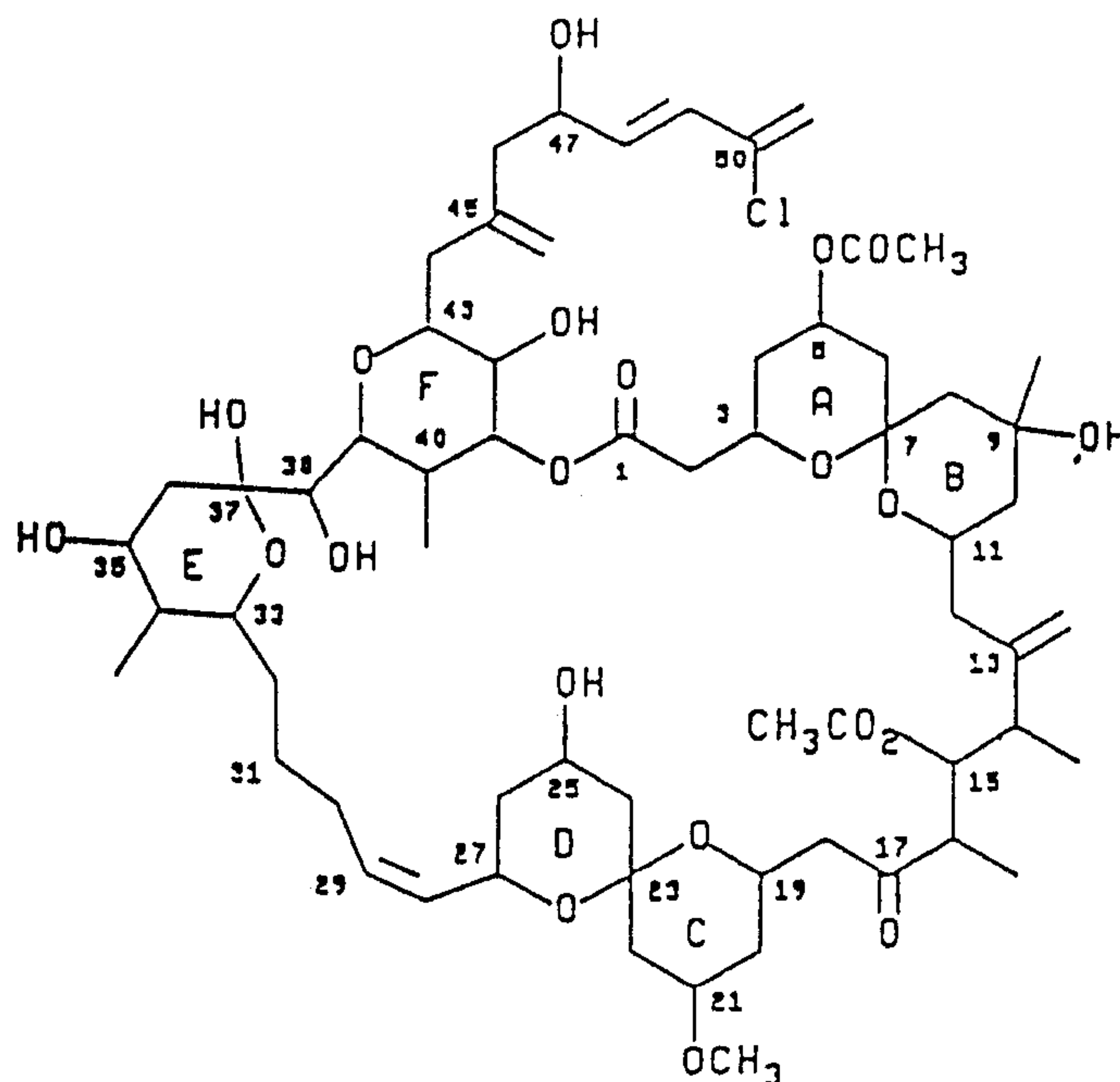




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(54) **ISOLEMENT ET STRUCTURE DE LA SPONGISTATINE 1**
(54) **ISOLATION AND STRUCTURE OF SPONGISTATIN 1**

