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ADDITIONAL LATE-TYPE STARS WITH TECHNETIUM

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ABSTRACT

We present the results of a survey of 279 late-type giants and supergiants for the spectral lines of the radioactive element technetium (Tc I) at 4297, 4262, and 4238 Å. We reach the following conclusions: (a) the presence of Tc correlates very strongly with the existence of light variability—nonvariable, low-amplitude semiregular and irregular M stars and M supergiants do not show Tc, whereas M star Mira variables tend to show Tc if $P > 300$ days; (b) evolutionary MS stars show Tc and spectroscopic MS stars do not show Tc; (c) single S stars show Tc; (d) SC stars show Tc; (e) about 75% of the C stars show Tc; (f) Ba II stars do not show Tc. Our findings are compatible with the predictions from stellar evolution theory that Tc, along with other *s*-process elements and carbon, is mixed with the surface materials after helium shell flashing episodes even though we observe Tc in stars not predicted to experience the third dredge-up. The presence of Tc is a very sensitive indicator of the third dredge-up and can be detected in the spectrum before enhancements of other *s*-process elements are measurable.

I. INTRODUCTION

Merrill (1952) first identified the resonance lines of the radioactive element technetium (Tc) in several S stars at 4297, 4262, and 4238 Å. Since then, Tc has been discovered in other evolved stars such as cool carbon stars (N stars) (Peery 1971), and MS and M stars (Little-Marenin and Little 1979 and references therein, hereafter referred to as Paper I).

The presence of Tc in the atmospheres of late-type stars is an unambiguous tracer of recent *s*-process nuclear reactions in stellar interiors. All the isotopes of Tc are radioactive, and the isotope ^{99}Tc has a halflife of about 2×10^5 yr. In stars, ^{99}Tc is assumed to be produced by the *s*-process and mixed to the surface during the late stages of stellar evolution in asymptotic giant-branch (AGB) stars (see Iben and Renzini 1983). Theoretical evolutionary models predict that the production and mixing of *s*-process elements and helium-burning products (primarily ^{12}C) into the outer envelope occurs during helium shell flashing at the end of the AGB evolution of stars (a process called the third dredge-up). At the temperatures that occur in the intershell region of these stars (about $2\text{–}3 \times 10^8$ K), it has been found that the halflife of ^{99}Tc decreases to < 40 yr (Schatz 1983; Cosner and Truran 1981). However, Mathews *et al.* (1986) have shown that the shorter decay rates for Tc are almost completely compensated by the larger neutron fluxes that occur at the higher temperatures, leaving the Tc abundances almost unaffected. It has also been suggested that Tc may be produced by surface nuclear reactions, most recently by Akopyan and Melik-Alaverdyan (1983), but there is little observational and theoretical support for this process.

Stars experiencing the third dredge-up should show an increasing amount of carbon and of *s*-processed elements with successive helium flashes and should evolve from M to C stars. The location of stars on the AGB of Magellanic Cloud intermediate-age globular clusters bears out the prediction that the $\mathrm{M} \rightarrow \mathrm{MS} \rightarrow \mathrm{S} \rightarrow (\mathrm{SC}) \rightarrow \mathrm{C}$ stars form, unambiguously, an evolutionary sequence of stars evolving to higher luminosities up the AGB (Wood 1985). The SC stars are enclosed in parentheses in order to indicate that not all stars may go through the SC phase.

Abundance analyses of galactic AGB stars also show an increase in the C/O ratio and *s*-process enhancement along the $\mathrm{M} \rightarrow \mathrm{C}$ sequence. M giants show only marginal, if any, *s*-process enhancements (Smith and Lambert 1985); MS stars show enhancements from about a factor of 2 to about 5 (Smith and Lambert 1985, 1986); four S stars are enhanced by a factor of 3–8 (Smith and Wallerstein 1983; Smith and Lambert 1986); in four SC stars Zr and Nb are enhanced by about a factor of 5–10 with Mo and Ru showing enhancements of about 50–100 (Dominy and Wallerstein 1983); and the cool C stars show enhancements in the 10–100 range (Utsumi 1985). The C/O ratio increases from about 0.4 in M stars, to ~ 0.64 in MS stars (Smith and Lambert 1985, 1986), to ~ 0.8 in S stars (if the C/O ratio is corrected for a likely overestimate in the O abundance) (Smith and Lambert 1986), to values very close to unity in SC stars (Keenan and Boeshaar 1980; Dominy, Wallerstein, and Suntzeff 1986), and to values in C stars ranging from about 1.01 to 1.5 with more than 40% of the stars having C/O < 1.05 (Lambert *et al.* 1986). The early R stars apparently do not belong to this sequence. They are not luminous enough to be on the AGB and show no *s*-process enhancements (Dominy 1984). Their carbon enrichment, in order to produce C/O > 1,

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must have been produced during a different evolutionary phase, possibly the He core flash (Dominy 1984).

In order to define more closely the onset and continuation of the *s*-process and dredge-up phase in stars on the AGB, we have conducted a systematic search of evolved stars, primarily variable M stars, for the presence of the neutral Tc lines. Our survey contains 227 stars, which are listed in Table I along with 52 stars analyzed by other investigators. Table I includes the stars published in Paper I.

II. OBSERVATIONS AND REDUCTIONS

The spectra for the present study were obtained over the last decade, primarily with the 0.9 m feed telescope to the coudé spectrograph of the 2.1 m telescope at Kitt Peak National Observatory (KPNO). A few 4 m echelle spectra were also obtained at KPNO and CTIO (Cerro Tololo Inter-American Observatory) and from the KPNO archives. The characteristics of the echelle spectra are discussed in greater detail by Hagen, Stencel, and Dickinson (1983). At the coudé feed, we have used since 1981 camera 5 with a cooled RCA two-stage S-20 image tube and grating C with the small collimator. This combination gives a dispersion of about 8 Å/mm in the blue. Spectra of stars brighter than ~9 mag in the blue were obtained on IIIa-J plates (baked in forming gas) or, if fainter than ~9 mag, on baked IIa-O plates. The stars we observed were selected to be brighter than ~9.5 mag in the blue, which meant that, in general, variable stars were observed near maximum light. The strongest lines of Tc I lie in the 4200–4300 Å region and are difficult to observe since these red stars emit relatively little light in the blue. Since typical exposure times are 2–4 hr, we found it impractical to try to obtain higher-dispersion spectra with the coudé feed. The effective resolution for camera 5 is about 0.2 Å for the IIIa-J plates and 0.25 Å for the IIa-O plates. The spectra obtained before 1978 have been described in Paper I. We traced the spectra using the PDS microdensitometer at KPNO, reduced them with a standard H-D curve derived from spot plates, and obtained intensity tracings for each spectrum. The differences in the H-D curves of plates from different batches and with different exposure times is small so that one H-D curve for the IIIa-J and one for the IIa-O plates was deemed adequate for most of the spectra for the purpose of identifying the presence of the Tc lines.

III. ANALYSIS

The resonance lines of Tc I are located at 4297.06, 4262.27, and 4238.19 Å, with intensity ratios of 5:4:3. Due to the crowding of the lines in late-type spectra, we find the spectral resolution we used to be marginal for separating weak Tc lines from the nearby blends, except for our 4 m IIIa-J echelle plates. Each of the Tc lines is near other blending features. In particular, the strongest line (4297) tends to be blended with a combination of a Ce II line, the Raie Ultime of Sm I and a weak Zr II line. This "blend" has an average wavelength of about 4296.7 Å. Since the *s*-process elements Ce, Sm, and Zr strengthen as Tc strengthens, we tend to find the central wavelength of the 4297 line to be shifted to approximately 4296.9 Å for a roughly equal contribution to the observed feature of the Tc line and the blend. Only in a few cases is the Tc line so strong as to dominate the feature so that only a negligible shift from the 4297.06 Å position is observed. The observed wavelength minimum of the 4297 feature is listed in column 11 of Table I. In a few of the warmer M stars we attributed a 4297.06 Å feature to Cr I (64) after checking for the other lines of the multiplet when we observed no corresponding features at the positions of the two weaker Tc lines. Despite the blending problems, we found the 4297 line to be our best indicator of Tc since the Cr I (64) line could be eliminated as a contributor relatively easily and the 4262 line is badly blended in the cooler stars. For a complete list of blending agents that affect the Tc lines, see Table III of Paper I.

Our analysis proceeded by fitting a dispersion solution through up to 30 photospheric absorption lines in the 4150–4350 Å region. This allowed us to calculate the wavelength of any feature with a typical accuracy of ± 0.05 Å. We then calculated the line centers of features near the Tc lines, checked all possible blending contributors, checked the relative intensities of all three Tc lines, and assigned a likelihood for the presence of Tc in the spectrum, which is listed in column 12 of Table I. The definitions are the same as in Paper I, as follows.

(1) **yes.** All three Tc lines are strong, in the correct intensity ratio, and a negligible shift in the central wavelength of the features is observed.

(2) **probable** (abbreviated as prob). The 4297 Tc line is blended with an approximately equally strong feature of Sm I, Ce II (and Zr II) so that the central wavelength of the observed feature is around 4296.90 ± 0.1 Å. The 4262 and 4238 lines are also blended and/or too weak to make the identification definite. In a few cases, the observed central wavelength is around 4296.7 Å, but the observed feature is distinctly asymmetric with a contributor estimated to be at ~4297.06. These cases are listed in the Remarks (column 14).

(3) **possible** (poss). The Tc lines are weak and badly blended, but features are located near all three Tc lines. In our judgment the evidence favors the presence of Tc.

(4) **doubtful** (dbfl). Any lines present at the Tc I positions are too weak or too badly blended to be identified with Tc even though features are present near the Tc lines. In our judgment the evidence favors the absence of Tc.

(5) **no.** No features are present that can be attributed to Tc.

Table I summarizes the results of the present survey, of Paper I, and of other investigators. The stars are listed in alphabetical order by the abbreviated name of the constellation. Column 3 gives the spectral class as listed in the fourth edition (Kholopov 1985) of the *General Catalog of Variable Stars* (GCVS) for the constellations Andromeda through Orion, and from the third edition (Kukarkin 1969) for Pegasus through Vulpecula for which the fourth edition is not yet available. The Remarks column (14) lists the spectral class from the *Bright Star Catalogue* (BSC) (Hoffleit and Jaschek 1982) if different from the GCVS. In a few cases we list other spectral classes in the Remarks if we felt they were especially relevant to our analysis. Column 4 lists the average spectral class observed at maximum (Keenan, Garrison, and Deutsch 1974). Columns 5, 6, and 7 list the variability type, the period, and the asymmetry in the light curve (defined as time of $[(\text{maximum} - \text{minimum})/P] \times 100$) from the GCVS, where a value of 50 indicates a symmetric light curve. Column 8 lists the radial velocity of the stars as given by Keenan, Garrison, and Deutsch (1974), Abt and Biggs (1972), Wilson (1953), Wallerstein and Fawley (1980), or Barbier-Brossat and Petit (1986). Column 9 contains coded information about H_2O, OH, and SiO stellar

TABLE I. Stars searched for technetium.

