2,3-epoxygeraniol, 62960-04-7; 6,7-epoxygeraniol, 40036-54-2; 2,3:6,7-diepoxygeraniol, 137917-59-0; 2,3-epoxynerol, 71030-55-2; 6,7-epoxynerol, 69855-16-9; 2,3:6,7-diepoxynerol, 137917-60-3; (2*E*,6*E*)-2,3-epoxyfarnesol, 83680-00-6; *threo*-(2*E*,6*E*)-6,7:10,11-diepoxyfarnesol, 52567-34-7; *threo*-(±)-6,7-epoxylinalool, 137917-61-4; *erythro*-(±)-6,7-epoxylinalool, 137917-62-5; *threo*-(±)-1,2-epoxylinalool, 137917-63-6; *erythro*-(±)-1,2-epoxylinalool, 137964-44-4; 1,2:6,7-diepoxylinalool, 137917-64-7.

On The Metalation-Silylation of *O*-Trimethylsilyl Aldehyde Cyanohydrins

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The metalation-trimethylsilylation of *O*-trimethylsilyl (saturated) aldehyde cyanohydrins was achieved by in situ treatment with LDA and trimethylchlorosilane at -78 °C. *C*-Silyl products (*O*-trimethylsilyl acylsilane cyanohydrins) generally predominated, but *N*-silyl derivatives (ketenimines) were found in some instances. LDA could be added across the C=N bond of the latter. The metalation-trimethylsilylation of *O*-trimethylsilyl benzaldehyde cyanohydrin could only be effected if 2 equiv of trimethylchlorosilane were employed per equivalent of cyanohydrin anion.

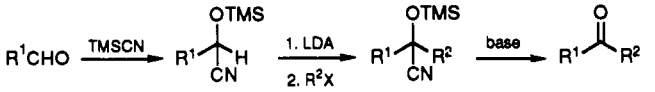
Introduction

The metalation and subsequent alkylation of *O*-silyl cyanohydrins (OSC) of aromatic or α,β-unsaturated aldehydes is a well-explored art which allows these substrates to serve as acyl anion equivalents in the synthesis of ketones (Scheme I, R^1 = Ar, RCH=CH, TMS = $SiMe_3$).[1] However, the literature is almost devoid of two clearly interesting aspects of this chemistry: (a) metalation of the OSC of saturated aldehydes[2] and (b) the possible silylation of carbanions obtained from the OSC of either saturated or aromatic aldehydes[3] (Scheme II, R^3 = alkyl, aryl). To our knowledge, the only report within this context is that of Wright and West,[4] who obtained low yields of **3a** from the metalation-silylation of the OSC of acetaldehyde (**1a**). Our interest in employing the OSC of acylsilanes (**3**) for the synthesis of oxazoles[5] led us to explore aspects of this area.

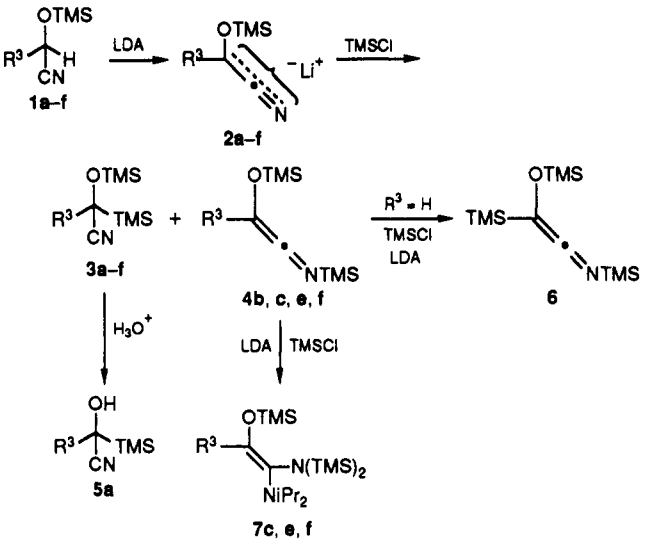
Results and Discussion

We have confirmed that *sequential*[4] metalation-silylation of **1a** affords low yields of **3a** but now find that an in situ procedure gives much improved results. Thus, when a THF mixture of slightly more than 1 equiv each of lithium diisopropylamide (LDA) and trimethylchlorosilane (TMSCl) was treated at -78 °C[6] with 1 equiv of **1a**, an 89% yield of 94% pure **3a** was isolated. This material could be readily hydrolyzed to the unprotected cyanohydrin **5a**.[7] In order to ascertain that **2a** did not undergo silyl group exchange between O and C prior to silylation, the product from the metalation-*triethyl*silylation of **1a** was hydrolyzed to give only the *C*-$SiEt_3$ product (**5a**, TMS = $SiEt_3$).[8]

