Charge Delocalization in Persistent Benz[*a*]anthracenium Cations BAH$^+$ and Related α-Carbocations/Carboxonium Ions: Modeling Epoxide Ring Opening in Potent Carcinogens

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Parent BA **1** protonates at C-7/C-12 to give **1H**$^+$ and **1aH**$^+$ in 3:1 ratio which remains unaffected by variation in temperature and the superacid system. Increasing steric crowding at the bay-region by introduction of a methyl at C-1 (1-MBA) changes the ratio of C-7/C-12 protonated arenium ions **2H**$^+$/**2aH**$^+$ to 10:1. The highly potent 7,12-dimethylbenz[*a*]anthracene, 7,12-DMBA, gives a 1:1 mixture of the two *ipso*-protonated cations **3aH**$^+$/**3H**$^+$ whose composition changes to 50:1 overtime in favor of **3aH**$^+$ (*ipso*-attack at bay-region), showing it to be the thermodynamic cation. 3-Methylcholanthrene, 3MC, is exclusively protonated at C-6 (→**4aH**$^+$). Cation **5**$^+$ (a simplified model for bay-region epoxide ring opening) is cleanly formed via its carbinol **5-OH** with FSO_3H/SO_2ClF. Ketone **6** is O-protonated in TFAH and in TFAH/H_2SO_4 to give the bay-region carboxonium ion **6H**$^+$; its diprotonation in $FSO_3H{\cdot}SbF_5$ (4:1)/SO_2ClF gave the first example of the oxonium−arenium dication **6H$_2$**$^{2+}$. α-BA-substituted secondary carbocation **7**$^+$ and the carboxonium ion **8H**$^+$ were generated to probe charge delocalization into the α-BA moiety via C-7. To gauge the importance of the benz[*a*] ring and for comparison, the anthracene-substituted carbocations **9**$^+$ and carboxonium ion **10H**$^+$ were generated and studied. Charge delocalization pathways into the PAH periphery are evaluated on the basis of $\Delta\delta^{13}C$ values. AM1 was used as a complementary tool for qualitative comparison with experiment. The resulting arenium ions and benzylic carbocations exhibit strong anthracenium ion character emphasizing the importance of an electron-deficient anthracene moiety. The present study constitutes the first direct investigation of carbocations in the BA series, whose bay-region and K-region diol epoxides are considered the ultimate carcinogens en route to PAH−DNA adduct formation.

Introduction

Whereas benzo[*a*]pyrene played a central role in much of the early development of PAH carcinogenesis and the "bay-region theory", benz[*a*]anthracene BA received attention in numerous subsequent structural/mechanistic, synthetic, and metabolic/binding studies because it exhibits remarkable structure/activity relationships.[1−4]

For the BA skeleton, there is a substantial body of experimental evidence suggesting that the diol epoxide activation path[1−4] and the direct PAH oxidation (→radical cation)[5−7] are both important en route to PAH−DNA adduct formation. The bay-region *anti*- and the *syn*-diol epoxides of **3** show extensive binding to DNA.[7,8] 7,12-DMBA-3,4-dihydrodiol (precursor to bay-region diol epoxide) itself is a potent tumorigen.[7] Extensive solvolytic studies have been carried out on the K-region BA epoxides,[9,10] showing that epoxide reactivity is influenced by distal substituents and that ring opening is more advanced than the new C−O bond forming step, indicative of partial positive charge development on the aromatic moiety. For the 11,12-epoxide of **4** (K-region), the rate-limiting formation of 11-hydroxy-3-methylcholanthrenium ion may be enhanced by inductive stabilization of the incipient delocalized cation.[11]

The X-ray structure of **3** shows that the annelated ring is tilted out of plane (24° buckling between the most distal rings).[12] The K-region 5,6-epoxide of **3** shows 35° buckling between the most distal rings. Epoxide ring-opening reactions of the latter exhibit strong preference for carbocation formation at C-6 (5-OH and 5-OAc formation).[12]

MacLean et al. in 1958 reported a 40 MHz ^{1}H NMR spectrum for **3** dissolved in TFAH/CCl_4 and assigned it to **3aH**$^+$ on the basis of the resemblance of its UV spectrum to that of protonated 7-MBA.[13] Formation of **4aH**$^+$ was previously inferred[14] on the basis of H−D exchange studies in D_2SO_4 which resulted in deuterium uptake at the C-1 methylene, consistent with electrophilic

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attack at C-6. A kinetic study on **3** (in TFAD/CCl_4)[15] showed facile H−D exchange at the 7-Me consistent with *ipso*-attack at C-12.