No (1)	Name (2)	Sp. Class(GCVS) (3)	<Sp.Cl> (4)	Var (5)	P (6)	f (7)	Vr (8)	Maser (10)	Int (11)	Wave (12)	Tc (13)	Ref (14)	Remarks (15)
1	R And	S3,5e-S8,8e(M7e)	S4,6	M	409	38	-11	XXX	4.5		yes	a,m,r	
2	W And	S6,1e-S9,2e/M4-M10	S8,2	M	396	42	-29	XXS	4	97.06	yes	b	
3	Y And	M3e-M4.5e	M3	M	221	48	- 7	X--		96.77	no	a	
4	Theta Aps	M6.5 III		SRb	119		+10			96.80	no	a	=BS 5261
5	R Aql	M5e-M9e	M6.5	M	284	42	+32	HOS		96.89	dbfl	a,b	period variable
6	RR Aql	M6e-M9	M7	M	395	47	+17	HOS	1	96.91	poss	b	
7	RT Aql	M6e-M8e(S)	M7	M	327	42	-41	HOS		96.75	no	b	
8	SY Aql	M5e-M7e	M6	M	356	37	-68	HOS		96.86	no	a	
9	V915 Aql	S5,2-S7,2		Lb					>5	97.10	yes	a	
10	R Aqr	M5e-M8.5e + pec	M7	M	387	42	-22	XXS	2	97.02	prob	b	Symbiotic star
11	S Aqr	M4e-M6e	M5.5	M	279	39	-58	X-X		96.84	dbfl	a	
12	T Aqr	M2e-M5.5e	M3	M	202	48	-39	X-X		97.46	no	b	
13	W Aqr	M6-M8e		M	381	42	-15	XXS	1.5	96.89	poss	a	
14	X Aqr	S6,3e:(M4e-M6.5e)		M	312	42	+10	X-X	2	96.86	prob	a,b	shows definte blend at 97.10 Ref (b) Tc=no; Sp.Cl. prob MS
15	T Ari	M6e-M8e	M6	SRa	317	49	+ 7	XXS		96.71	dbfl	b	Period and amplitude vary
16	R Aur	M6.5e-M9.5e	M6.5	M	458	51	+ 8	XXS	3	96.92	prob	a,kk	
17	U Aur	M7e-M9e	M7	M	408	39	+15	HXS		96.83	dbfl	a,b	
18	UU Aur	C5,3-C7,4(N3)		SRb	234		+12	XXX			no	p	
19	UV Aur	C6,2-C8,2Jep(Ne)		M	394		- 6	-X-		97.00	yes	a	Tc strong; C star with [NeIII] and [O III] emiss; Mass > $4M_{\odot}$
20	VX Aur	M4e-M6		M	322	43	+24	X--		96.8	no	a	
21	NO Aur	M2SIab		Lc			+ 6	-X-		96.77	no	a	=BS 1939, BSC: M2IIIS
22	Psi 1 Aur	K5-M0 Iab-Ib		Lc			+ 5	-X-		96.69	dbfl	a	=BS 2289
23	R Boo	M3e-M8e	M4.5	M	223	46	-58	HXX		96.92	no	a,b	
24	S Boo	M3e-M6e	M5.5	M	271	44	-17	XXX		96.91	dbfl	a	
25	V Boo	M6e	M5.5	SRa	258	49	-38	XXX	1.5	96.98	prob	b	
26	W Boo	M2-4III		SRb	450:		+ 6	--X		96.82	dbfl	a	=BS 5490, BSC: M3III
27	RV Boo	M5e-M7e		SRb	137	50	- 3	XXX		96.88	dbfl	b	
28	BY Boo	M4-4.5III		Lb:			-36	---		96.80	dbfl	a,tt	=BS 5299, BSC: M4III.
29	CF Boo	M2IIIab		Lb			-13	---		96.75	dbfl	a	=BS 5300, BSC: M1.5III
30	T Cam	S4,7e-S8.5,8e	S5,7	M	373	47	- 2	X-X	(1.5)	97.06	yes	a,b	
31	AA Cam	M5(S)		Lb			-52	---	2.5	96.98	prob	a	
32	BD Cam	S5,3 (M4III)		Lb			-22	---		96.86	dbfl	a,h,m,p,t	=BS 1105, BSC:S3.5/2, SB, poss. WD companion.
33	Zeta Cap	G4Ib(K0-Ba3)		NV			+ 3	---			no	c,w,x	=BS 8204; BSC: G4Ib; no Tc II (2600A)
34	S Car	K5e-M6e	M0	M	149	51	286	-X-		96.74	no	a	
35	BO Car	M4Ib		Lc			- 1	XX-		96.71	dbfl	a	
36	R Cas	M6e-M10e	M7	M	430	40	+21	HOS	1-	96.87	poss	b,l	
37	T Cas	M6e-M9.0e	M7.5	M	445	56	-12	XXS	(2.5)	96.83	prob	b	ZrO(.93 um), prob S, ref(vt)
38	U Cas	S3,5e-S8,6e	S4.5	M	277	44	-45	X-X	3		yes	m	
39	V Cas	M5e-M8.5e	M5.5	M	229	48	-31	XXX	0.5	96.83	poss	b	line asymmetric at 97.06
40	R Cen	M4e-M8IIe	M4.5	M	546		-24	HXX		---	no	a	has a double maximum
41	T Cen	K0:e-M4II:e	K5	SRa	90	47	+28	---		96.99	dbfl	a	prob. blend with CrI(64)
42	V396 Cen	M4Ia-Iab-M6		Lc:				XX-		96.68	no	a	
43	V806 Cen	M5III		SRb	12:		+41	---		96.84	dbfl	a	=2 Cen=BS 5192.
44	T Cep	M5.5e-M8.8e	M6.5	M	388	54	-13	XXS	(1.5)	96.95	yes	b,q,kk	ZrO(.93 um), prob MS, ref(vt)
45	VV Cep	M2epIa-Iab +B8		SRc			-19	XX-		---	no	a	=BS 8383, BSC:M2Iaep+B8Ve
46	MO Cep	M5 III		Lb:			- 4	---		96.97	dbfl	a	=18 Cep=BS 8416, BSC:M5IIIab
47	MU Cep	M2e Ia		SRc	730	33	+19	XXX		96.83	no	a,b	
48	R Cet	M4e-M9	M4.5	M	166	43	+42	HOS		96.69	no	a	
49	T Cet	M5-6S IIe		SRc	159		+ 9	XXX	2+	96.89	prob	b,r	= BS 85; BSC: M5IIe
50	U Cet	M2e-M6e	M4	M	235	44	-27	HX-		96.95	dbfl	b	
51	W Cet	S6,3e-S9,2e	S6	M	351	51	+13	X-X	4	97.06	yes	a	
52	X Cet	M2e(S)-M6e	M3	M	177	49	+59	X--		96.90	dbfl	a	

TABLE I. (continued)