Scheme I



Scheme II



a, R^3 = Me; **b**, R^3 = H; **c**, R^3 = ipr; **d**, R^3 = $PhCH_2$, **e**, R^3 = *n*-Hex; **f**, R^3 = Ph

Table I. Products Obtained from the Metalation-Silylation of 1

$R^3CH(OTMS)CN$	1:LDA:TMSCl	products (ratio)[a]
1a (R^3 = Me)	1.0:1.2:1.2	**3a**
1b (R^3 = H)	1.0:1.2:2.4	**3b** (75), **6** (25)
	1.0:2.4:4.8	**3b** (15), **6** (85)
1c (R^3 = iPr)	1.0:1.1:1.1	**3c** (10), **4c** (90)
	1.0:2.0:2.0	**7c**
1d (R^3 = $PhCH_2$)	1.0:2.2:2.2	**3d**
1e (R^3 = *n*-Hex)	1.0:1.2:2.2	**3e** (60),[b] **4e** (40)[b]
		3e (100),[c] **4e** (0)[c]
	1.0:2.2:2.2	**3e** (60), **7e** (40)
1f (R^3 = Ph)	1.0:1.1:1.1	none[d]
	1.0:1.1:2.2	**3f**
	1.0:2.2:2.4	**7f**

[a] In some instances, conversion of **1** was incomplete; see Experimental Section. [b] Initial ratio. [c] Final ratio. [d] Aqueous workup returns **1f**.

Encouraged by these results, the metalation-silylation of other selected aldehyde OSC was undertaken (Table I).

(1) (a) Arseniyadis, S.; Kyler, K. S.; Watt, D. S. *Org. React.* **1984**, *31*, 1. (b) Albright, J. D. *Tetrahedron* **1983**, *39*, 3207. (c) Ager, D. J. *Chem. Soc. Rev.* **1982**, *11*, 493. (d) Deuchert, K.; Hertenstein, U.; Hünig, S.; Wehner, G. *Chem. Ber.* **1979**, *112*, 2045.

(2) The metalation and subsequent alkylation of *O*-(1-ethoxyethyl) cyanohydrins of saturated aldehydes proceed in a straightforward manner: Stork, G.; Maldonado, L. *J. Am. Chem. Soc.* **1971**, *93*, 5286.

(3) The metalation-silylation of the OSC of α,β-unsaturated aldehydes has been reported: Hünig, S.; Oller, M. *Chem. Ber.* **1980**, *113*, 3803.

(4) Wright, A.; West, R. *J. Am. Chem. Soc.* **1974**, *96*, 3214.

(5) Cunico, R. F.; Kuan, C. P. *Tetrahedron Lett.* **1990**, *31*, 1945.

(6) LDA and TMSCl are reported to be mutually unreactive at -78 °C: Corey, E. J.; Gross, A. W. *Tetrahedron Lett.* **1984**, *25*, 495.

(7) For a description of the acid-catalyzed hydrolysis of ketone OSC see Gassman, P. G.; Talley, J. J. *Tetrahedron Lett.* **1978**, 3773.

(8) This is in concert with the finding that **2f** does not appear to undergo O to C silyl group migration. See ref 1d. Efforts to convert **5a**, or its progenitor, **3a**, into acetyltrimethylsilane were unsuccessful.

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However, when monosilylation of the parent OSC (**1b**)[9] was attempted, conversion was incomplete, and a 3:1 mixture of **3b** and **6** was obtained. The formation of *N*-silylketenimines from the silylation of nitrile carbanions under sterically demanding conditions is precedented,[10] and the present results could be interpreted on the basis of a metalation rate for **3b** competitive with that of **1b**.[11] Nevertheless, subsequent experimentation indicated that **3b** was inert under these conditions, presumably due to steric factors. The simplest explanation for these observations is to postulate the N-silylation of carbanion **2b** to form **4b**. The latter may be kinetically more acidic than **3b** and thus proceed quickly to **6** by additional metalation–silylation (Scheme II). In any event, **3b** was prepared efficiently by exhaustive metalation–silylation of **1b** to form a 15:85 mixture of **3b** and **6**, followed by methanolysis (N–Si bond cleavage) to give only **3b**.