Tautomerization in suitable derivatives of **3** may generate an *exo*-methylene group at C-7; increased *peri*-strain enhanced tautomerization.[2] For 7,12-DMBA and 3-MC, in the activation model via "positive oxygen" it was suggested that nucleophilic sites may result (*exo*-methylene group) which may undergo electrophilic attack by cellular component to form adducts, in contrast to activation of BP which generates "electrophilic" centers that undergo nucleophilic attack by nucleotides.[14] Attempted synthesis of 6,7,8,12-TMBA gave only the 6,8,12-Me_3-7-CH_2-7,12-DHBA.[2] With 11F-THDMBA, a facile acid-catalyzed tautomerization led to quantitative formation of the 7-*exo*-methylene isomer,[16] with the driving force for attack at C-12 being relief of steric congestion at the bay-region (*peri*-F effect) which must be more important than F-stabilization of the arenium ion of protonation at C-7.

In continuation of our work on PAH arenium ions, α-PAH-substituted carbocations as epoxide ring-opening models, and in a search for possible relationships between certain charge delocalization mode(s) in PAH-arenium ions and in α-PAH-substituted carbocations and magnitude of carcinogenicity,[17−23] we report the first direct study of a series of arenium ions derived from BA exploring the role of substituents and structure in directing electrophilic attack and the charge delocalization mode in the resulting carbocations (Figure 1). To evaluate arenium ion character, carbocations $\mathbf{5}^+$, carboxonium ion $\mathbf{6H}^+$ (and dication $\mathbf{6H_2}^{2+}$) were generated as simplified models of bay-region epoxide ring opening,[24] whereas carbocations $\mathbf{7}^+$, $\mathbf{9}^+$, and carboxonium ions $\mathbf{8H}^+$ and $\mathbf{10H}^+$ were generated as models of benzylic carbocation formation (at C-7), which bear some relationship to cholanthrylene−epoxide ring opening (Figure 2) (see ref 24 for details regarding the analogy). Finally, we briefly examine whether a carbocation-based model can accommodate the reported biological activity of various alkyl and dialkyl (and fluoro) derivatives of BA.

Results and Discussion

NMR Assignments of the Carbocations and Their Precursors (Figures 3−6). Detailed NMR assignments were based on the ^{13}C, ^1H, H/H COSY, H/C HETCOR, and NOED spectral data. Depending on the structure, specific assignments of some of the quaternary ring carbons, most of which occurred in a narrow chemical shift range, could not be made; those are listed separately

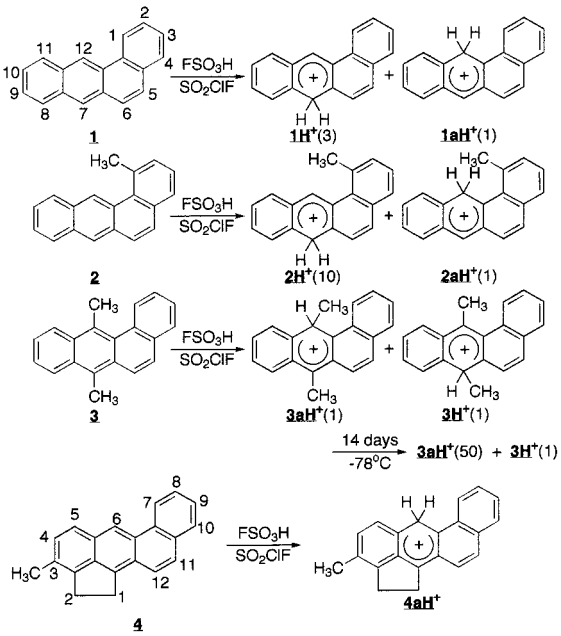

Figure 1. Superacid protonations of benz[*a*]anthracene (**1**), 1-methylbenz[*a*]anthracene (**2**), 7,12-dimethylbenz[*a*]anthracene (**3**), and 3-methylcholanthrene (**4**).