No (1)	Name (2)	Sp. Class(GCVS) (3)	<Sp.Cl> (4)	Var (5)	P (6)	f (7)	Vr (8)	Maser (10)	Int (11)	Wave (12)	Tc (13)	Ref (14)	Remarks (15)
53	AR Cet	M3III		SR:			+ 6	---		96.76	no	a	=BS 587
54	Alpha Cet	M2 III		Lb:			-26	X-X		96.87	no	b	=BS 911; BSC: M1.5IIIa
55	omic. Cet	M5e-M9e	M5.5	M	332	38	+64	HOS		97.01	yes	a,b,i,m,l	=Mira=BS 681; BSC:M7IIIe, VB no ZrO(.93 um), ref(vt)
56	Delta Cha	KOIII					+11			96.70	no	a	=BS 4231
57	Alpha CMa	A1Vm		NV			- 8	---			no	e	SB.
58	Sigma CMa	K7 Ib		Lc			+22	XX-		96.72	no	a	=BS 2646
59	R CMi	C7,1Je(CSep)		M	338	48	+48	X--	4-	97.12	yes	a,b	
60	S CMi	M6e-M8e	M7	M	333	49	+55	XXS	2.5	96.95	prob	a	
61	U CMi	M4e		M	414	52	+42	XX-		96.59	no	a	
62	V CMi	M4e-M10	M6.5	M	366	39	+37	XXX	3	97.03	yes	a	
63	R Cnc	M6e-M9e	M6.5	M	362	47	+32	HXS	var.	96.80	poss	a,b	line intensity varies (5 spectra) no ZrO(.93 um), ref (vt)
64	V Cnc	S0e-S7,9e	S1	M	272	46	- 1	X-X		96.72	dbfl	a	
65	X Cnc	C5,4(N3)		SRb	195:		- 1	X-X		---	no	b	=BS 3541, BSC: C6II
66	RR Cnc	M3e		M	298		+17	XX-		97.82	no	a	
67	RS Cnc	M6e Ib-II(S)		SRc	120:		+14	XXX	3	97.06	yes	b,p,r,t	=BS 3639, BSC:M6IIIaSe, also listed as Lb, <m> varies with P=1700 d
68	R Col	M3e-M7		M	328	39	+57	XXX	2	97.04	yes	a	
69	T Col	M3e-M6e	M5	M	226	50	+67	X-S		96.71	no	a	
70	R Com	M5e-M8ep	M6	M	363	38	- 3	HOS		96.87	dbfl	a	
71	S CrB	M6e-M8e	M6.5	M	360		- 1	HOS	1	97.06	poss	a	
72	W CrB	M2e-M5e	M4.5	M	238	45	+20	XXX		96.75	dbfl	a	
73	X CrB	M5e-M7e	M6	M	241	46	-104	X--		96.84	no	a	
74	Gamma Cru	M3.5 III		var?			+21			96.84	dbfl	a	=BS 4763/64
75	R Crv	M4.5e-M9:e	M5	M	317	41	-22	XX-	1-	96.89	poss	b	
76	R CVn	M5.5e-M9e	M6.5	M	329	46	- 6	XXS		96.80	dbfl	b	
77	V CVn	M4e-M6e IIIa:		SRa	192	50	- 2	HOX		96.90	dbfl	b	
78	Y CVn	C5,4J(N3)		SRb	157		+12	X-X			no	p	
79	TU CVn	M5 III		SRb	50		-17	X--	1.5	96.90	prob	b,kk	
80	2 CVn	M1 III + F7 V		NV			-14	---		97.04	no	a	=BS 4666
81	R Cyg	S2.5,9e-S6,9e(Tc)	S3	M	426	35	-25	XXX	3		yes	m	
82	U Cyg	C7,2e-C9,2(Npe)		M	463	48	+14	X-X	4	97.13	prob	a	
83	W Cyg	M4e-M6e(Tc:)III		SRb	131	5	-14	XXX	2-	96.92	prob	b,kk	=BS 8262, BSC: M5IIIae
84	RS Cyg	C8,2e(NOpe)		SRa	417		-52	---	3:	96.89	prob	a	
85	RT Cyg	M2e-M8.8e Ib	M3	M	190	44	-117	XXX		96.98	dbfl	a,b	
86	RU Cyg	M6e-M8e		SRa	233	5	- 5	XXX	(1)	97.01	prob	b	
87	TW Cyg	M6.5-M10ep		M	341	48	-48	XX-	1	96.90	poss	a	
88	AA Cyg	S7,5-S7.5,6(MpTc)		SRb	213			--X	4		yes	m	Var. type also given as Lb.
89	AF Cyg	M5e-M7		SRb	93		-15	X-X		96.82	no	b	
90	CY Cyg	CS(M2p)		Lb			+ 4				yes	u	
91	V460 Cyg	C6,4(N1)		SRb	180:		+10	---			yes	p	=DS Peg=BS 8297, BSC: C6,3.
92	V973 Cyg	M3IIIa		SRb	40:		-97	---		96.84	dbfl	a	=BS 7523, BSC: M3III
93	V1351 Cyg	M5IIIa		Lb			-28	---		96.86	dbfl	a	=BS 7509
94	Chi Cyg	S6,2e-S10,4e(MSe)	S7	M	408	41	- 2	XXS	3	97.05	yes	a,b,i,l,m	=BS 7564, BSC:S6+/1e,
95	R Del	M5e-M6e	M6-	M	285	45	-46	XXX		96.67	no	b	
96	T Del	M3e-M6e		M	332	45	-20	XX-	1.5	96.88	poss	a	
97	Z Del	S5,2.5e-S7,2e:	S5	M	304	48	+34	X-X	1		yes	m	
98	EU Del	M6.4III		SRb	60		-66	XX-		96.73	dbfl	a	=BS 7886, BSC: M6IIIFe-1
99	R Dra	M5e-M9e III	M5	M	246	45	-133	HXX		96.6	dbfl	a,b	
100	UX Dra	C7,3(NO)		SRa	168	5	+ 6	--X		96.97	yes	k,r	
101	CU Dra	M3III		Lb:			-11	---		96.81	dbfl	a,t	=10 Dra=BS 5226, BSC: M3.5III
102	T Eri	M3e-M5e	M4	M	252	45	+42	XX-		96.81	no	a	
103	U Eri	M4e	M4	M	275	49	-35	X--		96.88	no	a	
104	Z Eri	M4 III		SRb	80		-14	X-X		96.83	no	b	
105	RR Eri	M5 III		SRb	97		-11	X--			no	r	
106	DV Eri	M3 III		Lb:			-12	---		96.81	dbfl	a	=47 Eri=BS 1451
107	R Gem	S2,9e-S8,9e(Tc)	S3	M	370	36	-41	XXX	5		yes	m	
108	T Gem	S1.5,5e-S9,5e	S2.5	M	288	50	+22	X-X	4	97.07	yes	a	
109	V Gem	M4(S)e-M8	M4.5	M	275	45	+22	X--	3	97.10	yes	a	

TABLE I. (continued)

No (1)	Name (2)	Sp. Class(GCVS) (3)	<Sp.Cl> (4)	Var (5)	P (6)	f (7)	Vr (8)	Maser (10)	Int (11)	Wave (12)	Tc (13)	Ref (14)	Remarks (15)
110	X Gem	M5e-M8e(Tc:)	M6	M	264	49	+35	XXS	1.5	96.90	poss	a,b	
111	TV Gem	K5.5-M1.3Iab		SRc	182		+17	XO-		96.70	no	a	=BS 2190, BSC: M0-1 Iab
112	BU Gem	M1-M2 Ia-Iab		Lc			+22	-XX		96.81	no	a	=BS 2197, BSC: M1-2 Ia-Iab
113	NZ Gem	M3II-IIIS		SR			-16	---		96.97	dbfl	b	=BS 2967, BSC: M3 II-III.
114	Eta Gem	M3 IIIab		SRa	233	5	+19	X--		----	no	a,tt	=BS 2216, BSC: M3III
115	Mu Gem	M3.0IIIab		Lb			+55	XX-		96.84	dbfl	a,t	=BS 2286, BSC: M3IIIab
116	S Gru	M8 IIIe		M	402				4+	97.03	yes	a	
117	Beta Gru	M5 III		Lc			+ 2			96.81	dbfl	a	=BS 8636, BSC: also M5 II
118	Del 2 Gru	M4.5 IIIa		Lb:			+ 2	---		96.78	dbfl	a	=BS 8560
119	Pi 1 Gru	S5,7e		SRb	150:		-20	---	7		yes	a,s	=BS 852!, BSC: S5: To strong P variable
120	S Her	M4,Se-M7.5,Se	M5S	M	318	47	-10	X-X	2	97.00	yes	b	
121	T Her	M2.5e-M8e	M4	M	165	47	-122	X-X		97.03	dbfl	a	
122	U Her	M6.5e-M9.5e	M7	M	406	40	-28	HOS		96.81	dbfl	b	
123	X Her	M6e		SRb	95		-92	XXX		96.86	dbfl	b	
124	RU Her	M6e-M9	M7	M	485	43	-25	XXS	1+	96.95	prob	b	
125	RZ Her	M5e-M6e	M5	M	329	44	+38	X--	2	96.86	prob	a	
126	ST Her	M6-7 IIIaS		SRb	148		-29	X--	3.5	96.92	prob	a,p	
127	SV Her	M5e		M	239	46	-32	X--		----	no	a	
128	SY Her	M1e-M6e	M2.5	M	117	49	+33	X--		96.82	dbfl	a	
129	UV Her	M6e-M6.5e	M6	M	342	44	+ 0	-XX		96.85	dbfl	b	
130	CF Her	M0		M	306	46		X--		97.11	dbfl	a	
131	LQ Her	M4IIIa		Lb:			-25	---		96.84	dbfl	a	=10 Her= BS 6039, BSC: M4.5IIIa
132	OP Her	M5 IIb-IIIa(S)		SRb	121		+13	---	2	97.07	prob	a,r,t	=BS 6702, Ref (t): Tc=yes
133	Alf 1 Her	M5 Ib-II		SRc			-33	XXX		96.85	no	b,r	=BS 6406
134	2 Her	M3 III Ba 0.3		NV?			-10	---		96.85	no	a	=BS 5932
135	g Her	M6 III		SRb	89		+ 3	XXX		96.75	no	b,i,r,tt	=30 Her=BS 6146
136	R Hor	M5e-M8e II-III	M6.5	M	408		+60	HOS	5	97.05	yes	a	=BS 868, BSC: M7IIIe
137	R Hya	M6e-M9e S (Tc)	M6.5	M	389	49	-10	HOS	1.5	96.92	prob	a,b,l,m,r	=BS 5080 BSC: M7IIIe. P var.
138	T Hya	M3e-M9:e	M4	M	299	49	- 3	XXX	1	97.00	prob	a	
139	U Hya	C6.5,3(N2)(Tc)		SRb	450:		-25	X-X			yes	p,r	
140	W Hya	M7.5e-M9ep	M8	SRa	361	50	+42	HOS	2	96.89	prob	b	
141	X Hya	M7e-M8.5e	M7.5	M	301	42	+42	HOS		96.89	dbfl	a	
142	RR Hya	M3.0e-M8e		M	343	50	+33	X--	4	97.06	yes	a	
143	RT Hya	M6e-M8e		SRb	290	46	+40	XX-	(1.5)	97.06	prob	b	
144	RU Hya	M6e-M8.8e	M6.5	M	332	35	+ 2	HOX	0.5	96.84	poss	a	
145	T Ind	C7,2		SRb	320:		+ 2		4	97.06	yes	a	=BS 8145, BSC: C5 II
146	S Lac	M4e-M8.2e	M5.5	M	242	46	-61	X-X		96.66	no	b	
147	R Leo	M6e-M9.5 IIIe	M7	M	310	43	+13	HOS		96.81	dbfl	b,l,m,r	Ref(l):Tc v. weak, BSC:M8IIIe
148	DE Leo	M2IIIabS		SRb			-20	X--		96.87	dbfl	a,t	=44 Leo= BS 4088, BSC: M3IIIabS prob. + Cr(I) 64
149	T Lep	M6e-M9e		M	368	47	-18	HXS		96.75	dbfl	a	
150	RX Lep	M6.2III		SRb	60:		+46	XX-		96.87	dbfl	a	=BS 1693, BSC: M6III
151	RR Lib	M4e-M8e	M4	M	277	47	-33	X--		96.81	no	b	
152	RS Lib	M7e-M8.5e	M7	M	218	48	+ 9	XXS		96.83	dbfl	b	
153	RT Lib	M2.5pe-M8.2e	M4	M	251	45	+41	-X-		----	dbfl	b	
154	Sigma Lib	M3.5 IIIa		SRb			- 4	X-X		96.88	dbfl	a,b	=BS 5603, BSC:M3IIIa
155	R LMi	M6.5e-M9.0e(Tc:)	M7	M	372	41	+10	HOS	1	96.81	poss	b	no ZrO (.93 um), ref (vt)
156	S LMi	M2.0e-M8.2e	M5	M	234	42	- 2	HX-		97.00	dbfl	a	
157	S Lup	Se		M	340		-41		>5	97.04	yes	a	VB
158	Y Lyn	M6SIb-II		SRc	110		+ 7	XX-	3	96.90	prob	a	
159	R Lyr	M5 III		SRb	46:		-28	XOX		96.90	dbfl	a,b,i	=BS 7157, Ref (i) Tc=no
160	V Lyr	M7e		M	374	33	-22	XOX	1	96.93	poss	b	
161	XY Lyr	M4-5 Ib-II		Lc			-19	XX-		62.43	no	a,r	=BS 7009, BSC: M4-5II
162	Alpha Lyr	A0 Va		DSc	.19		-14	---			no	e	=BS 7001, BSC: DSctc variable
163	Del 2 Lyr	M4II		SRc			-26	X--		97.08	dbfl	a	=BS 7139
164	T Mic	M6e		SRb	347		+18	XXX		96.81	poss	a,b	
165	V Mon	M5e-M8e	M5	M	341	46	+24	XXS	3.5	96.96	prob	a	
166	X Mon	M1eIII-M6ep	M3	SRa	156	51	+162	X-X		96.75	dbfl	a	
167	U Oct	M4e-M6 II-IIIe		M	308					96.69	no	a	