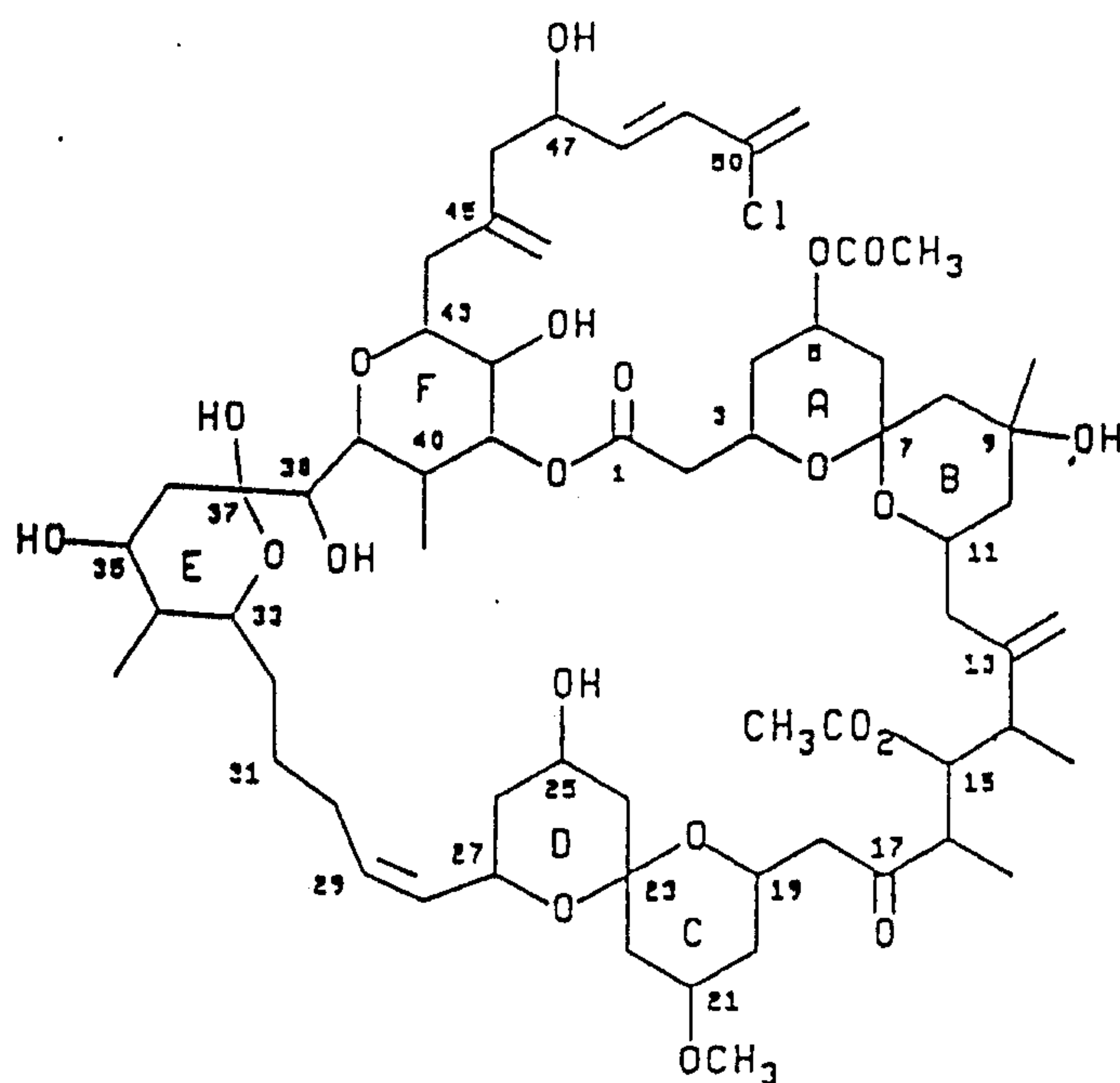


(57) An Eastern Indian Ocean marine sponge in the genus Spongia was located in the Republic of the Maldives and found to contain a structurally unprecedented macrocyclic lactone named spongistatin 1. The new perhydropyran-containing structure, as shown below, was found to be remarkably potent and specific, log molar TCI₅₀ to < -10, against twenty human cancer cell lines in the U.S. National Cancer Institute's panel of sixty.



ABSTRACT OF THE DISCLOSURE

An Eastern Indian Ocean marine sponge in the genus Spongia was located in the Republic of the Maldives and found to contain a structurally unprecedented macrocyclic lactone named spongistatin 1. The new perhydropyran-containing structure, as shown below, was found to be remarkably potent and specific, log molar TCI_{50} to < -10 , against twenty human cancer cell lines in the U.S. National Cancer Institute's panel of sixty.



ISOLATION AND STRUCTURE OF SPONGISTATIN 1

INTRODUCTION

10 The present invention relates to the discovery and isolation of new and extremely potent constituent of an Eastern Indian Ocean marine sponge of the genus Spongia herein denominated "spongistatin 1". This new perhydropan-containing structure was found to be remarkably potent and specific against twenty human cancer cell lines in the U.S. National Cancer Institute's panel.

BACKGROUND OF THE INVENTION

20 A great number of ancient marine invertebrate species in the Phyla Bryozoa, Mollusca and Porifera were well established in the earth's oceans over one billion years ago. Certainly such organisms had explored trillions of biosynthetic reactions in their evolutionary chemistry to reach present levels of cellular organization, regulation and defense. Marine sponges have changed minimally in physical appearance for nearly 500 million years, suggesting a very effective chemical evolution in response to changing environmental conditions for at least that time period. Some recognition of the potential for utilizing biologically potent marine animal constituents was recorded in Egypt about 2,700 BC, and by 200 BC sea hare extracts were being used in Greece for medicinal purposes. Such considerations, combined with the general observation that marine organisms (especially
30 invertebrates and sharks) rarely develop cancer, led to the first systematic investigation of marine animal and plant anticancer constituents.

By 1968 ample evidence had been obtained, based on the U. S. National Cancer Institute's key experimental cancer systems, that certain marine organisms would provide new and structurally novel

antineoplastic and/or cytotoxic agents. Analogous considerations suggested that marine organisms could also provide effective new drugs for other severe medical challenges, such as viral diseases. Furthermore, marine organisms were expected to contain potentially useful drug candidates (and biochemical probes) of unprecedented structural types, that would have eluded discovery by contemporary techniques of medicinal chemistry. 10 Fortunately, some of these expectations have been realized in the intervening period. Illustrative of these successes are the discoveries of the bryostatins, dolastatins, and cephalostatins by the Cancer Research Institute in Tempe, Arizona where several members of these series of remarkable anticancer drug candidates are either now in human clinical trial or preclinical development. See U.S. Patent Nos. 4,816,444, 4,833,257, 4,873,245, and 4,879,278.

20 As is well known to those presently engaged in medical research, the time between the isolation of a new compound, and its introduction to the market place takes at least several years in the best case and can take several decades. Consequently, industry, in association with the government, has devised a number of qualifying tests which serve two purposes. One purpose is to eliminate those substances whose results in the qualifiers unequivocally demonstrate that the further 30 expenditure of funds on developing those substances would be economically counter-productive. The second, and more important purpose, is to identify those substances which demonstrate a high likelihood of success and therefore warrant the requisite further investment necessary to obtain the data which is required to meet the various regulatory requirements imposed by those governments which regulate the market place into which such substances will enter.

The present cost of obtaining such data approaches Ten Million Dollars (\$10,000,000 U.S.) per substance. Economics dictate that such an investment not be made unless there is a reasonable likelihood that it can be recovered. Absent such an opportunity, there will be no such investment, and without investment, the research requisite for the discovery of potentially life saving drugs will stop.