(Figures 3 and 7). The Δδ values (in parentheses) provide a general measure of the charge delocalization mode.[23,25,26] NMR data for the precursors are not listed separately and can be derived by taking into account Δδ values (those for the carbinols and the acetyl derivatives are listed in the Experimental Section). The following observations in the NMR spectra of neutrals should be mentioned:

For parent **1**, irradiation of the distinct H-12 and H-7 singlets (δ 9.10 and 8.29) resulted in NOE enhancement at H-1/H-11 and at H-6/H-8, respectively. This NOE effect was also seen in **2**, where irradiation of H-12 (δ 9.34) caused NOE at H-11 and at the methyl (δ 3.24) which also showed a NOE effect with H-2; furthermore irradiation of H-7 (δ 8.33) led to a NOE effect at H-6/H-8. In **3**, the NOE effect was observed for 7-Me (δ 3.01) and 12-Me (δ 3.30). The same effect was detected in **4**, where NOE was observed between H-6 (δ 8.87) and H-5/H-7 and between 1-CH_2/H-12. A similar effect in carbinol **5** resulted in a NOE effect between H-12 and 1-Me (not OH)/H-11 and between H-7 and H-6/H-8. In the cyclohexenone-fused derivative **6**, H-12 appears at very low field (δ 10.07); this resonance moves upfield (δ 9.63) upon CO protonation (see later discussion). In the *sec*-carbinol **7-OH**, the NOE effect was observed between H-12 (δ 9.01) and H-1/H-11. The MeC**H**(OH) appears as a distinct quartet at δ 6.29, and the OH appears as a broad hump centered around 2.30 ppm with H-8 showing additional coupling (presumably to OH).

In the 7-acetyl derivative **8**, a similar NOE effect was observed (H-12 at δ 9.16 with H-1/H-11); the H-8 resonance had an unexpected appearance showing additional couplings. Similarly for **10**, a NOE effect was observed

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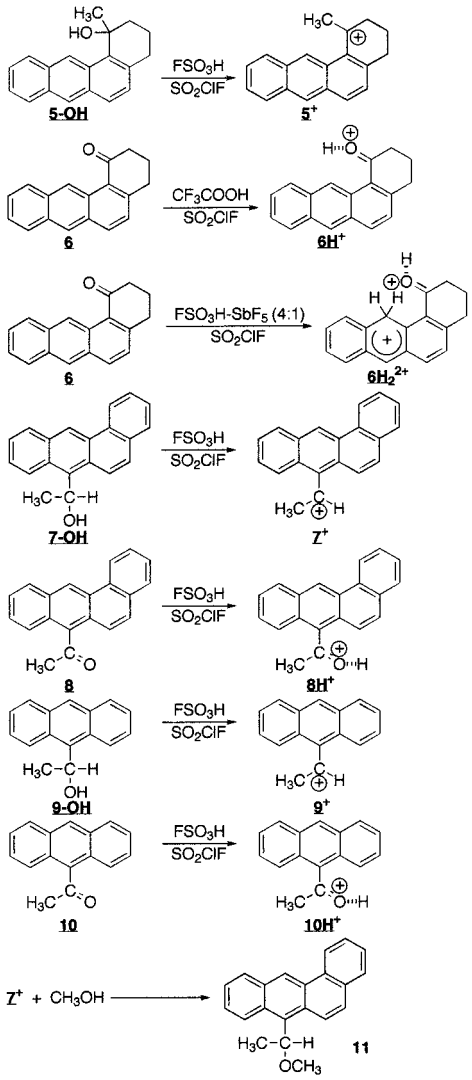

Figure 2. Generation of model carbocations and carboxonium ions.

between *meso* H-10 and the H-4 and the latter exhibited additional "unexpected" coupling. Finally in **9-OH**, NOE was detected between H-10/H-4, but the appearance of aromatic protons was complex.

