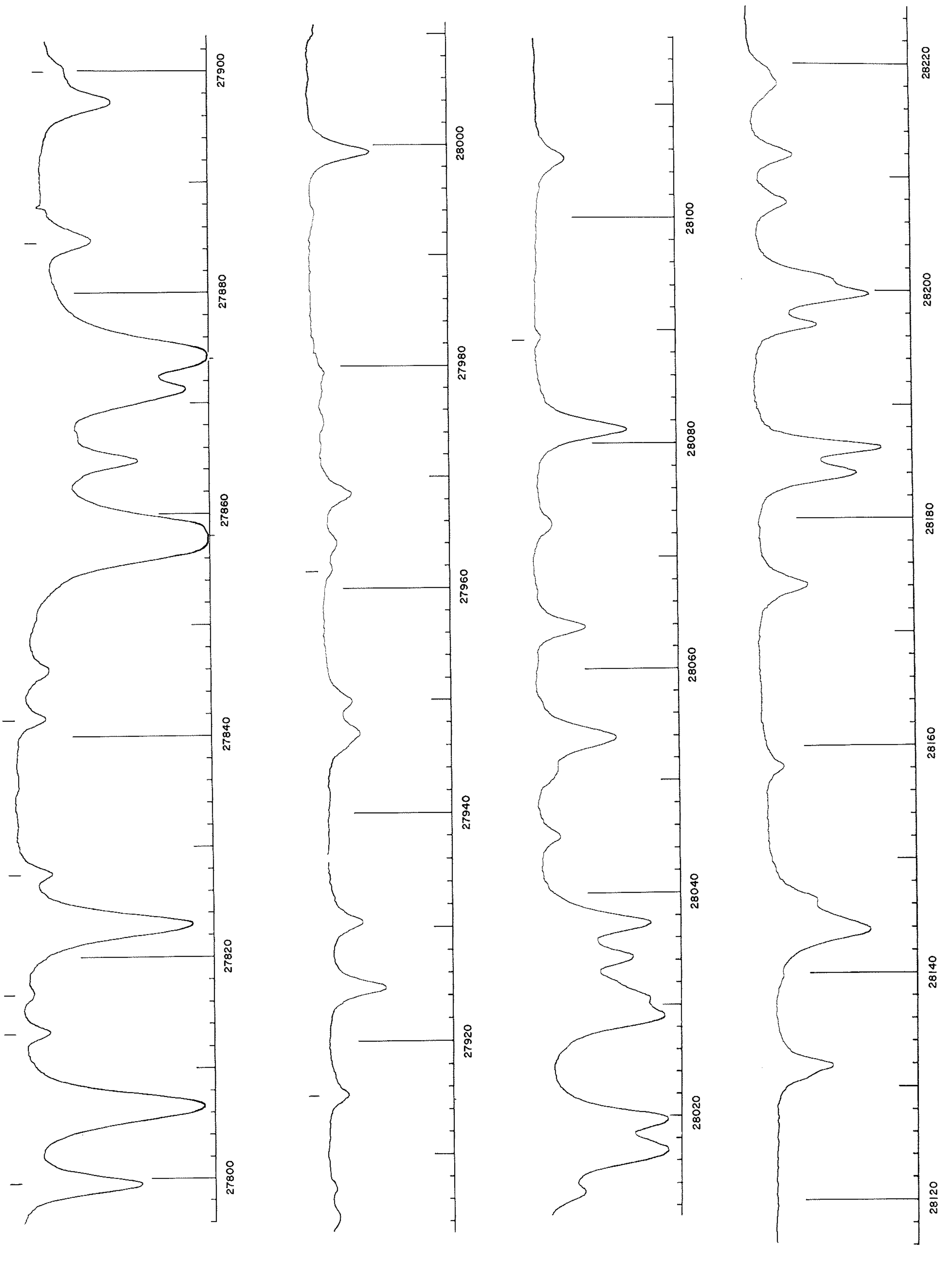

Fig. 26 Laboratory Spectrum of water vapor λλ 27796–28225, matching the solar spectrum Figs. 10*c*/*d*, 11, 12*a*/*b*.