10 Only two hundred years ago, many diseases
ravaged humankind. Many of these diseases now have
been controlled or eradicated. In the development
of the means to treat or control these diseases,
work with the appropriate common experimental
animals was of critical importance. With the
various types of cancers, and with the HIV virus,
such work is presently ongoing. The research for
the treatment of various types of cancer is
coordinated in the United States by the National
20 Cancer Institute (NCI). NCI, as a government
entity, has been charged with assisting anti-cancer
research. To establish whether a substance has
anti cancer activity, NCI has established a variety
of protocols, one of which involves testing the
candidate substance against a cell line panel
containing 60 human tumor cell lines. This
protocol has been verified and is generally
accepted throughout the scientific community. This
protocol and the established statistical means of
30 evaluating the results obtained therefrom have been
fully described in the literature. See Principles
& Practice of Oncology PPO Updates, Volume 3,
Number 10, October 1989, by Michael R. Boyd, M.D.,
Ph.D., for an indepth description of the test
protocol. The statistical analysis is explained in
"Display and Analysis of Patterns of Differential
Activity of Drugs Against Human Tumor Cell Lines:
Development of Means Graph and COMPARE Algorithm"
40 Journal of the National Cancer Institute Reports
Vol. 81, No. 14, Pg. 1088, July 14, 1989, by K.D.

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Numerous compounds have been discovered which demonstrate significant antineoplastic activity. As discussed above, many of these compounds have been extracted, albeit with great difficulty, from living creatures such as the sponge or the sea hare. However, once the isolation and testing of such compounds has progressed, a practical problem exists, namely, how to obtain a significant quantity of the compound.

10

Unlike cinchona bark which is collected to produce quinine and has an excellent yield, the collection and processing of the compounds of the present invention in the natural occurring state ranges from the grossly impractical to the utterly impossible. Even ignoring potential ecological effects, the population of such creatures is clearly insufficient. Accordingly, the elucidation of the absolute structure of such antineoplastic compounds is essential.

20

A major component of vigorous efforts for over two decades has been directed at marine sponge antineoplastic and/or cytotoxic biosynthetic products and it is toward the furtherance of that effort that the present invention is directed.

BRIEF SUMMARY OF THE INVENTION

Marine Porifera in the genus Spongia (family

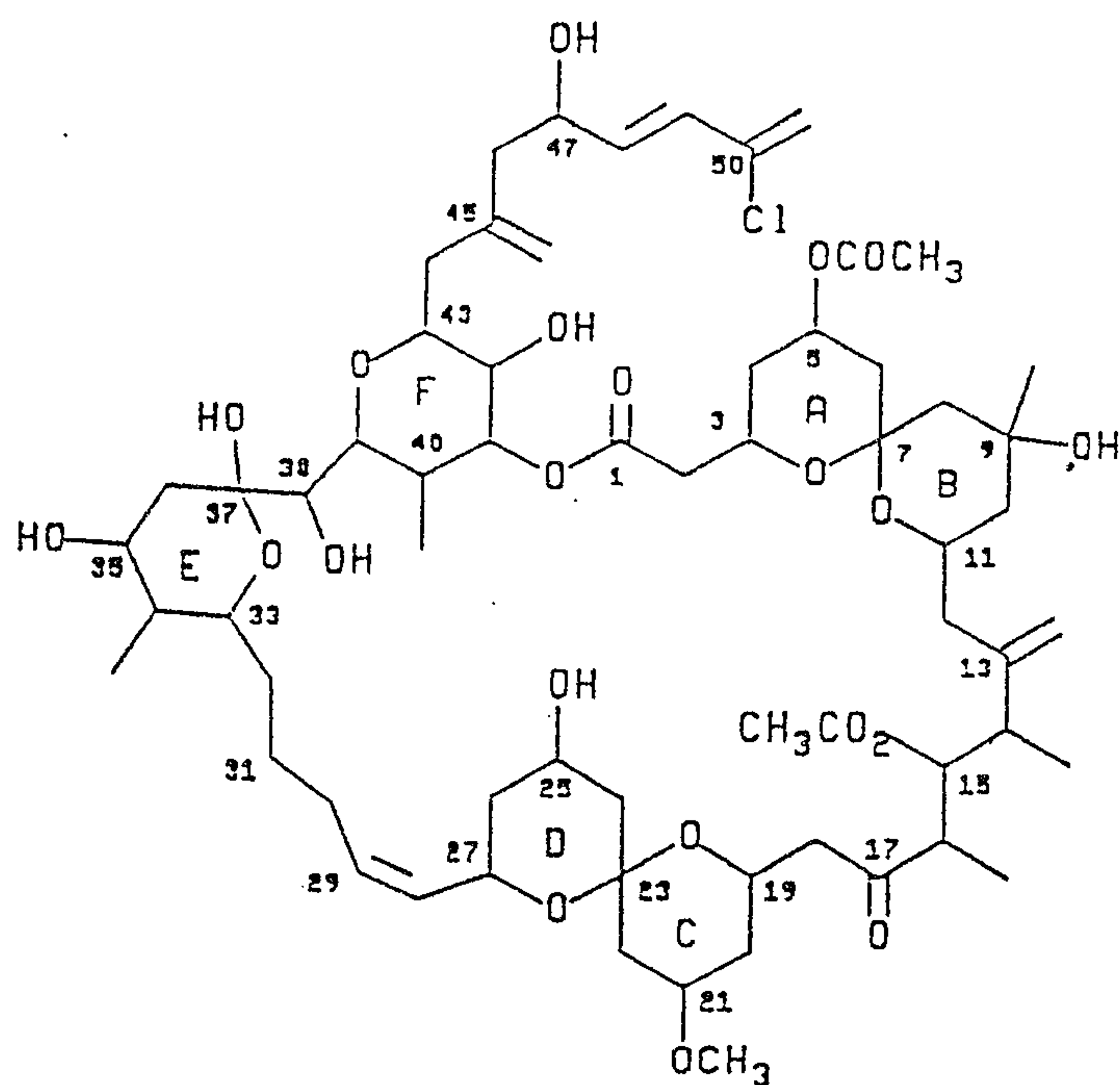
30

Spongiidae, Class Demospongiae) have proved to be good sources of tetracyclic diterpenes. Based on previous investigations the Spongia would not seem a particularly attractive reservoir of antineoplastic macrocyclic lactones. But natural products are replete with surprises. We are very pleased to report discovery in a Spongia sp. a macrocyclic lactone designated spongistatin 1 that possesses a remarkable structure exhibiting phenomenally potent (and selective) activity against twenty of the U.S. national Cancer Institute's (NCI) panel of sixty human cancer cell lines.