TABLE I. (continued)

No (1)	Name (2)		Sp. Class(GCVS) (3)	<Sp.Cl> (4)	Var (5)	P (6)	f (7)	Vr (8)	Maser (10)	Int (11)	Wave (12)	Tc (13)	Ref (14)	Remarks (15)
168	R	Oph	M4e-M6e	M5	M	307	45	-47	XXS		96.76	no	a,b	P variable
169	X	Oph	M5e-M9e	M6.5	M	329	53	-71	HXS	2	96.86	poss	a,b	=BS 7002, BSC: (K1III+M6IIIe) BSC: Mass=15.9Mo+5 Mo, but typical K III star has Mass about 1 Mo
170	Z	Oph	K3ep-M7.5e	K3	M	349	40	-78	-XX		96.86	dbfl	b	
171	RR	Oph	M3e-M7	M4.5	M	292	46	+60	X--		97.25	dbfl	a	
172	RY	Oph	M3e-M6e	M4.5	M	150	46	-56	XX-		96.95	no	a	
173	S	Ori	M6.5e-M9.5e	M7	M	414	48	+22	XXS		96.94	dbfl	a	
174	U	Ori	M6e-M9.5e	M6.5	M	368	38	-21	HOS	1-	97.02	poss	a	=BS 2063, BSC:M6.5IIIe, Tc wk feature in wing of str. line at 4296.70
175	BL	Ori	C6,3(Nb,Tc)		Lb			+13	---			yes	p	
176	Alf	Ori	M1-M2Ia-Ibe		SRc	2335		+21	XXX		96.79	no	a	=BS 2061, BSC: M1-2Ia-Iab
177	ò 1	Ori	M3.2IIIaS		SRb	30:		- 8	---	1+	96.99	prob	a,b,t, kk	=BS 1556 ,BSC: S3.5/1-, also S4Zr1Ti4 WD companion
178	S	Peg	M5e-M8e	M6.5	M	319	47	+ 3	XXX		96.90	dbfl	a	
179	T	Peg	M6e-M7e		M	374	49	-24	XX-	3	96.97	prob	a	
180	X	Peg	M2e-M5e	M4	M	201	49	-56	X--		62.39	no	a	no 4297 section
181	Z	Peg	M6e-M8e	M7	M	325	50	-31	XX-	4+	97.06	yes	b	
182	RV	Peg	M6e		M	389	38	-46	XOS	3	96.92	poss	a	
183	RZ	Peg	C9e;CS		M	439	44	-27	---			yes	o	
184	SW	Peg	M4e		M	396			-X-	3	96.92	prob	a	
185	TU	Peg	M7e-M8e	M7	M	322		+ 9	HXS		96.86	dbfl	a	
186	TW	Peg	M6-M7		SR	956		-27	HOX		96.77	dbfl	a	Small oscil. with P of 90d on P of 956d
187	GZ	Peg	M4IIIS + A2V		Lb?			+14	X--		97.07	dbfl	a,b,p	=57 Peg=BS 8815, primary Mass>5 Mo
188	HR	Peg	S4+/1+			50:		+11	X--	1.5	96.96	prob	b,p,t	=BS 8714, Ref(p):Tc=no
189	Beta	Peg	M2.5II-III		Lb			+ 9	---		96.80	no	b,h,i,tt	=BS 8775, Sp.Cl from BSC
190	U	Per	M6e-M7e	M5.5	M	321	46	+19	XXX	3-	96.98	prob	b,h	
191	RR	Per	M6e-M7e	M6	M	390	45	+ 9	XOX	0.5	96.85	poss	a	
192	SU	Per	M3.5 Iab		SRc	470		-39	XXX		96.85	dbfl	a	
193	AD	Per	M2-M3Iab		SRc	320		-45	-X-		97.03	dbfl	a	
194	FZ	Per	M1vIab		Lc	184		-48	-X-		96.74	dbfl	a	
195	KK	Per	M1.0-M3.5Ib		Lc			-42	-X-		96.78	dbfl	a	
196	PR	Per	K5eIb-M2Ib		Lc			-39	---		96.81	dbfl	a	
197	Rho	Per	M4 IIb-IIIa		SRb	50:		+28	XXX		96.74	dbfl	b,pp,t	=BS 921, BSC:M4II, asym. at 97.03 prob. Cr I(64)
198	R	Psc	M3e-M6e	M5	M	344	44	-48	XX-	1.5	96.86	prob	a	
199	TV	Psc	M3 III		SR	49	49	+ 6	XXX		96.91	dbfl	b	=BS 103, BSC:M3IIIv, Hyades group
200	TX	Psc	C6,2(NO)		Lb			+11	X-X	2-3		yes	p	=19 Psc=BS 9004, BSC: C5 II
201	Z	Pup	M4e-M9e	M5	M	510	38	+26	HOS		96.87	dbfl	a	
202	KQ	Pup	M2epIab +B2V					+22	-X-		96.77	dbfl	a	=BS 2902, VV Cep or symbiotic, shell spectrum
203	L 2	Pup	M5e-M6e		SRb	140	40	+53	HOS			prob	a	=BS 2748, BSC: M5IIIe
204	S	Scl	M3e-M8e	M6	M	365	48	+35	HXX	1.5	96.83	prob	b,g	
205	RR	Sco	M6II-IIIe-M8IIe	M6	M	280	47	-36	XXS		96.79	no	a,b	
206	RZ	Sco	M3e-M4e	M4	M	160	45	-174	H--		---	no	a	
207	AH	Sco	M5Ia-Iab		SRa	714	46	-14	HOS		96.97	dbfl	a	Sp. Cl. from Humphreys and Ney(1974)
208	Alf	Sco	M1.5Iab-Ib + B4Ve		SRa	1733		- 3	-XX		96.87	dbfl	b	=BS 6134, Sp. Cl. from BSC
209	R	Ser	M5e-M9e	M6.5	M	356	41	+24	HXS	2.5	97.02	yes	a,b,i	=BS 5894, BSC: M7IIIe prob ZrO (.93 um), ref (vv)
210	U	Ser	M4e:-M6e	M4	M	238	47	-31	-X-	2	96.89	poss	a,b	
211	FS	Ser	M3.5IIIa					-22	---		96.83	dbfl	a	=47 Ser=BS 6010; amp =0.04V
212	Tau 4	Ser	M5 IIb-IIIa		Lb			+ 4	X-X		96.82	dbfl	a,r	
213	16	Ser	K1-Ba1		NV			+ 8	---			no	x	=BS 5802, BSC: KOIII:CN1Ba0.7Sr2
214	Delta	Sge	M2 II + AO V		var			+3			96.74	no	a	=BS 7536, SBO
215	R	Sgr	M4e-M6e	M4.5	M	269	46	-45	XXX		96.82	no	b	
216	T	Sgr	S4.5,8e-S5.5,8e	S4.5	M	392	47	+ 3	--X	3		yes	m	
217	Z	Sgr	M4e-M6(Se)	M5	M	450	47	-21	XXX	1.5	96.96	prob	a	
218	RR	Sgr	M5e-M6e	M6	M	334	43	+85	HOS	2.5	97.01	prob	a	misprinted as Vr=-21 (Ap.J.Supp.,28,271)
219	RT	Sgr	M5e-M7e		M	305	47	+35	XX-		96.84	dbfl	a	
220	RV	Sgr	M5e		M	318	47	+24	XX-	2.5	97.02	yes	a,b	

TABLE I. (continued)

No (1)	Name (2)	Sp. Class(GCVS) (3)	<Sp.Cl> (4)	Var (5)	P (6)	f (7)	Vr (8)	Maser (10)	Int (11)	Wave (12)	Tc (13)	Ref (14)	Remarks (15)
221	RX Sgr	M5e		M	334	49	-37	---	2	97.05	yes	a	
222	SZ Sgr	C5,2		SRb	100?		-34			97.06	prob	a	
223	TY Sgr	M3e		M	326	44		---	2	97.03	prob	a	
224	VX Sgr	M4e Ia-M8		SRb	732	44	0	HOS		---	dbfl	a	Sp. Cl. from Humphreys (1974)
225	R Tau	M5e-M9e	M6	M	324	41	+32	HOS	2	96.96	prob	a,b	
226	CE Tau	M2Ib		SRc	165		+23	XXX		96.71	dbfl	a	=119 Tau= BS 1845, BSC: M2Iab-Ib
227	X TrA	C5,5		Lb			- 4			96.96	prob	a	=BS 5644
228	R Tri	M3e-M8.5e	M4	M	266	44	+67	HXS		96.80	no	b,l,kk	Maehara (1971), Tc=yes
229	V1 47 Tuc	M4e		M	212		- 8			96.92	no	a	Vr=-17 emissiom
230	BQ Tuc	M4 III		Lb?			-10	---		96.80	no	a	=BS 257
231	Nu Tuc	Me III		var			- 3			96.80	no	a	=BS 8582
232	S UMa	S0.5,9e-S5,9e	S0.5	M	226	47	+ 8	--X	1		yes	m,u	
233	T UMa	M4e-M7e	M4	M	257	41	-91	HXX		96.82	no	b,l	Maehara (1971): Tc=yes
234	Z UMa	M5e III		SRb	196		-53	XXX			no	r	
235	RR UMa	M4e		M	231	43:	-49	X--		---	no	a	
236	RY UMa	M2-3e III		SRa	311		-12	---			no	r	
237	VY UMa	C6,3(NO)		Lb			- 5	X--			yes	p,kk	=BS 4195, BSC: C5II
238	83 UMa	M2IIIab Ba 0.7:		NV?			-17	---		96.83	no	a	
239	S UMi	M7e-M9e	M7	M	326	50	-40	XXS		96.82	dbfl	b	
240	RR UMi	M5III		SR?	40?		+ 7	X--		96.81	no	a	=BS 5589, Hyades group
241	Lam Vel	K4 Ib-II		Lc			+18	---		96.67	no	a	
242	R Vir	M3.5e-M8.5e	M4.5	M	146	50	-26	XXX		96.79	no	b	
243	S Vir	M6e-M9.5e	M6.5	M	377	45	+10	HXS	1.5	97.01	prob	b	
244	U Vir	M2e-M5.5e	M3.5	M	207	47	-46	XXX		96.8	dbfl	a	
245	RS Vir	M6e-M7e		M	353	37	-26	HOS		96.64	no	b	
246	SS Vir	Ne(C5,3e)		M	355	48	+ 4	X--		96.86	dbfl	a	
247	ET Vir	M2III-IIIa		SRb	80		+18	---		96.86	dbfl		=BS 5301, GCVS:gM3
248	R Vul	M3e-M7e	M4	M	136	49	-12	X--		96.80	no	b	
249	BS 363	S3+/2-		NV?			+ 2	---		96.80	no	a,b,cc,p,t	BSC:S3Zr1Ti3; SB
250	BS 774	G8-Ba3		NV			+18				no	v	BSC:G8p Ba.
251	BS 2508	M1 Ib-IIa		NV?			+24	---		96.81	dbfl	a	
252	BS 3842	K0-Ba1		NV			+ 3	---			no	x	BSC: G8II
253	BS 5058	K1-Ba3		NV			+67	---			no	x	BSC: K0.5III:Ba3; no TcII(2600A)
254	BS 7442	M4.5IIIaS		Var			-10	---		96.83	dbfl	a,t	
255	BS 8062	S4/1		NV			+ 1	---			yes	t	
256	HD 26	G8-Ba3p		NV			-211				no	x	
257	HD 16458	G8-Ba3		NV			+18	---			no	x	
258	HD 31487	K0-Ba2		NV				---			no	x	
259	HD 35155	S4,1		NV			+75	---			no	p	poss underluminous companion
260	HD 44986	K4-Ba8		NV			+51				no	v	
261	HD 46407	K0-Ba3		NV			-14	---			no	f,x	
262	HD 60197	K2IV-Ba4		NV			+51				no	v	
263	HD 77247	G8-Ba2		NV				---			no	x	
264	HD 84678	K2-Ba4		NV				---			no	x	
265	HD 92626	K0-Ba5		NV			+11	---			no	x	
266	HD 100503	M1-Ba9		NV			- 4				no	v	
267	HD 101013	K1-Ba3		NV			- 4	---			no	x	
268	HD 121447	K7-Ba5		NV			-14	---			no	v,x	
269	HD 165774	S4,6		NV						96.74	no	a	
270	HD 175674	K5-Ba1		NV			+ 9	---			no	x	
271	HD 176021	CH-subgiant		NV			+115	---			no	d	
272	HD 178717	K3II-Ba5		NV			+13	---			no	u,v,x	
273	HD 183915	K1-Ba2		NV			-45	---			no	x	
274	HD 191226	M2III		NV			-24	---		96.81	no	b	SB, Sp.Cl. Mikami (1978)
275	HD 196673	K0-Ba2		NV			-27	---			no	x	
276	HD 199394	G8-Ba1		NV			0	---			no	x	
277	HD 199939	K0-Ba4		NV			-33	---			no	x	
278	HD 211594	G8-Ba3p		NV			- 7	---			no	x	
279	CPD-64 4333	K0-Ba7.5		NV			+23				no	v	