Attention then turned to the OSC of higher aldehydes (**1c–f**). Initial experiments (with **1c**) indicated that the metalation–silylation of these species was considerably slower than that of **1a**, and TMEDA was used to accelerate these reactions.[12] Similarly, the inclusion of an extra equivalent of TMSCl was seen to result in a moderate rate acceleration (with **1e**),[13] and this ratio was then extended to certain other runs. Regiochemical results (**3** vs **4**) were very individualistic (Table I), ranging from all *C*-silyl product (**3d**) obtained from **1d** to mostly *N*-silyl product (**4c**) from **1c**. The straight-chain OSC (**1e**) was intermediate in its behavior, at first producing a mixture of 60% *C*-silyl (**3e**) and 40% *N*-silyl (**4e**) product. Upon allowing this reaction mixture to stand at 25 °C for 5 days, **4e** isomerized to **3e**, leading to a **3e**:**1e** mixture (84:16) representing a 72% yield of **3e**. The use of 2 equiv *each* of LDA and TMSCl per equivalent of **1c** or **1e** led to isolation of the LDA adducts (**7**)[14] of the corresponding *N*-silylketenimines **4**. Thus, under these conditions, **1c** was converted to **7c**, and **1e** afforded a 60:40 mixture of **3e** and **7e** (paralleling the 60:40 **3e**:**4e** product ratio obtained using 1:2 LDA:TMSCl).

The behavior of **1f**, the OSC of benzaldehyde, toward metalation–silylation was exceptional. Although near-quantitative formation of the organolithium **2f** has been reported using LDA,[1d] we observed no silylation of **2f** upon addition of one equivalent of TMSCl.[15] However, treating **2f** with 2 equiv of TMSCl led to high yields of **3f**.[16,17] In an attempt to probe this unusual behavior, reaction mixtures containing only 1 equiv of TMSCl, initially at −78 °C, were treated in several ways: (a) derivatization with methyl iodide at −40 °C or, alternatively, after overnight at 25 °C, gave only[18] the C-methylated product (OSC of acetophenone); (b) derivatization with an additional equivalent of TMSCl at −20 °C gave **3f**; (c) a run which was allowed to warm to 25 °C was examined by IR spectroscopy after 2 h. A band at 2095 (2070 sh) cm^{-1} was present which had characteristics similar to those reported for a THF solution of lithiated phenylacetonitrile (2090, 2070 sh cm^{-1}).[19] These results strongly suggest that **2f** coexists with TMSCl as long as the latter is in a 1:1 ratio with (initial) LDA but retains its nucleophilicity towards additional electrophiles. We know of no precedent for this behavior, and it contrasts markedly with the apparently facile silylation (−78 °C, 1 equiv of TMSCl) of those **2** derived from saturated aldehydes. HSAB theory[20] offers only a partial rationalization for this phenomenon, in that the rate of reaction of the hard acid TMSCl with **2f** should be slower than that of aliphatic analogues because of the more delocalized ("softer") anion of the former.

With respect to the regiochemistry of silylation (C vs N) of **2**, the observed isomerization of **4e** (→**3e**) illustrates that, in this instance, the initial product distribution is at least partially kinetically determined. In fact, it seems reasonable to assume that crowded examples of the anion **2** should favor silylation at the less-hindered nitrogen terminus, possibly followed by partial or total isomerization to the *C*-silyl isomer. The behavior of **1f**, which affords only C-silylated product with 1 equiv of LDA, was examined in the presence of 2 equiv of LDA and slightly more than 2 equiv of TMSCl. The latter establishes conditions under which anion **2f** should undergo silylation, and the former affords the possibility that LDA could add to a transient *N*-silylketenimine (compare the behavior of **1c** and **1e**, above). Indeed, the adduct **7f** was identified as the sole product of this reaction,[21] suggesting that under "normal" conditions (1 equiv of LDA), **4f** is initially formed, but isomerizes rapidly to **3f** under the reaction conditions.

Differentiation between *C*-silyl products **3** and *N*-silylketenimines **4** was made on the basis of IR and NMR data. The ν(CN) band in **3** was weak (ca. one-third of C–H stretch for **3e**) and located at 2210–2220 cm^{-1}, whereas the ketenimine absorption in **4** was strong (equal to C–H stretch in **4e**) and located at 2020–2030 cm^{-1}.[22] ^1H NMR spectra of both **3** and **4** displayed $SiMe_3$ absorptions in the δ 0.1–0.2 range, but those of the latter bracketed those of the former, allowing for quantitation of such mixtures. Very indicative were ^{13}C NMR absorptions for CN (δ 121.7 for **3e**) vs C=C=N (δ 214.5 for **4e**) and COSi absorptions of δ 70.2 and δ 102.1, respectively.