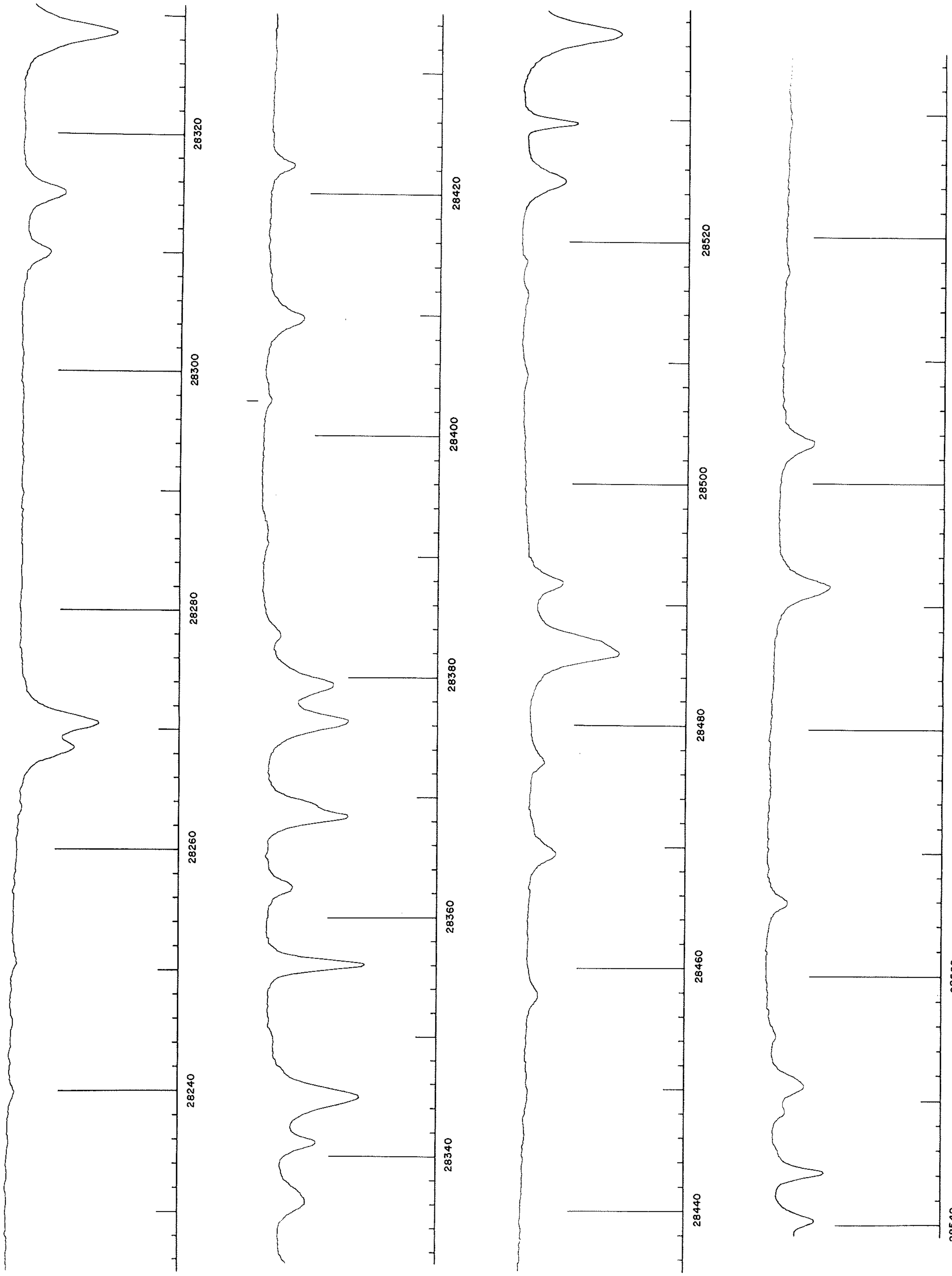

Fig. 27 Laboratory Spectrum of water vapor λλ 28225–28635, matching the solar spectrum Figs. 12*c*/*d*, 13, 14*a*/*b*.