A 1988 recollection (400 kg wet wt.) of the dark brown (to black) Spongia sp. from the Eastern Indian Ocean (Republic of the Maldives), was extracted with methanol followed by methylene chloride-methanol. A methylene chloride fraction derived from the combined extract was carefully separated (guided by P388 lymphocytic leukemia bioassay) employing an extensive series of LH-20 SEPHADEX[®] gel permeation and partition (also on SILICA GEL) chromatographic procedures followed by final isolation using reversed phase (PREPEX[®] 5-20 μ , C8 column) high performance liquid chromatography with 5:5:7 acetonitrile-methanol-water as eluent to afford (13.8 mg, 5.1 10^{-4} yield) colorless spongistatin 1 as an amorphous powder, mp 161-162°C; $[\alpha]^{22D} + 26.2^\circ$ (c=0.32, CH₃OH); UV (CH₃OH) λ_{max} 216 nm, ϵ 8490; IR (film) 3430, 2928, 1736, 1383, 1232, 1177, 1085, 993 cm⁻¹ and high resolution FAB MS, m/z 1245.5949 (M+Na)₊ corresponding to C₆₃H₉₅ClO₂₁Na (calcd. mass 1245.5952) with low resolution FAB peaks at m/z 1245.5 [M+Na]⁺ as parent peak and 1187.5 [M-35] representing loss of chlorine.

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Spongistatin 1 has the following structure:



Accordingly, the principal object of the present invention is the isolation of a structurally unprecedented macrocyclic lactone herein denominated "spongistatin 1" having a log molar TGI_{50} of about <-10 against various human cancer cell lines.

Another object of the present invention is the structural elucidation of the substance denominated "spongistatin 1".

10 These and still further objects as shall hereinafter appear are readily fulfilled by the present invention in a remarkably unexpected manner as will be readily discerned from the following detailed description of an exemplary embodiment thereof.

DESCRIPTION OF PREFERRED EMBODIMENTS

20 Structural elucidation of spongistatin 1 was especially challenging and required three separate (and in-depth), high field 400 and 500 MHz 2D NMR analyses (APT, 1H - 1H -COSY, 1H - ^{13}C -COSY, HMBC, and NOE) employing acetonitrile- d_3 , pyridine- d_5 and methanol- d_3 solvent systems. The assignments are recorded in Table 1. Results of a series of selective acetylation experiments assisted in deducing some of these assignments.

30 Spongistatin 1 was found to be incredibly active and selective against twenty (CCRF-CEM, HL-60, SR leukemias; NCI-H226, NCI H23, NCI H460, NCI H522 non-small cell lung; DMS 114, and 273 small cell lung; Colo 205, DCC-2998, HCT-116, RT29, KM 2022 colon; SF-239. U-251 CNS; SK-MEL-5 melanoma; OVCAR-3 and -8 ovarian; and A-498 renal cancers) of the NCI panel of sixty human cancer cell lines with log molar TGI_{50} ranging from -8.98 to <-10.00 .

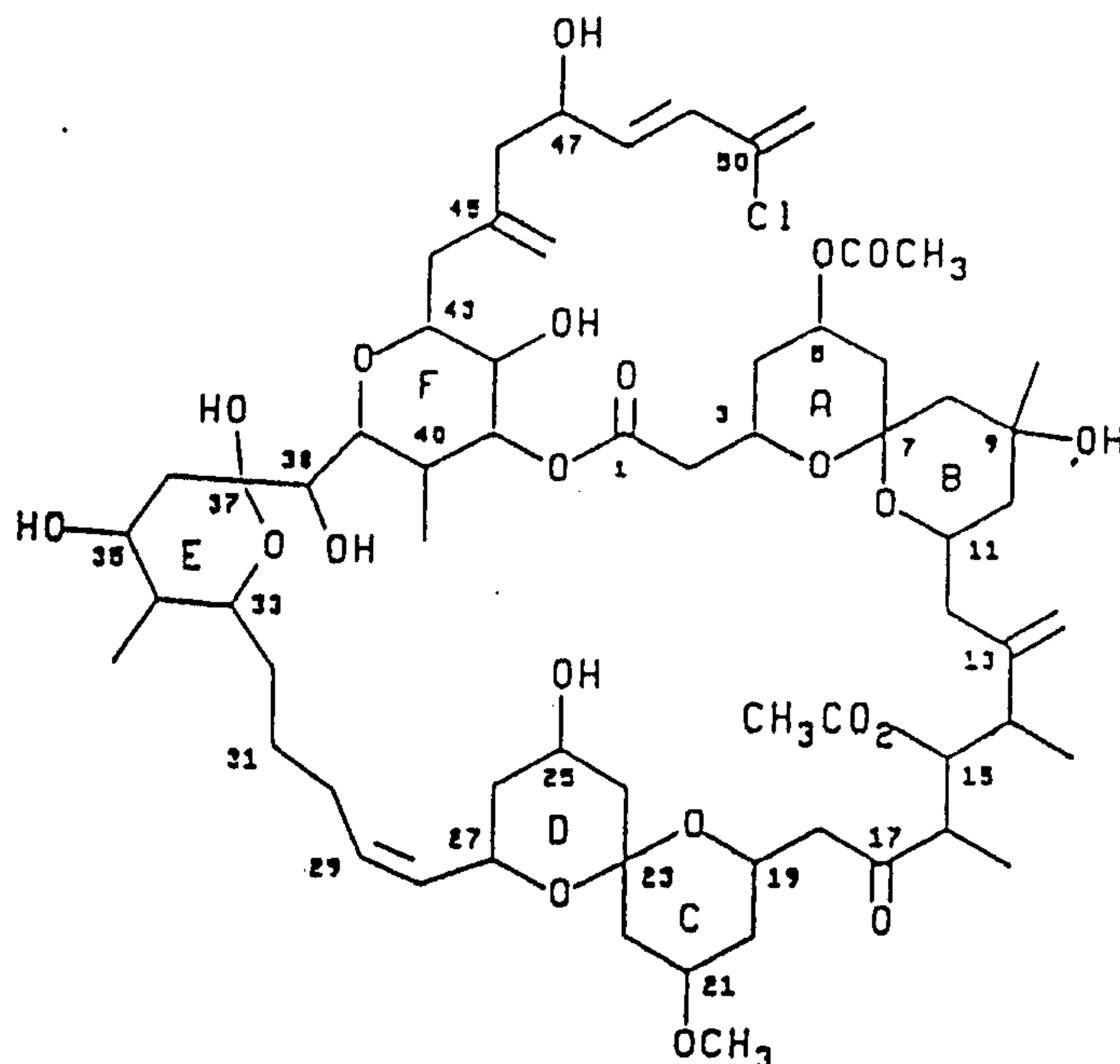
Table I. NMR assignments for spongistatin 1 recorded in CD₃CN. Coupling constants are in Hz (in parenthesis). The mixing time for the HMBC was set at 130 microsecond).