Experimental Section

NMR spectra were obtained using $CDCl_3$ solutions ($CHCl_3$ taken as δ 7.24) and a Brucker WP 200SY spectrometer. Except as noted, IR spectra were determined on neat films. VPC analyses utilized a 2 ft × 0.25 in. 20% SE-30 column at the indicated temperature. Samples for combustion analysis were obtained by preparative VPC. Column chromatography employed 70–230-mesh silica gel 60 or 100-mesh Florisil. Oven temperatures are listed for Kugelrohr distillations. All reactions were carried out under positive argon pressure. THF was distilled from sodium benzophenone ketyl immediately before use. The known OSC

(9) The preparation of **1b** has been reported (Evans, D. A.; Truesdale, L. K.; Carroll, G. L. *J. Chem. Soc., Chem. Commun.* **1973**, 55), but in our hands proved slow to form. See the Experimental Section for an improved procedure.

(10) Watt, D. S. *Synth. Commun.* **1974**, *4*, 127.

(11) The trimethylsilyl group is known to enhance the acidity of an α-proton. See: Wetzel, D. M.; Braumann, J. I. *J. Am. Chem. Soc.* **1988**, *110*, 8333 and references therein.

(12) Addition of TMEDA increases the kinetic acidity of triphenylmethane toward LDA some 40-fold: Fraser, R. R.; Mansour, T. S. *Tetrahedron Lett.* **1986**, *27*, 331.

(13) Whether this reflects a concentration effect or a hightened reactivity for "LDA-uncomplexed" TMSCl (see later) is unknown.

(14) Indicated stereochemistry assumed on the basis of previous considerations: Cunico, R. F.; Kuan, C. P. *J. Org. Chem.* **1990**, *55*, 4634.

(15) Use of the reported[1d] alternative generation of **2f** using *n*-butyllithium led, after addition of TMSCl, to a complex mixture containing no significant amounts of **3f**.

(16) Use of between 1 and 2 equiv of TMSCl led to corresponding intermediate yields of **3f**.

(17) We are aware of an earlier instance in which an LDA:chlorosilane ratio of 1:2 was used to metalate–silylate nitriles,[10] but no rationale for this ratio was presented.

(18) Some starting **1f** was also present.

(19) Juchnovski, I. N.; Binev, I. G. *J. Organomet. Chem.* **1975**, *99*, 1.

(20) Ho, T. L. *Chem. Rev.* **1975**, *75*, 1. It is unclear how N–Si coordination would alter these considerations. See: Corriu, R. J. P. *J. Organomet. Chem.* **1990**, *400*, 81.

(21) No **7f** was formed when **3f** was treated similarly with LDA and TMSCl.

(22) Similar values have been reported for other known *N*-silylketenimines; see refs 4 and 10.

1a, 1c, 1d, and 1f were prepared using the method of Duboudin, et al.[23]

General Procedure for Metalation–Silylation of 1 To Form 3. LDA solutions were prepared by dropwise addition of an equimolar amount of 2.5 N *n*-butyllithium in hexane to a THF solution of diisopropylamine held at −78 °C. These solutions were utilized after 15–20 min at this temperature by slowly adding a solution of 1 and TMSCl in THF precooled to −78 °C.[24] After addition, reaction mixtures were kept at −78 °C for between 2 and 12 h and then allowed to slowly warm to 25 °C. The term "anhydrous workup" indicates that the reaction mixture was evacuated at 1 mmHg (25 °C), pentane was added, and the mixture was filtered by glass frit under argon. The term "aqueous workup" indicates that the reaction mixture was partitioned between pentane and water, and the organic phase washed with dilute $NaHCO_3$ and saturated NaCl solution, dried (anhydrous $MgSO_4$), and concentrated.

2-[(Trimethylsilyl)oxy]ethanenitrile (1b). A mixture of 1,3,5-trioxane (2.64 g, 29.3 mmol), cyanotrimethylsilane (8.7 g, 88 mmol), and 0.15 g (0.47 mmol) of ZnI_2 was stirred for 1 day, followed by addition of an additional 0.15 g of ZnI_2. After another day, no trioxane remained and direct distillation gave 10.2 g (90%) of **1b**, bp 148–149 °C (760 mm). If more ZnI_2 is added initially, a strongly exothermic reaction ensues.