Notes to TABLE I—Key to the references

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a) present study
b) Little-Marenin and Little (1979)
c) Boesgaard and Fesen (1974)
cc) Boesgard (1969)
d) Bond (1974)
e) Boyarchuk and Snow (1978)
f) Burbidge and Burbidge (1957)
g) Cohen (1973)
h) Davis (1968)
i) Dominy and Wallerstein (1986)
k) Hackos (1974)
kk) Kipper and Kipper (1984)
l) Maehara (1971)
m) Merrill (1952)
n) Merrill (1956)
o) Peery, Keenan, and Marenin (1971)
p) Peery (1971)
pp) Peery (1985)
q) Sanner (1977)
r) Sanner (1978)
s) Scalo (private communication)
tt) Smith and Lambert (1985)
t) Smith and Lambert (1986)
u) Smith and Wallerstein (1983)
v) Smith (1984)
vv) Spinrad and Newburn (1965)
vt) Spinrad et al. (1966)
w) Tech (1971)
x) Warner (1965)

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abundance analyses available for the stars listed under reference i,kk,t,tt,u,v masers found in the literature. A number of our stars were searched for H_2O emission by Benson *et al.* (1987). A positive detection of a maser is indicated as H (first position) for water, O (second position) for OH, and S (third position) for SiO. A dash (—) in the appropriate position means the star has not been searched, and X indicates that the star has been searched but has not been detected. A positive detection is listed in preference to a negative result if both cases are found in the literature. Column 10 lists our estimate of the depth of the 4297 line relative to the local continuum on a scale of 1 to 10. This is a very crude estimate of the intensity and should be interpreted with caution. Estimates in parentheses are from density tracings and do not have the same quality as those from intensity tracings. Column 11 gives the central wavelength of the observed 4297 feature. For XY Lyr and X Peg we list the wavelength of the 4262 feature as measured on 4 m archival echelle plates since the 4297 Å line was off the end of the order. Column 12 gives the likelihood for the presence of Tc. Column 13 gives references to Tc searches: (a) refers to stars analyzed for the present study, (b) to Paper I. Other references are keyed to a list at the end of the table. In the Remarks (column 14) we give the BS number (Hoffleit and Jaschek 1982) and the spectral class if different from the GCVS and other comments; SB indicates a spectroscopic binary and VB a visual binary as listed in the BSC. Since the variable star designation for a number of low-amplitude variables is not yet well established in the literature, we have listed in Table II all the stars with BS numbers and their corresponding variable star names.

TABLE II. Cross reference between BS numbers and variable star names.

BS	Star name
85	T Cet
103	TV Psc
257	BQ Tuc
587	AR Cet
681	o Cet
868	R Hor
911	α Cet
921	ρ Per
1105	BD Cam
1451	DV Eri = 47 Eri
1556	o^1 Ori
1693	RX Leo
1845	CE Tau = 119 Tau
1939	NO Aur
2061	α Ori
2063	U Ori
2190	TV Gem
2197	BV Gem
2216	η Gem
2286	μ Gem
2289	ψ^1 Aur
2646	σ CMa
2748	L^2 Pup
2902	KQ Pup
2967	NZ Gem
3541	X Cnc
3639	RS Cnc
3882	R Leo
4088	DE Leo = 44 Leo
4195	VY UMa
4231	δ Cha
4666	2 CVn
4763	γ Cru
5080	R Hya
5192	V806 Cen = 2 Cen
5226	CU Dra = 10 Dra
5261	θ Aps
5299	BY Boo
5300	CF Boo
5301	ET Vir
5490	W Boo
5589	RR UMi
5603	σ Lib
5644	X TrA
5802	16 Ser
5894	R Ser
5932	2 Her
6010	τ^4 Ser = 47 Ser
6039	LQ Her = 10 Her
6134	α Sco
6146	g Her = 30 Her
6406	α^1 Her
6702	OP Her
7001	α Lyr
7002	X Oph
7009	XY Lyr
7139	δ^2 Lyr
7157	R Lyr
7509	V1351 Cyg
7523	V973 Cyg
7536	δ Sge
7564	χ Cyg
7886	EU Del
8145	T Ind
8204	ζ Cap
8262	W Cyg
8292	V460 Cyg
8383	VV Cep
8416	MO Cep = 18 Cep
8521	π^1 Gru
8560	δ^2 Gru
8562	NU Tuc
8636	β Gru
8714	HR Peg
8775	β Peg
8815	GZ Peg = 57 Peg
9004	TX Psc = 19 Psc

IV. DISCUSSION

Table I lists the 279 stars that have been searched for Tc. The Ba II stars (25) show *s*-process enhancements that appear to be derived from the binary nature of the stars (McClure 1984). No Tc I lines have been detected in any Ba II star. However, Tc is expected to be primarily ionized in these higher-temperature stars. A search for the resonance lines of Tc II (2647, 2610, and 2543 Å) in ζ Cap, o Vir, and BS 5058 in *IUE* (*International Ultraviolet Explorer* satellite) spectra has also proved negative (Little-Marenin and Little 1987), implying that the *s*-process episode producing the observed enhancements occurred more than 10^6 yr ago, most likely by mass transfer from a companion. A subgiant, two A stars, and three K stars are excluded from the rest of the discussion since they do not show Tc lines and are not AGB stars. The remaining stars include 190 M stars (108 are Mira variables), 17 MS stars (five Miras), 24 S stars (15 Miras), three SC stars (two Miras), and 16 C stars (five Miras). We reach the following 12 general conclusions (exceptions will be discussed in subsec *c*).

a) General Conclusions

1) M stars

(1) Nonvariable (NV) M stars *do not show* Tc.

(2) M supergiants *do not show* Tc.

(3) Irregular variable (Lb) M giants *do not show* Tc. In general, these are low-amplitude variables (mean $\Delta m \sim 0.2$ mag).

(4) M star Mira variables tend to *show* the Tc I lines if their period is longer than 300 days. This confirms the main conclusion of Paper I. Subsection *b* contains a longer discussion of the Mira variables and the exceptions.

(5) The semiregular (SRb) M giants *do not show* Tc if

$P < 100$ days or $P > 150$ days (except for TU CVn—50 days, RT Hya—290 days, and T Mic—347 days). Only seven SRa's have been observed. In general the longer-period SRa's show Tc and the shorter-period ones do not (see Fig. 3). SRc variables are estimated to be supergiants and *do not show* Tc (see discussion on MS supergiants in subsec *c*).

(6) M stars *with Tc* have spectral types later than M2.

2) MS stars

(7) Evolutionary MS stars, as defined in subsec *c*, *show* Tc.

(8) Spectroscopic MS stars, as defined in subsec *c*, *do not show* Tc.

3) S stars

(9) Single S stars *show* Tc (usually quite strongly). The five stars, BS 363, HD 35155, HD 165774, BD Cam (BS 1105) and V Cnc, that do not show Tc are discussed in subsec *c*.

4) SC stars

(10) The three SC stars listed in Table I *show* the resonance lines of Tc. Table I does not include the two SC stars FU Mon and GP Ori, which *do not show* the Tc I intercombination line at 5924 Å (Dominy and Wallerstein 1986). This line is much weaker than the resonance lines we observed, and its absence does not preclude the presence of the resonance lines. Clearly, more SC stars should be searched for the Tc I resonance lines in order to establish whether all SC stars show the Tc I lines. We are not making a distinction between SC and CS stars in this paper.

5) C stars

(11) Twelve out of the 16 C stars (75%) *show* Tc. All four Lb C stars *show* Tc. The C star Lb's have larger amplitudes ($\Delta m \sim 1$ mag) than the M star Lb's mentioned in (3). The four C stars, SS Vir, UU Aur, X Cnc, and Y CVn, that do not show Tc are discussed in subsec *c*.