	¹³ C(100 MHz)	XHCorr. (400 MHz)	HMBC(500 MHz, C to H)
	1 173.07		H-2;H-41
	2 40.86	2.44 dd(10,18) 2.53 dd(2,18)	H-4
10	3 63.59	4.25 brt(10)	H-2;H-8
	4 34.65	1.55*;1.68*	H-2;H-6
	5 67.06	4.92 brs	
	6 38.17	1.67 dd(5,14); 1.78 brd(14)	H-5;H-8
	7 99.26		H-6;H-8;H-9a
	8 46.76	1.47 d(14);1.60*	H-9a;H-6
	9 69.64		H-9a;OH(C9);H-8
	9a 30.21	1.06 s	H-8;H-10
	10 44.96	1.28*;1.55*	H-9a;H-12;H-8
20	11 65.00	4.25 brt(10)	H-12;H-13a;H-15;H-6
	12 44.24	1.99*;2.27 brd(14)	H-10;H-13a
	13 148.03		H-12;H-13a;H-14a;H-15
	13a 114.86	4.83 brs;4.83 brs	H-12;H-14
	14 36.60	2.78*	H-13a;H-14a;H-15; H-16;H-12
	14a 12.09	1.04 d(6.9)	H-15
	15 75.34	5.12 dd(1.7,11)	H-13a;H-14a;H-16;H-16a
	16 47.62	3.04 dq(7,11)	H-15;H-16a
	16a 13.73	1.15 d(7)	H-15;H-16
30	17 213.52		H-16;H-16a;H-18;H-15
	18 51.94	2.62 brd(18) 2.86 dd(11,18)	H-16;H-20
	19 66.16	4.00 brt(11)	H-18
	20 37.70	0.97 ddd(12,12,12); 1.98*	H-18;H-22
	21 73.98	3.46 tt(4,4,12,12)	H-22;H-OMe;H-20
	22 44.18	1.08 t(12);1.99*	H-21;H-20
	23 99.91		H-18;H-22;H-24;H-27
	24 34.91	1.55*;2.28*	H-22
40	25 64.41	3.93 brm	H-26;H-27;H-24
	26 39.11	1.57*;1.57*	H-28;H-24
	27 61.22	5.00 ddd(4.3,10,10)	H-26;H-29
	28 131.22	5.32 brt(10)	H-27;H-30
	29 133.42	5.48 ddd(10,10,10)	H-27;H-30
	30 28.07	2.00*;2.19*	H-28;H-29;H-31;H-32
	31 27.04	1.23*;1.60*	H-29;H-33;H-30;H-32
	32 32.82	1.30 m;1.42 m	H-33

¹³ C(100 MHz)	XHCorr.(400 MHz)	HMBC(500 MHz, C to H)
33 67.15	4.13 dt(3.4,3.4,8)	H-34a
34 39.32	1.57 m	H-34a;H-36
34a 11.55	0.81 d(7)	H-33;H-34
35 71.47	3.65 brs	H-34a;H-33;H-36
36 33.79	1.61*;1.89*	OH(C37);H-34
37 99.41		H-33;H-36;OH(C37),H-38
38 73.11	3.34 brs	H-36
39 81.30	3.72 brd(10)	H-40a;H-41
40 37.26	1.91*	H-40a;H-39;H-41
40a 12.69	0.74 d(7)	H-40;H-41
41 80.60	4.75 dd(9,11)	H-40a;H-39;H-40; H-42;H-43
42 73.11	3.12 t(9)	H-40;H-41;H-43;H-40a
43 78.72	3.39 brt(9)	H-39;H-41;H-42;H-44
44 40.24	2.08*;2.76 brd(13)	H-42;H-46;H-45a
45 144.00		H-45a;H-43;H-44; H-46;H-47
45a 116.61	4.86 brs;4.89 brs	H-44;H-46
46 43.93	2.33 brdd(7,14); 2.19*	H-44;H-45a
47 70.13	4.36 ddd(6,7,11)	H-46;H-48
48 139.21	6.11 dd(6,15)	H-46;H-47
49 126.99	6.41 brd(15)	H-47;H-48;H-51
50 139.21		H-48;H-49;H-51
51 116.48	5.35 brs;5.45 brs	H-48;H-49
OMe 55.72	3.24 s	H-21
OAc 21.78	1.94 s	
171.61		H-OAc(δ1.94);H-5
OAc 21.00	1.84 s	
170.21		H-OAc(δ1.84);H-15
OH(C25)	4.39 d(9.9)	
OH(C37)	4.73 d(2)	
OH(C9)	4.32 brs	
OH	3.83 brm	

* Coupling constants for these signals were not measured due to overlapping.