2-[(Trimethylsilyl)oxy]octanenitrile (1e). To a solution of sodium iodide (2 g) in acetonitrile (40 mL) was added potassium cyanide (5.2 g, 80 mmol), TMSCl (8.7 g, 80 mmol), and pyridine (0.8 g). The mixture was stirred overnight, and then heptanal (8.7 g, 95% pure, 72 mmol) was added. After 20 h at 25 °C, an aqueous workup was followed by distillation (6 in Vigreux column) to give 1.9 g of recovered aldehyde and 7.7 g of **1e**, bp 85–87 °C (0.3 mm), which VPC (130 °C) indicated was 95% pure. IR: 1260 cm^{-1}. ^1H NMR: δ 0.16 (s, 9 H), 0.85 (m, 3 H), 1.2–1.5 (m, 8 H), 1.74 (m, 2 H), 4.35 (t, 1 H). ^{13}C NMR: δ −0.5, 13.9, 22.4, 24.4, 28.5, 31.5, 36.2, 61.4, 120.0. Anal. Calcd for $C_{11}H_{23}NOSi$: C, 61.91; H, 10.86; N, 6.56. Found: C, 61.49; H, 10.48; N, 6.24.

2-(Trimethylsilyl)-2-[(trimethylsilyl)oxy]propanenitrile[4] (3a). A solution of **1a** (2.9 g, 20 mmol) in THF (25 mL) was added to a mixture of LDA (24 mmol) and TMSCl (24 mmol) in THF (50 mL). After 1 h, aqueous workup followed by short-path distillation gave 3.8 g (84%) of 94% pure **3a**, bp 64–70 °C (5 mm).

2-Hydroxy-2-(trimethylsilyl)propanenitrile (5a). A mixture of **3a** (0.45 g), ether (20 mL), and 3 N HCl (10 mL) was stirred at 25 °C overnight.[25] After an aqueous workup, Kugelrohr distillation gave 0.25 g (83%) of **5a** (65–70 °C, 8 mm). Sublimation (60 °C, 760 mm) afforded an analytical sample with mp 46.5–48.0 °C. IR: 3420 (s), 2240 (m), 1260 (s) cm^{-1}. ^1H NMR: δ 0.18 (s, 9 H), 1.54 (s, 3 H), 2.85 (br s, 1 H). ^{13}C NMR: δ −5.0, 23.3, 59.9, 123.1. Anal. Calcd for $C_6H_{13}NOSi$: C, 50.30; H, 9.15; N, 9.78. Found: C, 50.40; H, 9.27; N, 9.89.

2-Hydroxy-2-(triethylsilyl)propanenitrile. A solution of **1a** (0.8 g, 5 mmol) and triethylchlorosilane (0.83 g, 5.5 mmol) in THF (15 mL) was added to LDA (5.5 mmol) in THF (15 mL). After 2 h at −78 °C and overnight at 25 °C, an anhydrous workup afforded a crude product which was combined with ether (20 mL) and 3 N HCl (10 mL) and stirred at 25 °C for 2 days. Aqueous workup followed by chromatography on silica gel (5% ether–hexane) gave 0.9 g of 2-(triethylsilyl)-2-[(trimethylsilyl)oxy]-propanenitrile[4] and 0.3 g of the title compound as analytically pure liquid. IR: 3430 (s), 2215 (m). ^1H NMR: δ 0.72 (q, 9 H), 1.07 (t, 6 H), 1.59 (s, 3 H), 2.37 (s, 1 H). ^{13}C NMR: δ 1.3, 7.2, 24.6, 59.8, 123.5. Anal. Calcd for $C_9H_{19}NOSi$: C, 58.32; H, 10.33; 7.56. Found: C, 58.38; H, 10.48; N, 7.52.

1,3-Bis(trimethylsilyl)-3-[(trimethylsilyl)oxy]-1-azapropadiene (6). A solution of **1b** (0.65 g. 5.0 mmol) and TMSCl (2.6 g, 24 mmol) in THF (25 mL) was added to LDA (12 mmol) in THF (25 mL). After 9 h at −78 °C and overnight at 25 °C, anhydrous workup followed by Kugelrohr distillation gave 1.2 g of material (60–79 °C, 1 mm) which VPC (120 °C) indicated contained 85% (75% yield) of **6** and 15% (18% yield) of **3b**. IR (**6**): 2020 (s), 1255 (s) cm^{-1}. ^1H NMR: δ 0.7 (s, 9 H), 0.11 (s, 9 H), 0.23 (s, 9 H). ^{13}C NMR: δ −1.8, −0.6, 0.2, 81.5, 196.3. Anal. Calcd for $C_{11}H_{27}NOSi_3$: C, 48.28; H, 9.95; N, 5.12. Found: C, 48.39; H, 9.80; N, 5.16.