6) Masers

(12) Maser emission from H_2O, OH, and SiO shows no correlation with the presence of Tc.

b) The M Star Miras and Semiregular Variables

The main conclusion reached from this analysis is that the onset of the third dredge-up occurs in M stars on the AGB (as predicted by theory) and is accompanied by the onset and the continuation of variability. Nonvariable stars do not show Tc (with the exception of the S star BS 8062 (S4,1)); even the small-amplitude irregular (Lb, Lc) variables do not show Tc. For Miras the third dredge-up appears to correlate very strongly with period (Fig. 1).

In Figs. 1(b) and (c) we plot histograms of the Miras listed as having Tc-no or Tc-doubtful (b) and those with Tc-yes, Tc-probable, and Tc-possible (c). The periods are binned in 15 day intervals. Usually, only Miras with $P > \sim 300$ days show Tc (Fig. 1(c)). There are three exceptions: V Cas—229 days, U Ser—238 days and X Gem—264 days (Fig. 1(c)). However, all three are listed as Tc-possible, meaning that their Tc lines tended to be weak and blended. We will assume for the rest of the discussion that $P > 300$ days is the most realistic division for Miras with Tc.

The onset of the detectability of *s*-process products on the surface appears to be quite sharp, and the percent of stars

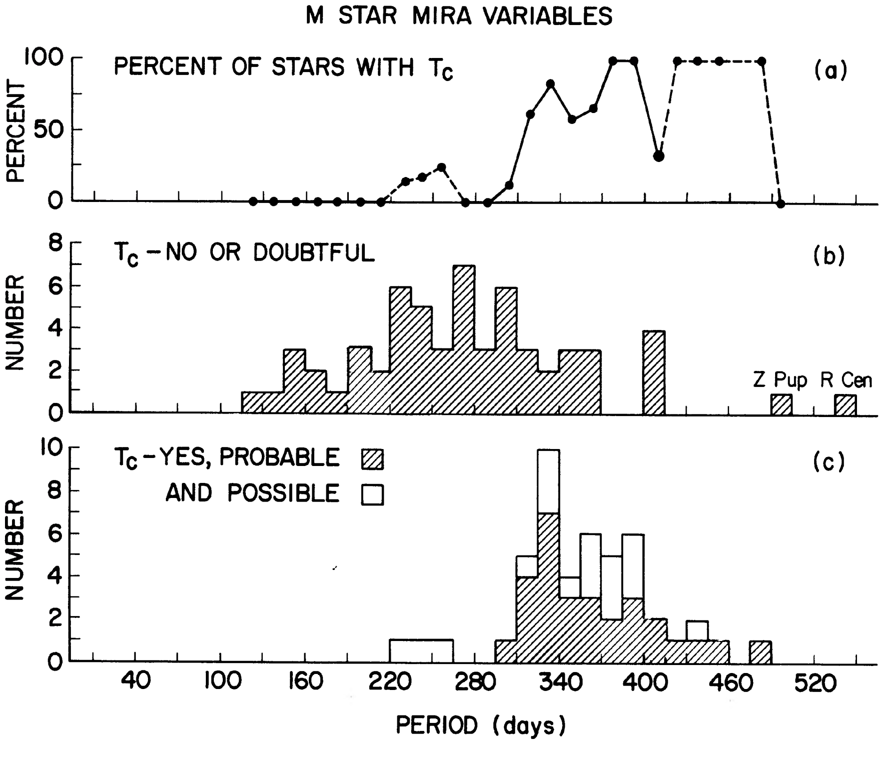

FIG. 1. Histogram of the M Mira variables versus period binned in 15 day intervals. The bottom panel (c) shows the stars with Tc present (Tc-yes or probably present) indicated as hatched areas and stars with Tc possibly present indicated as open areas. The middle panel (b) shows the stars with Tc-no or -doubtful. The top panel (a) plots the percent of stars with Tc. As can be seen, stars with Tc in general have $P > 300$ days.

with Tc rises rapidly for stars with $P > 300$ days, reaching 100% for Miras with periods between 370 and 400 days (Fig. 1(a)). We have been able to observe only 13 Miras with $P > 400$ days. Even though the statistics are poor, the trends are suggestive. Four out of the six stars with $400 < P < 415$ days (U CMi—414 days, S Ori—414 days, U Aur—408 days, U Her—406 days) *do not have* Tc, whereas the five stars with $415 < P < 490$ days (RU Her—485 days, R Aur—458 days, T Cas—445 days, R Cas—420 days, Z Sgr—420 days) *do show* Tc. The two stars with $P > 500$ days (R Cen—546 days, Z Pup—510 days) *do not show* Tc. R Cen, with alternating deep and shallow minima, may actually have a period of ~ 275 days as suggested previously. However, the light curve for Z Pup shows no such double structure (American Association of Variable Star Observers (AAVSO) 1983). If the true period of both stars were half their published value, then the lack of Tc would agree with the other stars we observed in the 260–280 day period range.

Miras form a fairly well-defined group. Kinematic studies of Miras have shown that the shorter-period Miras ($P \sim 150$–200 days) tend to be old (Pop. II), low-mass objects with masses around 1 $\mathscr{M}_\odot$, whereas the longer-period Miras ($P \sim 300$–400 days) are somewhat younger (intermediate Pop. I) with masses between 1.5 and 2.5 $\mathscr{M}_\odot$ (Feast 1963; Clayton and Feast 1969). The kinematic studies of C stars by Dean (1974) show that most C stars have F5 main-sequence progenitors with masses around 1.2$\mathscr{M}_\odot$. This agrees with the kinematic studies of the Pop. I Miras since M type AGB stars are predicted to develop into C stars.

In a given globular cluster, Miras tend to have a very limited range of periods, and the mean period increases with metallicity. This implies that Pop. II Miras of a given period form a homogeneous set of mass, age, and composition (Feast 1980). Not enough data are available about the Pop. I Miras to establish whether these stars also form a homogeneous set for a given period. The fact that both R Hya ($P = 388$ days Tc-yes) and RR Sco ($P = 280$ days, Tc-no) probably belong to the Hyades Supercluster (i.e., relatively young), and R Leo ($P = 312$ days, Tc-dbfl) and S Scl ($P = 366$ days, Tc-prob) are assigned to the old-disk moving groups Wolf 630 and 61 Cyg, respectively (Eggen 1970, 1975), argues against the same-age Pop. I stars having similar characteristics. Our data seem to indicate that Tc (and other *s*-process elements) is mixed with the outer layers, presumably during the third dredge-up in the 1.5–2.5 $\mathscr{M}_\odot$ Pop. I stars and not in older, lower-mass objects. The lack of Tc in V1 (47 Tuc) lends support to this conclusion. Our data do show that mixing occurs in higher-mass stars. For example, the carbon star UV Aur (Tc-yes) has a B8.5 V companion and hence should have a mass $> 4\mathscr{M}_\odot$. However, very few stars have individually determined masses.

Miras define a period-luminosity (*P-L*) relationship that is given by Glass and Lloyd Evans (1981) for the LMC Miras as

$$M_{\rm bol} = 0.56 - 2.09 \log P .$$

Using the slope of their LMC *P-L* relation, Glass and Lloyd Evans fit the galactic Mira data of Robertson and Feast (1981) with

$$M_{\rm bol} = 0.76(\pm 0.11) - 2.09 \log P .$$

There is a difference of 0.2 mag between the two *P-L* relationships which may be related to differences in metallicity between the LMC and the Milky Way and/or to uncertainties in the distance modulus of the LMC (Feast 1984). Using the galactic *P-L* relationship implies that Miras with observed Tc lines (i.e., P between 300 and 500 days) should have $M_{\rm bol}$ between -4.4 and -4.9. Hence our data seem to indicate that stars showing Tc I are Pop. I stars ($Z = 0.01$–0.02) that have experienced the third dredge-up with masses in the 1.5–2.5$\mathscr{M}_\odot$ range and luminosities in the 5–6×10^3 $L_\odot$ range. Current evolutionary models do not predict the third dredge-up in this mass, luminosity, and metallicity range (Iben 1983; Iben and Renzini 1983; Lattanzio 1986, 1987).

The Mira sequence can be extended to longer-period (500–1500 days) objects by including the Type II OH/IR sources. Since the mass-loss rates also increase towards the longer period, we find that these objects are heavily enshrouded in dust shells. The Type II OH/IR sources are strongly concentrated towards the galactic plane, and their masses are estimated to be > 4 $\mathscr{M}_\odot$. Theory predicts that they should be experiencing the third dredge-up. Unfortunately, the thick dust shells make it impossible to observe these stars for Tc. In general, we were able to observe only stars with optically thin dust shells, as estimated from *IRAS* low-resolution spectra and *IRAS* point-source fluxes for the stars in Table I. We find no correlation between the strength of the 10 μm silicate emission observed in the *IRAS* low-resolution spectra and the presence of Tc. With a few exceptions, such as R Cet, we were able to obtain spectra only of stars with relatively weak emission features in the 8–22 μm region, i.e., from optically thin shells.

Theory predicts that ^{12}C is brought to the surface during the third dredge-up with an accompanying increase in the ^{12}C/^{13}C ratio. Comparing our Tc data for Mira variables with the ^{12}C/^{13}C ratios determined from the second overtone of CO (Hinkle, unpublished), we find that $^{12}{\rm C}/^{13}{\rm C} \sim 8$ for the Miras with Tc-doubtful or Tc-no (only three stars), ~ 13 for the Miras with Tc-yes, Tc-probable, or Tc-possible (12 stars), ~ 33 for four MS Miras and ~ 55 for two S Miras. We included T Cas, T Cep, and χ Cyg among the MS stars (see discussion in subsec *c*). The difference in the ^{12}C/^{13}C ratio between the M Miras with and without Tc is small, but appears to be real (Fig. 2). Smith and Lambert (1985, 1986) found a similar trend in the ^{12}C/^{13}C ratio for their non-Mira M, MS, and S stars. However, their average ratio for the M stars with no *s*-process enhancements is about 14, similar to the value Hinkle obtains for the M Miras with Tc. More ^{12}C/^{13}C ratios for Miras without Tc would be very useful. An exception to the trend in the ^{12}C/^{13}C ratios is S Ori, a 414 day M star Mira with Tc-doubtful and a ^{12}C/^{13}C ratio of 40, typical of the MS stars.

The intensity of the 4297 Å Tc line does not correlate with period. Neither does the presence of Tc correlate with the asymmetry in the light curve (listed in Table I, column 7). Vardya (1985) suggests that the asymmetry is a measure of the strength of the shock and that the intensity of the 4297 Å line as listed in Paper I (marginally) correlates with the light-curve asymmetry for S stars. If the shock strength is related to thermal shell flashing, one might expect that Tc is more likely to be observed in stars with a more asymmetric light curve. However, the marginal correlation disappears with the addition of a few new S stars. For example, T Gem has a symmetric light curve ($f = 50$) and an intensity 4 Tc I line.