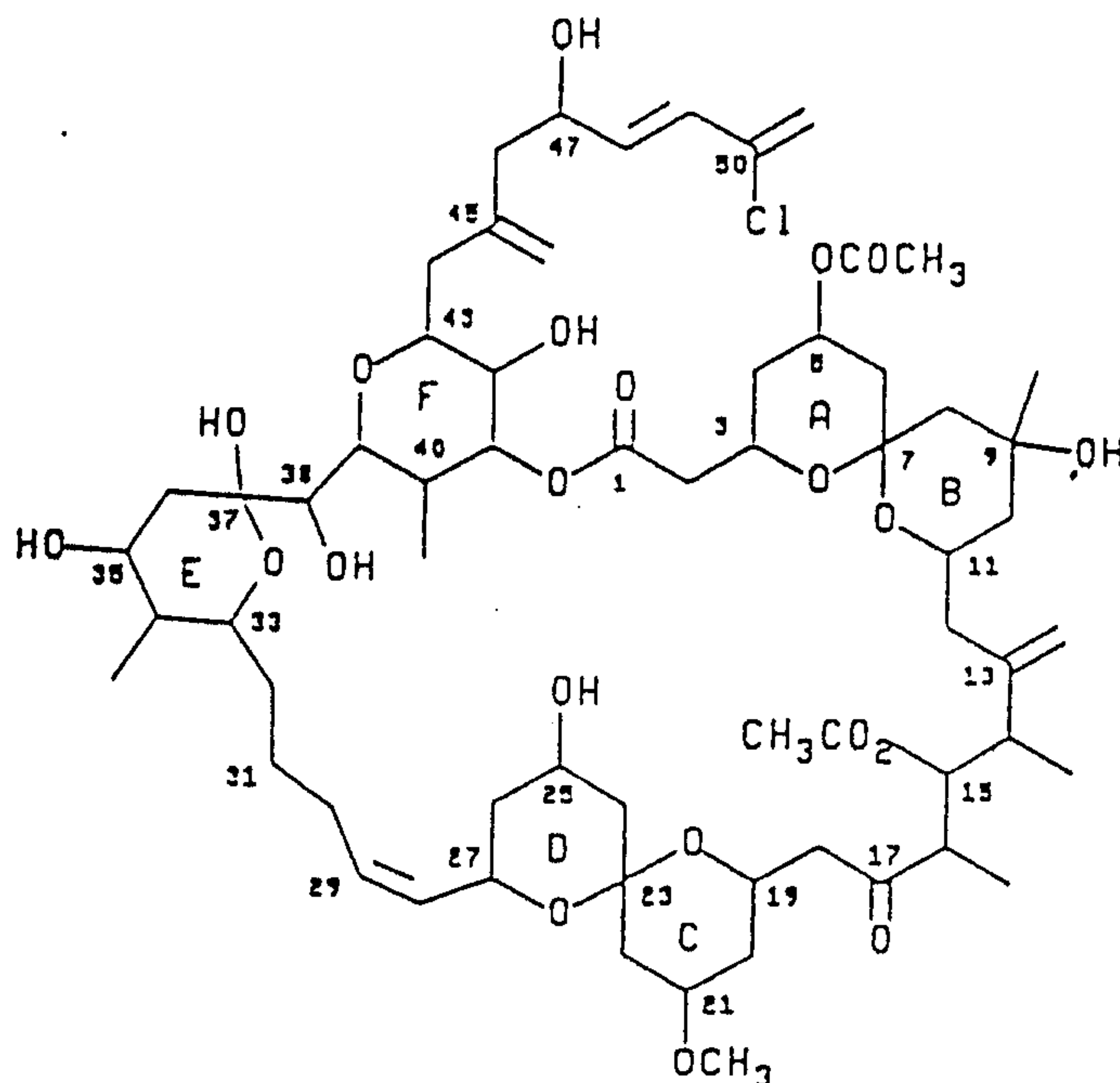
The derived physical structure of the compound named herein as spongistatin 1 is as follows.



From the foregoing it is apparent that an invention has been herein described and illustrated which fulfills all of the aforestated objectives in a remarkably unexpected fashion. It is of course understood that such modifications, alterations and adaptations as may readily occur to the artisan confronted with this disclosure are intended within the spirit of this disclosure which is limited only by the scope of the claims appended herein.

CLAIMS

1. A compound denominated herein as spongistatin 1 and having the following structural formula:



2. A compound according to claim 1 and having, when recorded in CD_3CD , the NMR assignments;

	^{13}C (100 MHz)	XHCorr.(400 MHz)	HMBC(500 MHz, C to H)
1	173.07		H-2;H-41
2	40.86	2.44 dd(10,18) 2.53 dd(2,18)	H-4
3	63.59	4.25 brt(10)	H-2;H-8
4	34.65	1.55*;1.68*	H-2;H-6
5	67.06	4.92 brs	
6	38.17	1.67 dd(5,14); 1.78 brd(14)	H-5;H-8
7	99.26		H-6;H-8;H-9a
8	46.76	1.47 d(14);1.60*	H-9a;H-6
9	69.64		H-9a;OH(C9);H-8
9a	30.21	1.06 s	H-8;H-10
10	44.96	1.28*;1.55*	H-9a;H-12;H-8
11	65.00	4.25 brt(10)	H-12;H-13a;H-15;H-6
12	44.24	1.99*;2.27 brd(14)	H-10;H-13a
13	148.03		H-12;H-13a;H-14a; H-15
13a	114.86	4.83 brs;4.83 brs	H-12;H-14
14	36.60	2.78*	H-13a;H-14a;H-15; H-16;H-12
14a	12.09	1.04 d(6.9)	H-15
15	75.34	5.12 dd(1.7,11)	H-13a;H-14a;H-16; H-16a

* Coupling constants for these signals were not measured due to overlapping.