2-(Trimethylsilyl)-2-[(trimethylsilyl)oxy]ethanenitrile (3b). A solution of **1b** (3.25 g, 25 mmol) and TMSCl (6.0 g, 55 mmol) in THF (25 mL) was added to LDA (55 mmol) in THF (50 mL). After 9 h at −78 °C and overnight at 25 °C, the mixture was cooled to 0 °C and methanol (3 mL, 74 mmol) added dropwise. After 2 h at 25 °C, anhydrous workup followed by distillation (6 in Vigreux) gave 4.15 g (82%) of **3b**, bp 50–51 °C (1 mm) which VPC (80 °C) showed was over 95% pure. IR: 2960 (m), 2900 (w), 2210 (w), 1400 (w), 1305 (w), 1255 (s), 1245 (w), 1060 (s), 850 (s), 760 (m), 695 (w) cm^{-1}. ^1H NMR: δ 0.16 (s, 9 H), 0.17 (s, 9 H), 4.00 (s, 1 H). ^{13}C NMR: δ −4.5, −0.6, 53.7, 120.4. Anal. Calcd for $C_8H_{19}NOSi_2$: C, 47.71; H, 9.51; N, 6.95. Found: C, 47.77; H, 9.69; N, 7.10.

3-Methyl-2-(trimethylsilyl)-2-[(trimethylsilyl)oxy]butanenitrile (3c) and 4-Methyl-1-(trimethylsilyl)-3-[(trimethylsilyl)oxy]-1-azapenta-1,2-diene (4c). A solution of **1c** (2.14 g, 12.5 mmol) and TMSCl (1.5 g, 13.8 mmol) in THF (25 mL) was added to LDA (13.8 mmol) and TMEDA (1.60 g, 13.8 mmol) in THF (25 mL). After 2 h at −78 °C and 25 °C overnight, anhydrous workup was followed by short-path distillation to give 2.73 g (90%) of silylated product, bp 46–52 °C (0.1 mm), which VPC (100 °C) indicated to be a 1:9 (**3c**:**4c**) mixture. **3c**. IR: 2220 cm^{-1}. ^1H NMR: δ 0.18 (s, 9 H), 0.20 (s, 9 H), 1.00 (d, J = 3.5 Hz, 3 H), 1.03 (d, J = 3.5 Hz, 3 H), 2.04 (m, 1 H). ^{13}C NMR: δ −2.4, 1.8, 18.5, 18.7, 35.9, 70.2, 121.7. Anal. Calcd for $C_{11}H_{25}NOSi_2$: C, 54.26; H, 10.35; N, 5.75. Found: C, 54.38; H, 10.41; N, 5.62. **4c**. IR: 2030 cm^{-1}. ^1H NMR: δ 0.12 (s, 9 H), 0.22 (s, 9 H), 0.96 (d, J = 6.7 Hz, 6 H), 2.39 (septet, J = 6.7 Hz, 1 H). ^{13}C NMR: δ −0.8, 0.1, 20.0, 29.3, 102.1, 214.5. Anal. Found: C, 54.32; H, 10.47; 5.65.

3-Methyl-1-[bis(1-methylethyl)amino]-1-[bis(trimethylsilyl)amino]-2-[(trimethylsilyl)oxy]-1-butene (7c). A solution of **1c** (0.18 g, 1.1 mmol) in THF (5 mL) was added to LDA (2.2 mmol) and TMSCl (0.26 g, 2.2 mmol) in THF (5 mL). After 2 h at −78 °C and overnight at 25 °C, an anhydrous workup gave 0.5 g of **7c** which VPC (150 °C) and NMR analysis indicated to be 90% pure. IR: 1250 (s), 1260 (s) cm^{-1}. ^1H NMR: δ 0.17 (s, 18 H), 0.24 (s, 9 H), 1.00 (d, J = 7.0 Hz, 6 H), 1.15 (d, J = 6.8 Hz, 12 H), 2.93 (septet, J = 7.0 Hz, 1 H), 3.47 (septet, J = 6.8 Hz, 2 H). ^{13}C NMR: δ 3.0, 3.5, 20.3, 24.3, 30.0, 48.5, 133.0, 136.0. Anal. Calcd for $C_{20}H_{48}N_2OSi_3$: C, 57.62; H, 11.61; N, 6.72. Found: C, 57.68; H, 11.85; N, 6.53.

3-Phenyl-2-(trimethylsilyl)-2-[(trimethylsilyl)oxy]-propanenitrile (3d). A solution of **1d** (6.9 g, 31 mmol) and TMSCl (7.5 g, 69 mmol) in THF (100 mL) was added to LDA (69 mmol) and TMEDA (8.0 g, 69 mmol) in THF (60 mL). After 12 h at −78 °C and overnight at 25 °C, an aqueous workup afforded 8.4 g of material, bp 98–140 °C (0.1 mm) which VPC (165 °C) indicated was 90% **3d** (84% yield) and 10% **1d**. Anhydrous workup of a separate run showed the same ratio of **3d**:**1d**. IR: 2220 cm^{-1}. ^1H NMR: δ −0.14 (s, 9 H), 0.18 (s, 9 H), 2.92 (s, 2 H), 7.29 (s, 5 H). ^{13}C NMR: δ −4.2, 1.0, 42.7, 65.8, 121.6, 127.3, 128.3, 130.8, 135.7. Anal. Calcd for $C_{15}H_{25}NOSi_2$: C, 61.80; H, 8.64; N, 4.80. Found: C, 61.83; H, 8.62; N, 4.88.