Overall, the observed NOE effects greatly facilitated specific assignments of the *peri* and "bay-region" hydrogens.

Superacid Protonations (Figures 1−6). (a) Protonation of 1−4. Low-temperature reaction of **1** with FSO_3H/SO_2ClF gave a dark-red solution whose NMR data are consistent with the formation of two arenium ions **1H**$^+$ and **1aH**$^+$ resulting from attack at the *meso* positions (C-7/C-12 respectively in 3:1 ratio). For **1H**$^+$ (at −50 °C), H-12 is at 10.51 ppm and C**H**$_2$ is at 5.29 ppm; for **1aH**$^+$ H-7 is at 9.80 and C**H**$_2$ is at 5.59 ppm. The **1H**$^+$:**1aH**$^+$ ratio was independent of temperature, and efforts to generate pure **1H**$^+$ by protonation even at −120 °C resulted in the same mixture. Attempts to change the ratio by protonation with $FSO_3H{\cdot}SbF_5$ (4:1) again produced the same carbocation mixture.

As a comparison, AM1 predicted that formation of **1H**$^+$ is favored over **1aH**$^+$ by only 1.1 kcal/mol. Charge delocalization pattern deduced from $\Delta\delta(^{13}C)$ values clearly points to extensive delocalization within the anthracene

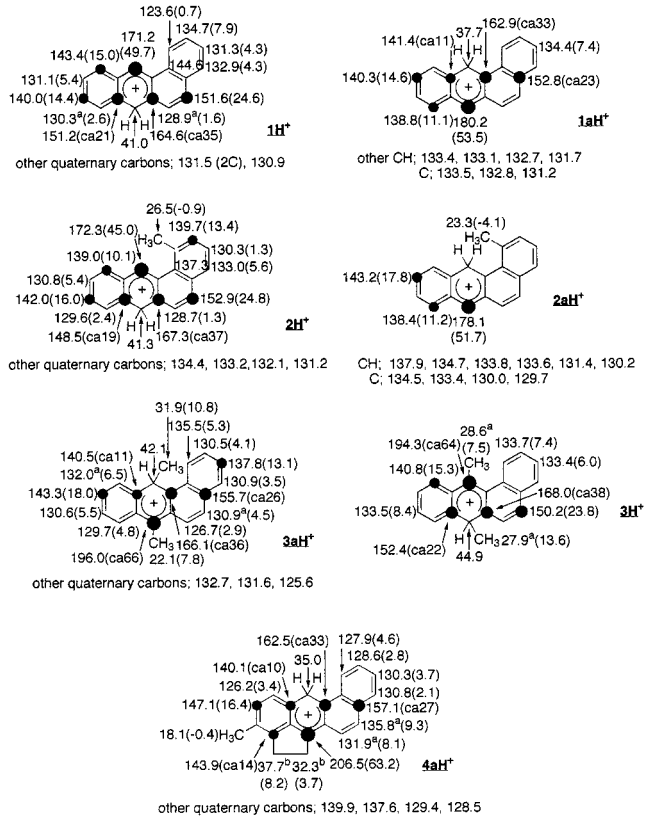

Figure 3. ^{13}C NMR assignments and $\Delta\delta^{13}C$ values for the derived arenium ions. "a" indicates pair of resonances whose assignments may be interchanged.