(continued)

¹³ C(100 MHz)		XHCorr.(400 MHz)	HMBC(500 MHz, C to H)
16	47.62	3.04 dq(7,11)	H-15;H-16a
16a	13.73	1.15 d(7)	H-15;H-16
17	213.52		H-16;H-16a;H-18; H-15
18	51.94	2.62 brd(18) 2.86 dd(11,18)	H-16;H-20
19	66.16	4.00 brt(11)	H-18
20	37.70	0.97 ddd(12,12,12); 1.98*	H-18;H-22
21	73.98	3.46 tt(4,4,12,12)	H-22;H-OMe;H-20
22	44.18	1.08 t(12);1.99*	H-21;H-20
23	99.91		H-18;H-22;H-24; H-27
24	34.91	1.55*;2.28*	H-22
25	64.41	3.93 brm	H-26;H-27;H-24
26	39.11	1.57*;1.57*	H-28;H-24
27	61.22	5.00 ddd(4,3,10,10)	H-26;H-29
28	131.22	5.32 brt(10)	H-27;H-30
29	133.42	5.48 ddd(10,10,10)	H-27;H-30
30	28.07	2.00*;2.19*	H-28;H-29;H-31; H-32
31	27.04	1.23*;1.60*	H-29;H-33;H-30;H-32
32	32.82	1.30 m;1.42 m	H-33
33	67.15	4.13 dt(3,4,3,4,8)	H-34a
34	39.32	1.57 m	H-34a;H-36
34a	11.55	0.81 d(7)	H-33;H-34
35	71.47	3.65 brs	H-34a;H-33;H-36
36	33.79	1.61*;1.89*	OH(C37);H-34
37	99.41		H-33;H-36;OH (C37);H-38
38	73.11	3.34 brs	H-36
39	81.30	3.72 brd(10)	H-40a;H-41
40	37.26	1.91*	H-40a;H-39;H-41
40a	12.69	0.74 d(7)	H-40;H-41
41	80.60	4.75 dd(9,11)	H-40a;H-39;H-40; H-42;H-43
42	73.11	3.12 t(9)	H-40;H-41;H-43; H-40a
43	78.72	3.39 brt(9)	H-39;H-41;H-42;H-44
44	40.24	2.08*;2.76 brd(13)	H-42;H-46;H-45a
45	144.00		H-45a;H-43;H-44; H-46;H-47
45a	116.61	4.86 brs;4.89 brs	H-44;H-46
46	43.93	2.33 brdd(7,14); 2.19*	H-44;H-45a
47	70.13	4.36 ddd(6,7,11)	H-46;H-48
48	139.21	6.11 dd(6,15)	H-46;H-47
49	126.99	6.41 brd(15)	H-47;H-48;H-51

* Coupling constants for these signals were not measured due to overlapping.

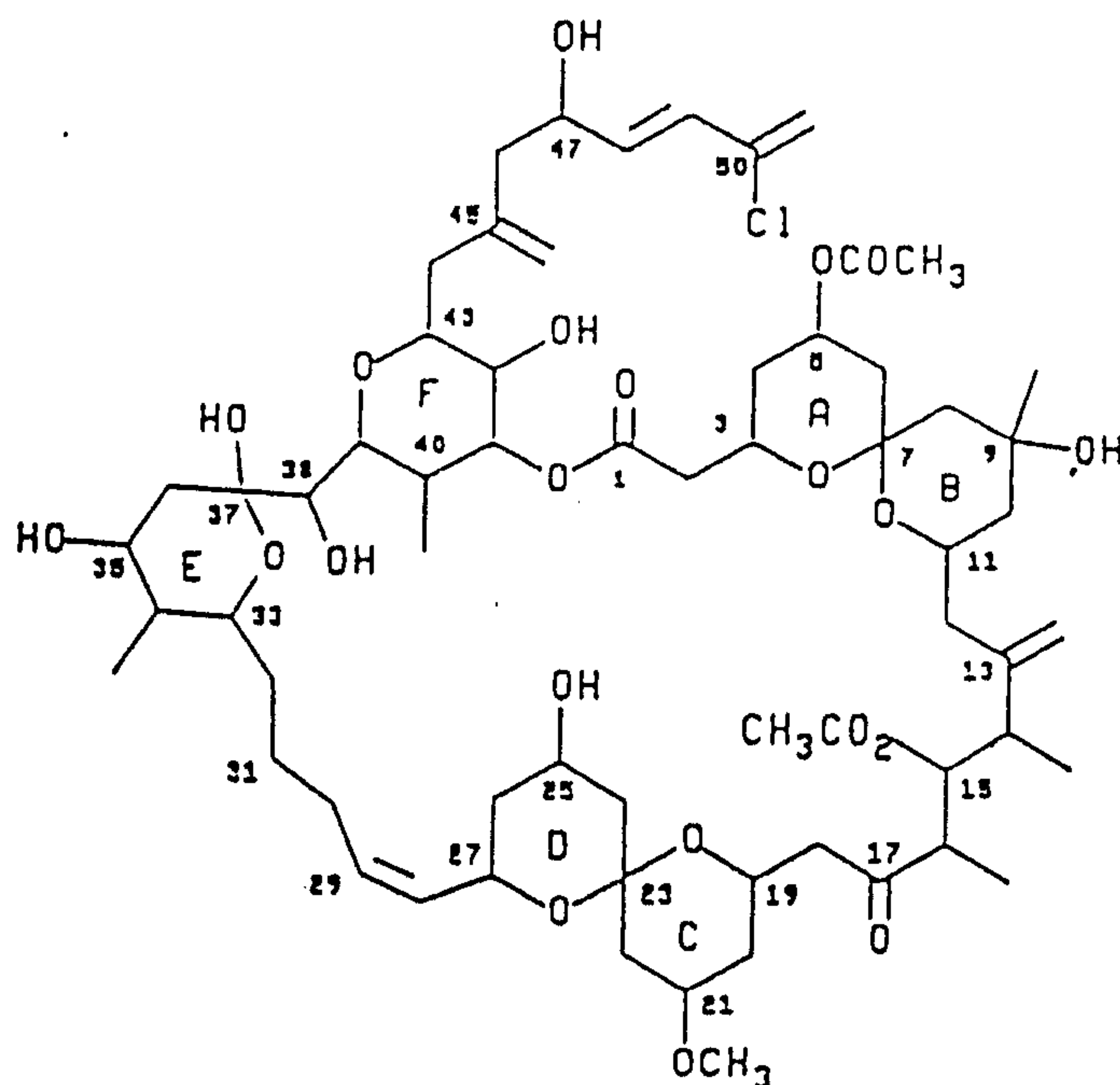
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¹³ C(100 MHz)		XHCorr.(400 MHz)	HMBC(500 MHz, C to H)
50	139.21		H-48;H-49;H-51
51	116.48	5.35 brs;5.45 brs	H-48;H-49
OMe	55.72	3.24 s	H-21
OAc	21.78	1.94 s	
	171.61		H-OAc(δ1.94);H-5
OAc	21.00	1.84 s	
	170.21		H-OAc(δ1.84);H-15
OH(C25)		4.39 d(9.9)	
OH(C37)		4.73 d(2)	
OH(C9)		4.32 brs	
OH		3.83 brm	