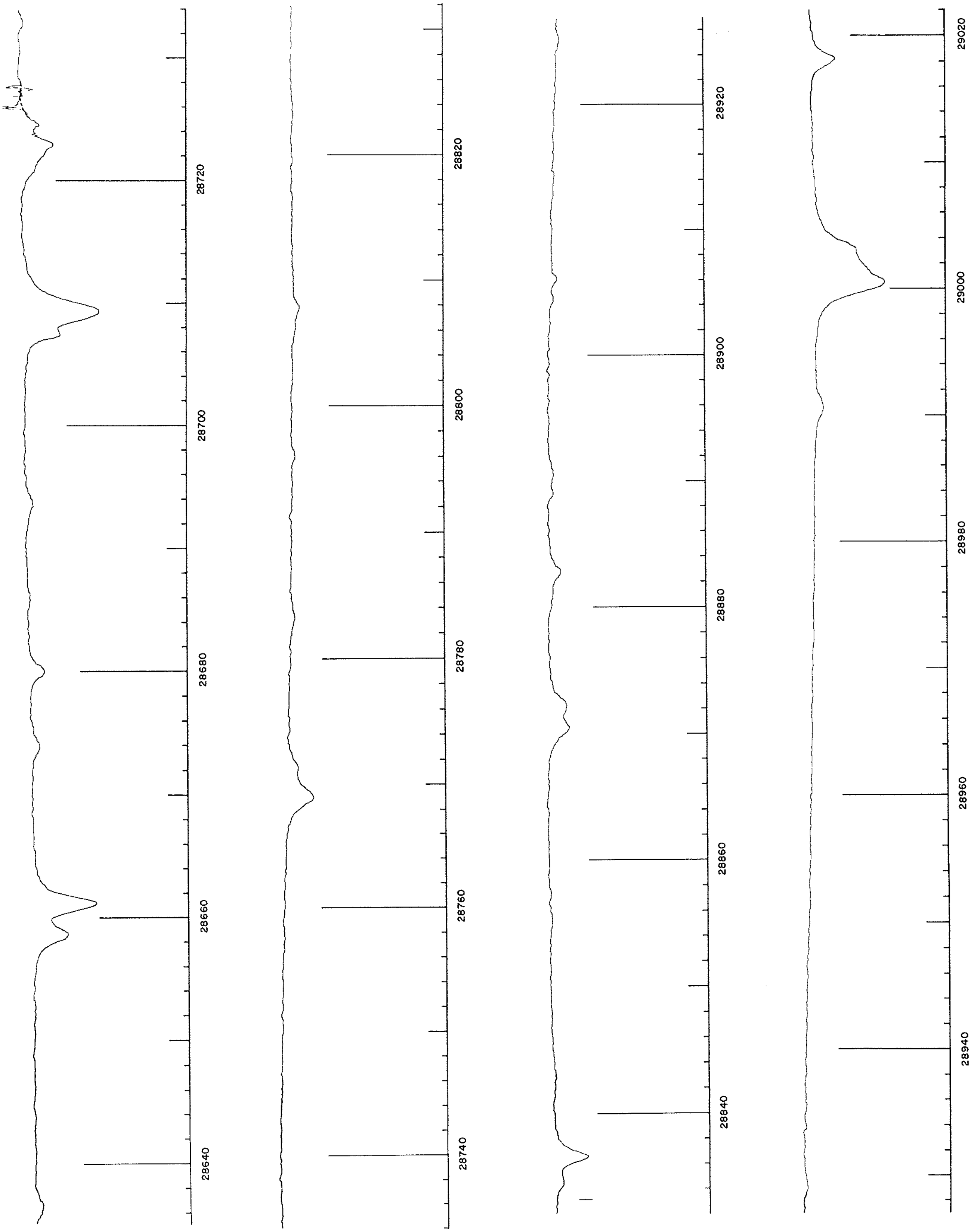

Fig. 28 Laboratory Spectrum of water vapor λλ 28635–29022, matching the solar spectrum Figs. 14*c*/*d*, 15, 16*a*/*b*.