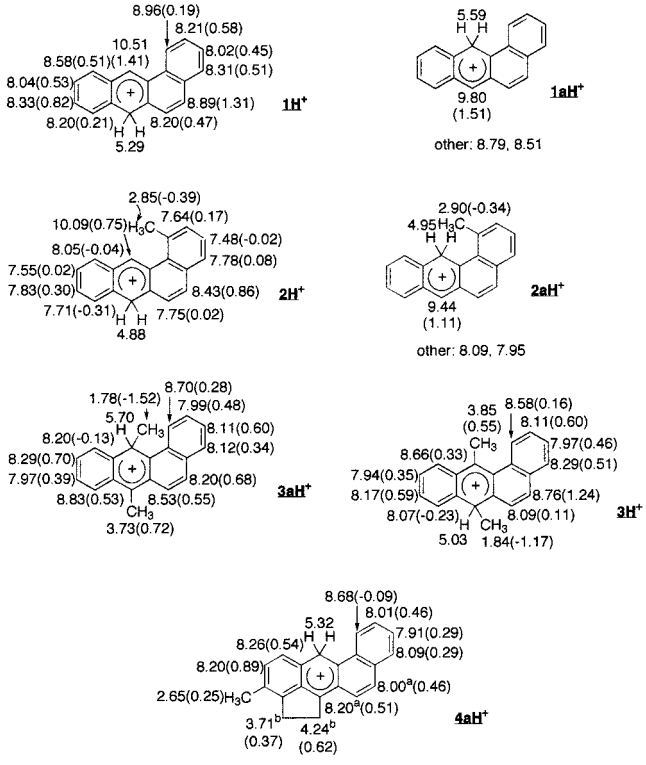

Figure 4. ^1H NMR assignments and $\Delta\delta$ values for the derived arenium ions. "a" and "b" indicate pairs of resonances whose assignments may be interchanged.

moiety and minor delocalization into the annelated ring (mainly at C-2), establishing strong anthracenium ion

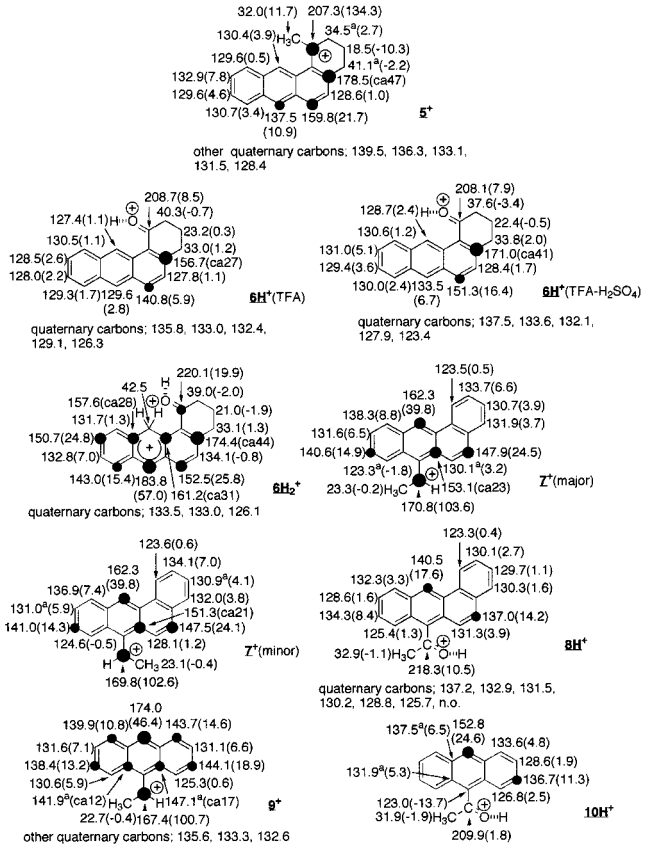

Figure 5. ^{13}C NMR assignments and $\Delta\delta$ values for the carbocations and carboxonium ions. "a" indicates a pair of resonances whose assignments may be interchanged.