Figure 3 shows the distribution of the semiregular variables with known periods as a function of Tc. Two out of the three M star SRb's with periods between 130 and 141 days

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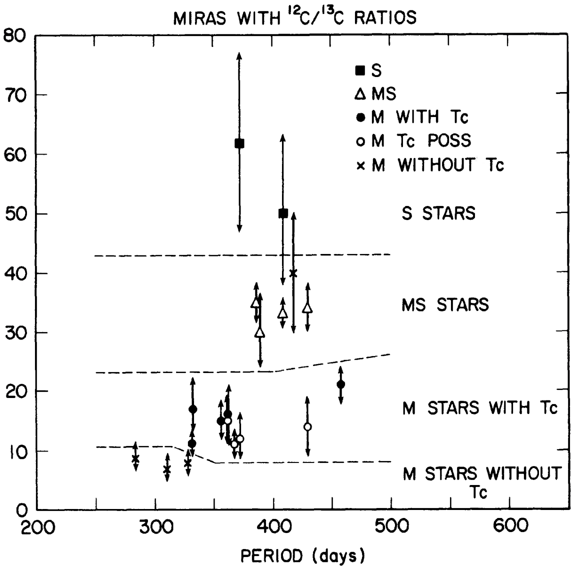

FIG. 2. The ^{12}C/^{13}C ratio (Hinkle, private communication) of M stars without Tc (crosses), M stars with Tc-probable and Tc-yes (dark circles), M stars with Tc-possible (light circles), MS stars (triangles), and S stars (squares).

show Tc (Fig. 3(b)). These two may be stars equivalent to Miras but pulsating in the first overtone rather than in the fundamental mode (Willson 1982). As can be seen in Fig. 3(b), the semiregular MS stars with Tc are also located in this region of the histogram and are also likely to be first-overtone pulsators. Two long-period SRb stars (RT Hya—290 days; T Mic—347 days) *show* Tc and may be related to the Miras, i.e, pulsating in the fundamental mode. However, the light curve of RT Hya shows the small amplitude variations typical of the semiregular variables (AAVSO 1983) and hence it is not a misclassified Mira. No light curve of T Mic has been published by the AAVSO.

c) Exceptions

1) MS stars

Among the 17 MS stars listed in Table I, we were surprised to find seven that do not show the Tc lines: RT Aql (M—327 days); X Cet (M—177 days); DE (44) Leo (SRb—$P = ?$); NZ Gem (BS 2967) (SR—$P = ?$); GZ (57) Peg (Lb); NO Aur (Lc); and BS 7442 (var?). Smith and Lambert (1985, 1986) determined abundances for nine out of the 11 MS stars listed by Yamashita (1967) and found that four (DE Leo, BS 7442, CU (10) Dra, and BS 2508) showed no enhancements of the *s*-process elements whereas the five others did (RS Cnc, HR Her, OP Her, o^1 Ori, and BS 8062). (CU Dra and BS 2508, although classified as M3 IIIaS by Yamashita (1967), are not included among our 17 MS stars since they are not listed with an MS classification in either the GCVS or BSC.)

MS stars were originally defined by Keenan (1954) as stars that show weak ZrO bands and enhanced lines of Ba II and Sr II in the blue spectral region. It appears to us that the MS stars should be divided into two classes which we shall call *evolutionary* MS stars and *spectroscopic* MS stars. We define *evolutionary* MS stars as those stars in the intermediate evolutionary phase between the M and the S stars. These *evolutionary* MS stars show the same spectroscopic characteristics as the MS stars defined by Keenan, but in addition

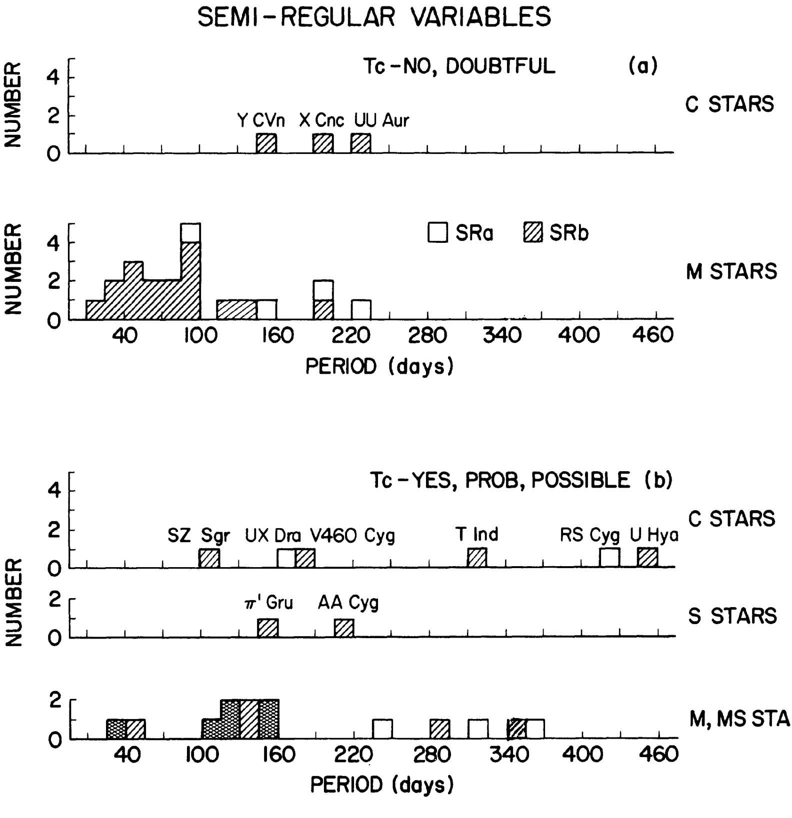

FIG. 3. (a), (b) Histograms for the semiregular variables binned in 15 day intervals. The bottom panel (b) shows the stars with Tc. The M and MS stars, C, and S stars are plotted on separate lines. SRb variables are indicated as hatched areas, SRa's as open areas and MS semiregular variables as double-cross-hatched areas. The top panel (a) shows the stars with Tc-no or -doubtful. The three SRb C stars are plotted on a separate line. No semiregular S or MS stars without Tc are known.

they have abundances of the *s*-process elements (including Tc) and C/O ratios intermediate between the M and the S stars, e.g., RS Cnc and OP Her. (Smith and Lambert (1986) call our *evolutionary* MS stars true MS stars.)

It seems that atmospheric conditions in certain stars are also able to produce enhanced strengths of Sr and Ba lines, i.e., enhancements not due to increased abundances, for example, DE Leo and CU Dra (Smith and Lambert 1985, 1986). The Smith and Lambert abundance analyses point out the difficulty in interpreting classification criteria in terms of abundances. It is also likely that some MS stars will be found with *s*-process enhancements and no Tc. A possible example is g Her, which shows mild *s*-process enhancements by about a factor of 2 but no Tc. These types of objects may be cooler analogs of barium stars whose enhancements are likely to be produced by mass transfer from a companion. We postulate the existence of these types of objects among the S and the C stars. We will refer to the MS stars with observed enhanced *s*-process lines and no Tc as *spectroscopic* MS stars. The presence of Tc will distinguish between the *evolutionary* and the *spectroscopic* MS stars, but only a complete abundance analysis will distinguish between atmospheric enhancements and real *s*-process enhancements produced in the past.

ST Her and NZ Gem (BS 2967) are listed in Table I as MS stars and are also among the MS stars of Yamashita (1967). ST Her shows strong Tc lines and Smith and Lambert (1986) did notice enhanced *s*-process lines on its spectrum (although they derived no abundances). We will consider it to be an *evolutionary* MS star. NZ Gem shows neither Tc (present study) nor enhanced *s*-process lines (Smith and Lambert 1986) and may be either a *spectroscopic* MS star or an ordinary M star.

NO Aur and GZ Peg, listed as MS stars in Table I, are low-amplitude irregular variables that do not show Tc I lines. GZ Peg should be examined for *s*-process abundance enhancements. We include it among the *spectroscopic* MS stars.

NO Aur is listed as M2 SIab in the GCVS and as M2 IIIS in the BSC. However, our 4 m echelle spectrogram is more consistent with its supergiant classification. The *IRAS* low-resolution spectrum of NO Aur shows an emission feature in the 9 to 13 μm that is typical of many S stars (Little and Little-Marenin 1986). Supergiants in general do not show the Tc lines (subsec *a*, conclusion no. 2). Red supergiants (usually irregular or semiregular variables) are estimated to be in the beginning stages of core helium burning (Stothers and Leung 1970). The lack of Tc in any M supergiants agrees with this conclusion. However, three MS stars, classified as supergiants or bright giants, *do show* strong Tc lines (RS Cnc (M6e Ib-II(S)), Y Lyn (M6S Ib-II) and T Cet (M5-6S IIe)). Their luminosity class may be suspect since luminosity criteria such as the Sr lines are also enhanced by the *s*-process and as the conflicting classification for RS Cnc shows: M6e Ib-II(S) in the GCVS and as M6 IIIaSe in the BSC. Until we are certain about the supergiant classification of these MS stars, we will believe that no supergiants show Tc. Hence we reach two contradictory conclusions for NO Aur. Its supergiant characteristics and its low amplitude are consistent with no Tc lines in its spectrum. On the other hand, its *IRAS* spectrum argues for NO Aur having S star characteristics and as such it should show Tc. An abundance analysis is needed in order to clarify its status.

The two MS Miras, RT Aql and X Cet, may be classified incorrectly as MS stars and should be considered M star Miras. Neither shows Tc, and Keenan, Garrison, and Deutsch (1974) observe no ZrO in RT Aql. However, their spectrum of X Cet was too underexposed for ZrO to be observable. X Cet should be reobserved at classification dispersion and should be reanalyzed for Tc. Two M Miras, T Cas and T Cep, should probably be classified as *evolutionary* MS stars. They show fairly strong Tc lines and definitely show ZrO bands around 9300 Å (Spinrad *et al.* 1966). R Ser probably shows the 9300 Å ZrO bands (Spinrad and Newburn 1965) and weakly ZrO in the blue at two out of four phases (Keenan, Garrison, and Deutsch 1974) and strong Tc. However, its ^{12}C/^{13}C ratio of 15 ± 3 (Hinkle, unpublished) is more typical of M stars with Tc and we will not include it among the *evolutionary* MS stars until its *s*-process abundances can be determined. A comparison of the intensity of the ZrO band as listed by Keenan, Garrison, and Deutsch (1974) and our Tc data show that stars with Tc have ZrO intensities of $\geqslant 1$ or have intensities of about 0.5 at several phases. An occasionally weakly visible ZrO band does not indicate the presence of Tc and may relate to unusual atmospheric conditions.