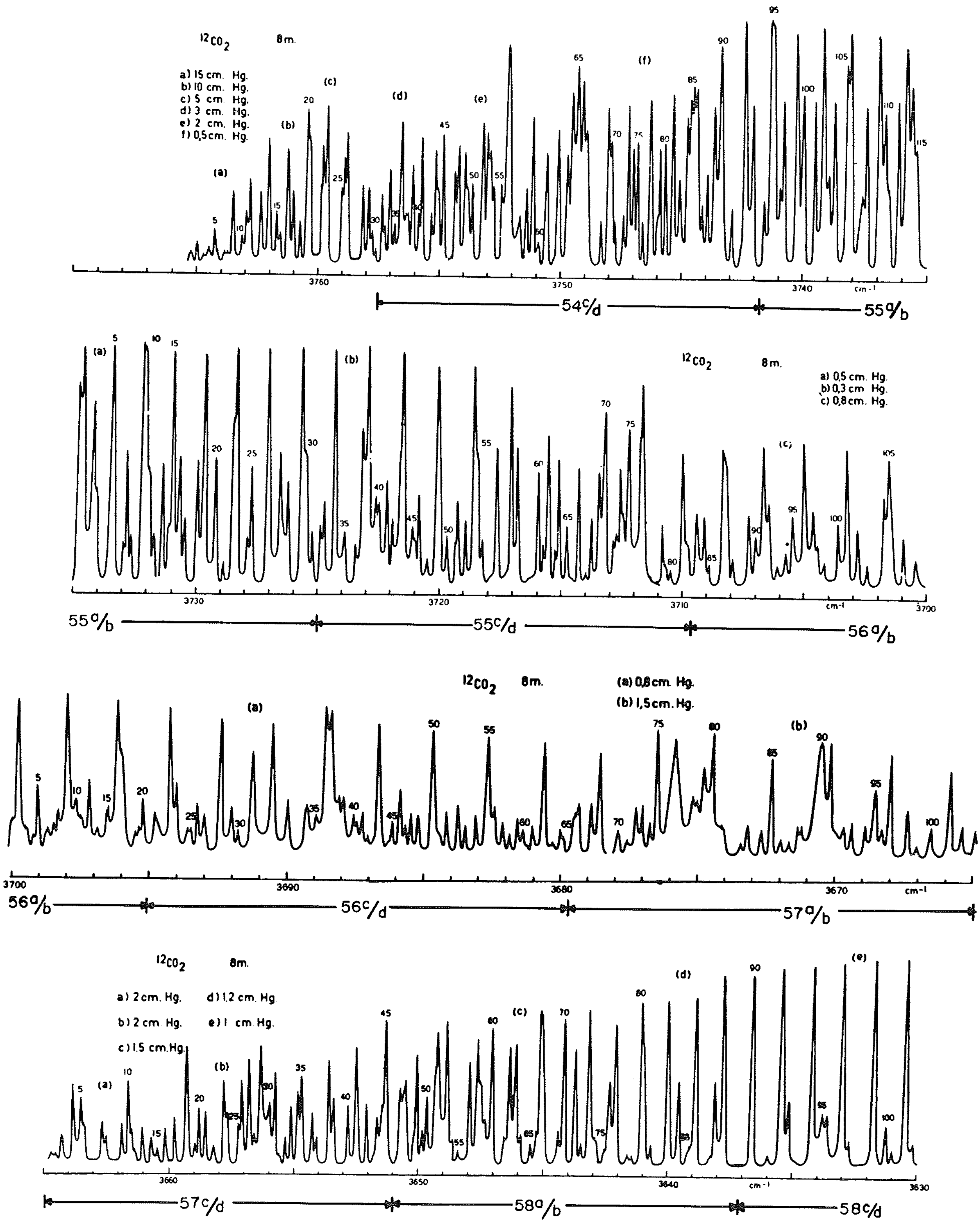

Fig. 29 Laboratory spectrum of CO_2 by C. P. Courtoy. Scales in wavenumbers. Arrows indicate corresponding parts of solar records. (Reproduced with permission).