3. A pharmaceutical composition comprising a compound as defined in claim 1 or 2, and a pharmaceutically acceptable carrier.

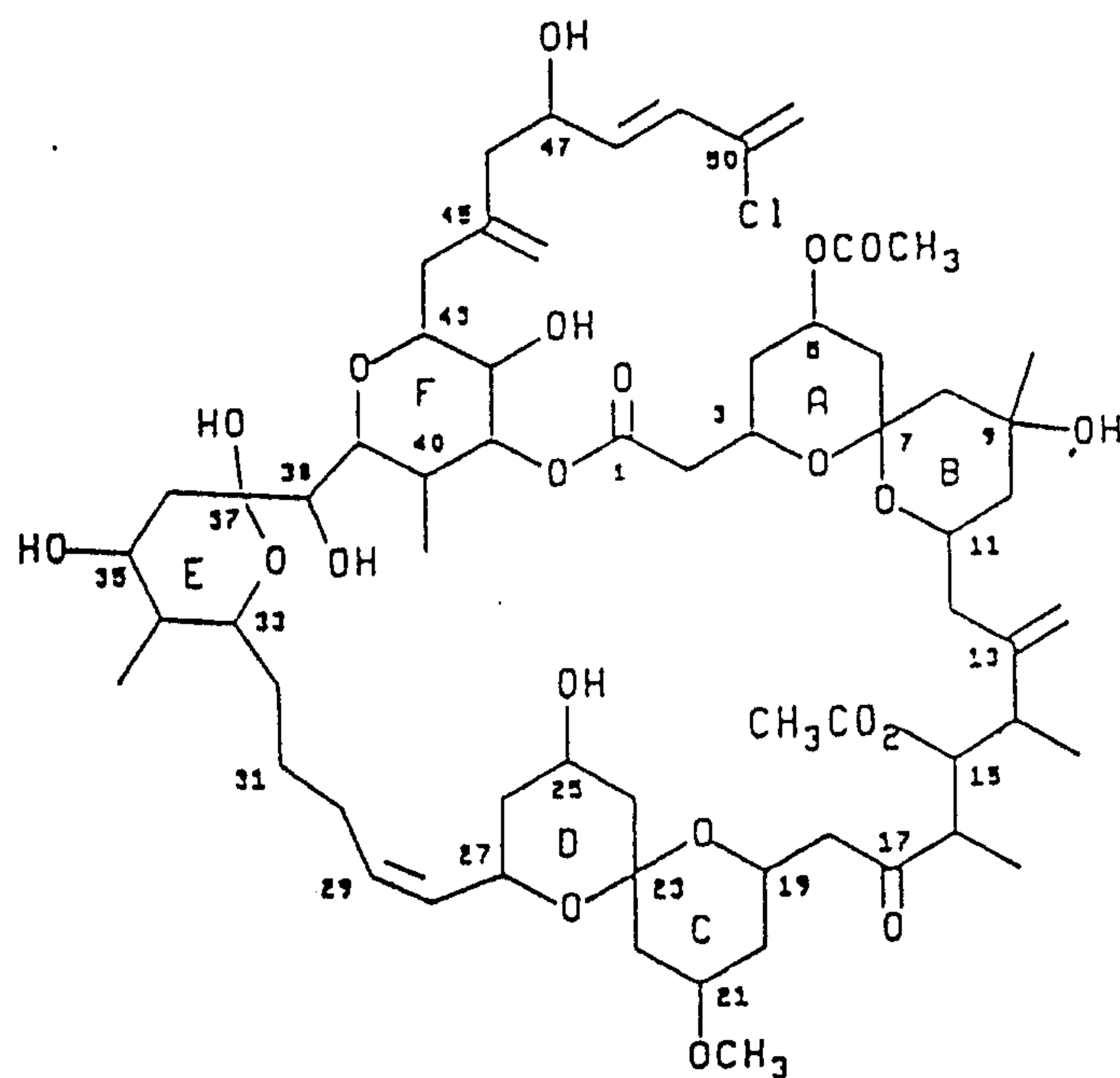
4. A method for inhibiting the growth of human cancer cells which comprises administering to an in vitro environment containing such human cancer cells a pharmaceutically acceptable carrier combined with the compound of claim 1 in an amount effective to inhibit the growth of such human cancer cells in said environment.

5. The use of a compound having the structural formula:



in medicine.

6. The use of a compound having the structural formula:



in the manufacture of a medicament for inhibiting the growth of human cancer cells.