2-(Trimethylsilyl)-2-[(trimethylsilyl)oxy]octanenitrile (3e). A solution of **1e** (5.1 g, 24 mmol) and TMSCl (5.6 g, 52 mmol) in THF (55 mL) was added to LDA (28 mmol) and TMEDA (3.6 g, 28 mmol) in THF (55 mL). After 10 h at −78 °C and overnight at 25 °C, an aliquot showed complete conversion of **1e** to a 60:40 (**3e**:**4e**) mixture. After 5 more days at 25 °C, **4e** had completely isomerized to **3e** with concomitant production of some **1e**. An aqueous workup followed by short-path distillation gave 5.88 g of material, bp 70–76 °C (0.2 mm), which ^1H NMR analysis indicated consisted of 84% (72% yield) of **3e** and 18% **1e**. Isolation of **3e** from **3e**/**1e** mixtures could be effected by the following procedure. To 0.5 g of a **3e**/**1e** mixture containing ca. 0.25 g of **3e** was added methanol (0.75 mL) and acetic acid (0.05 mL), and the mixture was stirred for 28 h at 25 °C. After an aqueous workup, silica gel chromatography (5% ether–hexane) gave 0.2 g of **3e**. IR: 2220 cm^{-1}. ^1H NMR: δ 0.14 (s, 9 H), 0.19 (s, 9 H), 0.88 (m, 3 H), 1.15–1.6 (m, 8 H), 1.70 (m, 2 H). ^{13}C NMR: δ −4.0,

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(24) The same results were obtained if TMSCl was first added to the LDA solution at −78 °C, followed by addition of 1 cooled to −78 °C. Complex mixtures were generally obtained if precooling of 1 was omitted.

(25) Hydrolysis was substantially complete after 1 h.

1.6, 14.0, 22.5, 25.0, 29.4, 31.6, 37.5, 65.5, 122.1. Anal. Calcd for $C_{14}H_{31}NOSi_2$: C, 58.88; H, 10.94; N, 4.90. Found: C, 59.03; H, 10.99; N, 4.97.

1-[Bis(1-methylethyl)amino]-1-[bis(trimethylsilyl)-amino]-2-[(trimethylsilyl)oxy]-1-octene (7e). A solution of **1e** (0.21 g, 1.0 mmol) in THF (5 mL) was added to LDA (2.2 mmol), TMEDA (2.2 mmol), and TMSCl (2.2 mmol) in THF (5 mL). After 2 h at −78 °C and overnight at 25 °C, an anhydrous workup afforded a 60:40 mixture of **3e:7e**, as deduced from spectral data. IR: 1255 (s), 1265 (s) cm^{-1}. ^1H NMR: δ 0.14 (s, 18 H), 0.18 (s, 9 H), 0.87 (m, 3 H), 1.19 (d, J = 7 Hz, 6 H), 1.2–1.55 (m, 8 H), 2.12 (m, 2 H), 3.47 (septet, J = 7 Hz, 2 H). ^{13}C NMR: δ 2.2, 3.1, 14.1, 22.7, 24.6, 27.3, 29.8, 31.8, 33.9, 49.4, 133.4, 133.9.

2-Phenyl-2-(trimethylsilyl)-2-[(trimethylsilyl)oxy]-ethanenitrile (3f). A solution of LDA (0.16 mol) in THF (250 mL) at −78 °C was treated with **1f** (30.0 g, 0.146 mol) followed by TMSCl (35.0 g, 0.32 mol). **1f** and TMSCl were added neat and not precooled. After overnight at 25 °C, an anhydrous workup followed by short-path distillation gave 37.4 g of **3f**, bp 71–84 °C (0.2 mm), which VPC (120 °C) showed to be over 95% pure (88% yield). IR: 2220 (w), 1600 (w), 1250 (s) cm^{-1}. ^1H NMR: δ 0.08 (s, 9 H), 0.15 (s, 9 H), 7.32 (m, 5 H). ^{13}C NMR: δ −4.9, 1.0, 69.2, 121.4, 124.4, 127.0, 128.2, 138.7. Anal. Calcd for $C_{14}H_{23}NOSi_2$: C, 60.59; H, 8.35; N, 5.05. Found: C, 60.60; H, 8.25; N, 4.92.