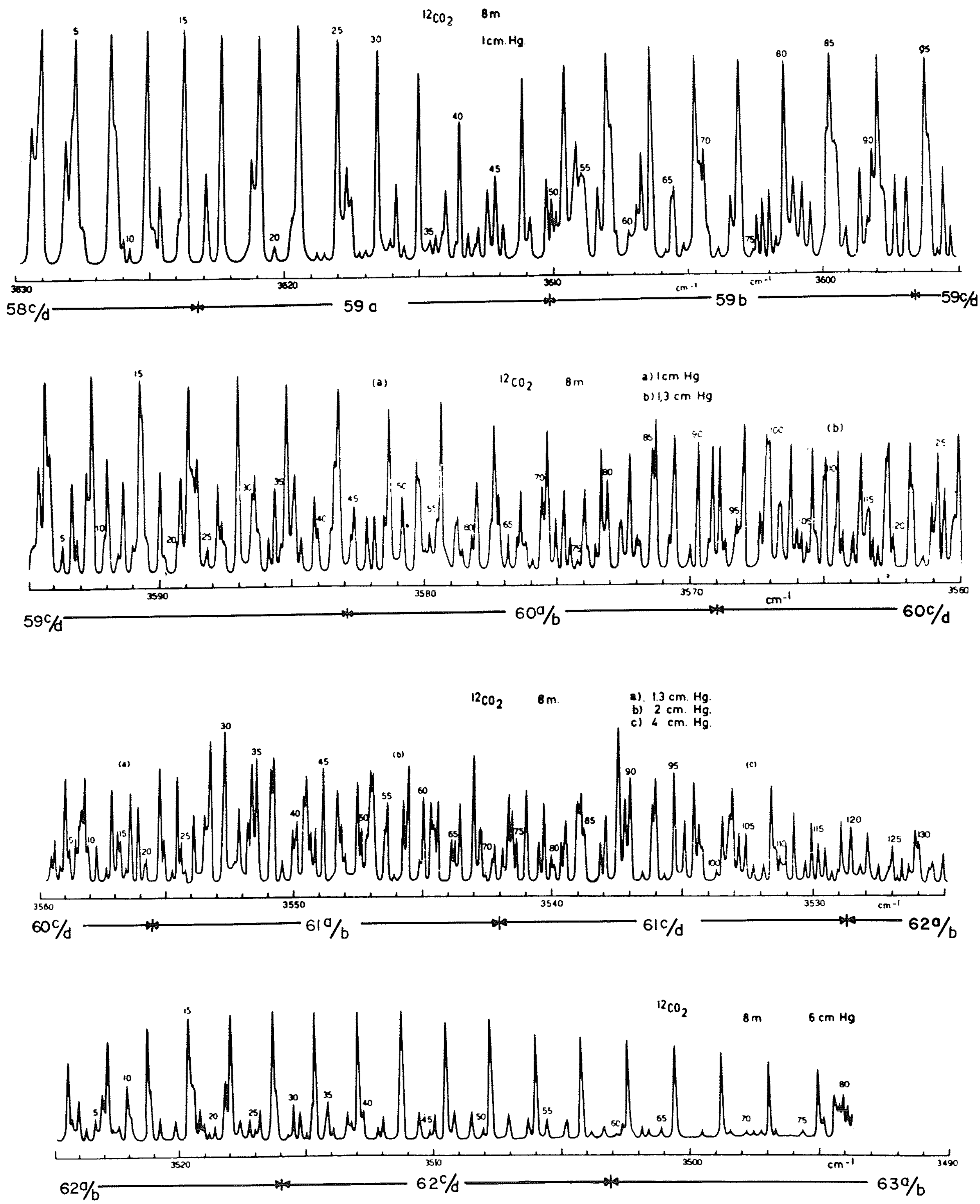

Fig. 30 Laboratory spectrum of CO_2 by C. P. Courtoy. Scales in wavenumbers. Arrows indicate corresponding parts of solar records. (Reproduced with permission).

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