Summarizing, we find that *evolutionary* MS stars show Tc, whereas *spectroscopic* MS stars do not. This is a somewhat circular argument in that we have excluded from the *evolutionary* MS group those stars that do not show Tc. The value of the distinction between the two groups lies in the fact that we are able to distinguish between unusual atmospheric conditions (or possible mass transfer from a companion) and real abundance anomalies produced very recently in AGB stars. The presence of Tc establishes a star as belonging to the *evolutionary* MS category without having to perform complex abundance analyses, especially for the Mira variables for which good atmospheric models are not yet available.

2) S stars

The S stars BS 363, HD 35155, HD 165774, BD Cam (BS 1105)-Lb and V Cnc (M—272 days) that do not show Tc are of particular interest since their spectral classification implies that the other *s*-process elements are enhanced. BD Cam (= BS 1105) is a low-amplitude Lb variable in a binary system (Griffin 1984), and its *s*-process enhancements (Smith and Lambert 1986) may be due to mass transfer from a companion analogous to the enhancements observed in Ba II stars. Peery (1985) reports the possible detection of an underluminous (white dwarf?) companion to BD Cam in an *IUE* spectrum and Johnson and Ake (1984) interpret the very strong C IV and N V lines in an *IUE* spectrum of HD 35115 as possibly being produced in an interacting binary system. Hence the *s*-process enhancements in both these stars may be related to mass transfer. BS 363 may be similar since it is listed as a probable spectroscopic binary in the BSC. However, no white dwarf companion with M_v brighter than 11.1 has been detected with *IUE* (Johnson and Ake 1986). It should be searched for radial-velocity variations. No extra information on HD 165774 is available. V Cnc is the only S type Mira with no Tc lines, and it definitely needs to be reobserved. We observed it near maximum when it is quite warm (S0) and Tc is somewhat ionized. It would be most unexpected to find an S star Mira without Tc lines since this type of star is a prime candidate for the third dredge-up. V Cnc is also a visual binary; however, the secondary is too bright ($m_v = 13.5$ mag) to be a white dwarf and the separation is too large (10″) for the companion to have exchanged mass with V Cnc. We conclude that all *single* S stars show the products of recent *s*-processing in their atmospheres. The few S stars without Tc are nonvariable or low-amplitude binaries (V Cnc may be an exception). The only nonvariable star to show Tc is BS 8062 (S4,1). It may be temporarily in a quiet evolutionary phase since all other Tc stars are relatively large-amplitude variables. It is of interest to point out that a white dwarf companion can be present and Tc be observed in the atmosphere of a star. For example, the MS star o^1 Ori shows Tc and has a white dwarf companion (Johnson and Ake 1986).

3) Carbon stars

The four C stars that do not show the Tc lines are SS Vir (M—355 days), UU Aur (SRb—234 days), X Cnc (SRb—195 days), and Y CVn (SRb—157 days). Utsumi (1970, 1985) has found that C stars rich in ^{13}C (type J) such as Y CVn do not show *s*-process enhancements. Hence it is not surprising that Y CVn does not show Tc. No other J type stars have yet been searched for Tc. Lambert *et al.* (1986) determined a C/O ratio of 1.087 for Y CVn. Its greater-than-unity C/O ratio together with its low ^{12}C/^{13}C ratio of 3.5 implies a compositional change during an earlier evolutionary phase and not the third dredge-up. On the other hand, UU Aur and X Cnc show the typical *s*-process enhancements (Utsumi 1985) and C/O ratios of C stars (Lambert *et al.* 1986) (SS Vir was not analyzed by Utsumi and no C/O ratio was determined by Lambert *et al.* 1986). The lack of Tc in these two stars is difficult to understand unless the third dredge-up has ceased in these stars more than 10^6 yr ago so that Tc has had time to decay away. However, the AGB lifetime of low-mass stars is only a few times 10^6 yr (Iben 1983). The cutoff for the third dredge-up would have to be very finely tuned in order to allow for the formation of a C star and the decay of Tc before the star ends its AGB evolution with the ejection of a planetary nebula. Another possibility is that these particular stars are cooler analogs to the barium stars (i.e., unidentified binary stars). More C stars should be searched for Tc and binary companions. It is, however, very difficult to observe carbon stars for the Tc I resonance lines since their ultraviolet depression makes most of them quite faint in the 4200–4300 Å region.

V. CONCLUSIONS

During the late stages of evolution, stars on the upper part of the AGB can experience helium shell flashing and the third dredge-up which mixes carbon (a product of helium burning) and *s*-process elements with the atmosphere. During this phase, M stars progressively evolve from M → MS → S → (SC) → C stars. Abundance analyses of stars along this sequence confirm an increase in the C/O ratio and in the amount of *s*-processed elements in their atmospheres. The detection of Tc in our much larger sample of stars agrees very well with the increasing amounts of *s*-process elements observed in the sequence from M → C stars. We find that all *evolutionary* MS, probably all single S stars, and all SC stars show Tc. However, among the C stars, we find a significant percentage of stars that do not show Tc even if other *s*-process elements are enhanced. Whether the decrease in the percent of C stars with Tc is related to undiscovered binary systems is not yet known.

In M stars we find that the presence of the Tc lines in the spectrum is a very sensitive indicator of the mixing of *s*-processed elements. At times, we can detect the presence of an *s*-process product (i.e., Tc) more readily than can abundance analyses of other *s*-process elements since the detection of Tc is more easily accomplished than the determination of abundance enhancements. We find a significant number of M stars with Tc even when no *s*-process enhancements have been determined by spectroscopic abundance analyses. Specifically, the pure M star *o* Cet (Mira) shows the Tc I lines and no apparent enhancement of Zr and Nb (Dominy and Wallerstein 1986), R Ser shows a strong Tc line but ZrO appears to be present only occasionally and then very weakly (Dominy and Wallerstein 1986; Keenan, Garrison, and Deutsch 1974; Spinrad and Newburn 1965), and no ZrO has been observed in Mira. The detection of Tc in a large number of stars allows us to delineate those stars in which *s*-process products have recently been mixed with surface materials. The percent of stars with Tc rises from 0% for nonvariable M stars to probably 100% in the MS, S, and SC stars.

The onset of the third dredge-up is accompanied by light variability in these stars. The nonvariable and low-amplitude variables do not show Tc, whereas larger-amplitude semiregular (SR) and Mira variables do show Tc. In Mira variables the presence of Tc is a very strong function of their period and Tc is not usually detected in stars with $P < 300$ days. Some of the semiregular M stars in the 130–150 day period range also show Tc and may be first-overtone pulsators corresponding to the longer-period fundamental-mode Mira pulsators.

We argue that the MS stars should be divided into two categories: (a) the *evolutionary* MS stars, which represent the intermediate evolutionary phase between M and S stars and have the intermediate abundance characteristics between the two spectral classes (including Tc); and (b) the *spectroscopic* MS stars in which unusual atmospheric conditions or possibly enhancements due to mass transfer from a companion produce enhanced Sr II and Ba II lines but no Tc I lines.

The few S stars that do not show Tc may have companions and their *s*-process enhancements may be related to a mass-transfer process as suggested for the barium stars.

Supergiants do not appear to be in a third dredge-up phase since they do not show Tc and probably are likely to be in their core-helium-burning phase. The supergiant classification of the MS stars is suspect because of the difficulty in finding luminosity criteria that are independent of *s*-process elements. Holweger and Kovacs (1984) observed several K giants and supergiants with apparent abundance enhancements of Sr and Ba which they attribute to a weak *s*-process. However, Smith and Lambert (1986) point out that the apparent enhancements are likely to be related to non-LTE effects in the Sr lines and not a weak *s*-process. The lack of Tc in our three K stars lends support to the suggestion by Smith and Lambert.

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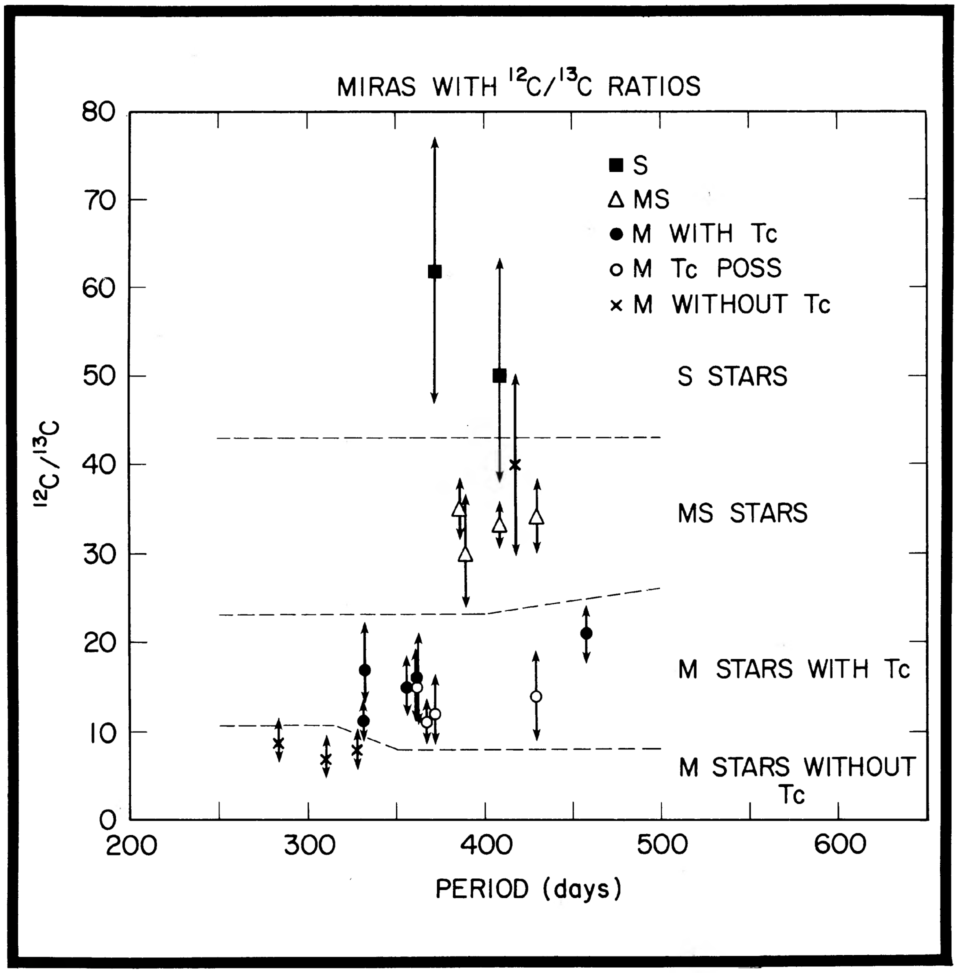

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