In another experiment, a solution of LDA (2.4 mmol) in THF (10 mL) was treated at −78 °C with **1f** (0.44 g, 2.1 mmol) and then with TMSCl (0.26 g, 2.4 mmol). Two hours after the mixture was allowed to warm to 25 °C, the solution was concentrated under vacuum to ca. 2 mL. A sample was then withdrawn by syringe under argon and its IR spectrum obtained (vs THF) in matched cells (0.1 mm). The spectrum showed a band at 2095 (2070 sh) cm^{-1} with A = 1.1.

1-[Bis(1-methylethyl)amino]-1-[bis(trimethylsilyl)-amino]-2-phenyl-2-[(trimethylsilyl)oxy]ethene (7f). To a mixture of LDA (8.8 mmol) and TMEDA (1.33 mL, 8.8 mmol) in THF (20 mL) at −78 °C were added **1f** (0.88 g, 4.0 mmol) and TMSCl (1.22 mL, 9.6 mmol) sequentially. After overnight at 25 °C, TMSCl (0.8 mL, 6.4 mmol) was added, and the mixture was worked up (anhydrous) after 2 h to give 1.68 g of crude material which NMR analysis indicated contained **7f** together with a small amount of **1f** and other $SiMe_3$-containing impurities. Kugelrohr distillation (middle cut, 90–110 °C, 0.2 mm) afforded a sample for spectral data. ^1H NMR: δ −0.17 (s, 9 H), 0.22 (s, 18 H), 0.85 (d, J = 7.0 Hz, 12 H), 3.54 (septet, J = 7.0 Hz, 2 H), 7.0–7.5 (m, 5 H). ^{13}C NMR: δ 2.1, 2.9, 24.3, 51.1, 127.4, 127.9, 132.4, 132.8, 137.1, 139.3. Due to air-sensitivity and high molecular weight, further purification of **7f** proved difficult. Preparative VPC (2 ft × 0.25 in. 3% SE-30, 180 °C, 1 h retention time) afforded an analytical sample which NMR analysis indicated had undergone partial isomerization to a 2:1 mixture of **7f** and its geometrical isomer [^1H NMR: −0.14 (s, 9 H), −0.06 (s, 18 H), 1.30 (d, J = 7.0 Hz, 12 H), 3.58 (septet, J = 7.0 Hz, 2 H), 7.0–7.35 (m, 5 H)]. Anal. Calcd for $C_{23}H_{46}N_2OSi_3$: C, 61.27; H, 10.28; N, 6.21. Found: C, 62.03; H, 9.78; N, 6.24.

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Diterpenoids from the Gorgonian *Solenopodium stechei*

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Twenty-five new diterpenoids with representatives from three skeletal classes, briareins, eunicellins, and cembranes, have been isolated from a Pacific gorgonian, *Solenopodium stechei*. The structural diversity of the diterpenoids isolated indicates significant biosynthetic versatility for this gorgonian. Stecholides **1–20** are diterpene lactones of the briarein family distinguished by the presence of an α,β-epoxide group in the lactone ring. These structures were deduced by spectroscopic analyses. The structure of solenopodin D, **24**, a eunicellin-type diterpenoid, was established by X-ray analysis while the structures of three other solenopodins, **20–23**, were confirmed by spectral analyses and comparison to data for **24**. Solenopodins A–D are the only eunicellin-type diterpenoids isolated to date which do not have an ether bridge across the 10-membered carbocyclic ring. Only one cembranoid, **25**, was isolated. Diterpenoids **1**, **3**, and **20** show cytotoxicity to murine leukemia cells (P388).

Gorgonians (order Gorgonacea, phylum Cnidaria) and soft corals (Alcyonacea, phylum Cnidaria), have proven to be rich sources of terpenoids.[2] As part of our continuing search for bioactive compounds we have studied the encrusting Indopacific gorgonian *Solenopodium stechei* which was collected at Dalton Reef on the Great Barrier Reef off Australia. Taxonomically, the genus *Solenopodium* is very difficult to distinguish from the Caribbean *Briareum* genus[3] which has yielded a variety of diterpenoids, the majority of which belong to the diterpene skeletal class first observed in briarein-A obtained from *Briareum asbestinum*.[4] In addition to species of the genus *Briareum*, briareins have also been isolated from one species of soft coral (*Minabea* sp.),[5] several sea pens (Pennatulaceae),[6-12] and the sea pansy *Renilla*.[13]

An earlier report on another *Solenopodium* sp. collected in the vicinity of Palau described a group of six briarein-type diterpenes.[14] The present study resulted in the

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