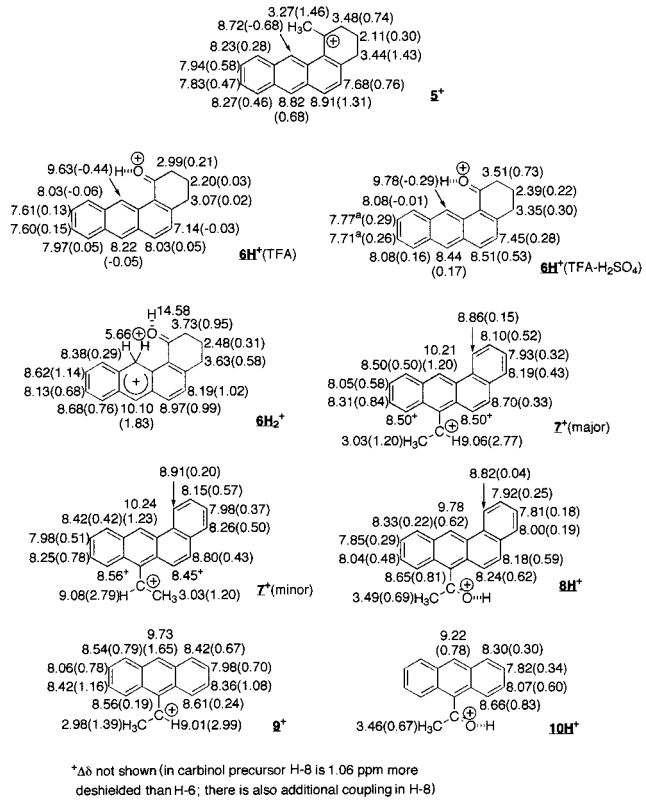

Figure 6. ^{1}H NMR assignments for the carbocations and carboxonium ions.

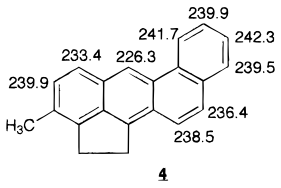

Figure 7. AM1 energies for various arenium ions from the protonation of **4**.

character. Qualitatively, the AM1-derived pattern of changes in carbon charges agree with the NMR-based arguments.[27]

Increasing steric crowding at the bay-region by introducing a methyl group at C-1 directs the attack more strongly to C-7. Thus low-temperature protonation of **2** in FSO_3H/SO_2ClF gave a 10:1 mixture of $\mathbf{2H}^+/\mathbf{2aH}^+$ arenium ions as a dark-red solution. For $\mathbf{2H}^+$(major) irradiation of H-12 (δ 10.09) caused a NOE effect at *peri*-Me/H-11. For both carbocations the methyls are tilted toward the arenium ion periphery and experience anisotropic shielding. Although positive charge resides primarily within the anthracenium moiety (C-12/C-12b/C-5/C-7a/C-9/C-11), C-2 is also noticeably deshielded.

The observed preference for attack at C-7 was not predicted by AM1 which showed $\mathbf{2aH}^+$ to be 0.5 kcal/mol lower in energy.

Low-temperature protonation of **3** with FSO_3H/SO_2ClF resulted in a 1:1 mixture of the arenium ions of attack at the *meso*-positions $\mathbf{3aH}^+$ and $\mathbf{3H}^+$. The same cation mixture (ca. 1:1) was obtained by protonation with $FSO_3H{\cdot}SbF_5$ (4:1)/SO_2ClF (−60 °C).

In the ^{1}H NMR spectrum (−51 °C) coupling of C**H**(**Me**) gives rise to two sets of quartet/doublets. The NOE effect is seen for both carbocations whereby irradiation of the *meso*-methyls gave rise to NOE at "bay-region"/*peri* hydrogens. Cold storage of the sample caused the original mixture to change ($\mathbf{3aH}^+$ increasing at the expense of $\mathbf{3H}^+$). After 4 days at dry ice/acetone temperature the ratio changed to 70:30, and after 14 days $\mathbf{3H}^+$ was barely visible (50:1 ratio), thus establishing $\mathbf{3aH}^+$ as the thermodynamic cation for which steric compression at the bay-region is reduced by rehybridization at C-12, with the methyl group sitting over the aromatic periphery and experiencing strong anisotropic shielding. Methyl geometrical change and tilting also occurs in $\mathbf{3H}^+$ but to a lesser degree.

In concert with experiment, AM1 predicted $\mathbf{3aH}^+$ to be more stable than $\mathbf{3H}^+$ (by 2.31 kcal/mol). The charge delocalization patterns for both arenium ions emphasize the importance of the anthracenium ion moiety with limited delocalization into the annelated ring.

The low-temperature reaction of **4** under similar conditions resulted in clean formation of a single arenium ion by protonation at the *meso* position (C-6) to give $\mathbf{4H}^+$ for which the overall pattern of charge delocalization remains very similar to that in $\mathbf{3aH}^+$. For comparison, the relative energies of arenium ions of protonation at nine available ring positions of **4** were computed by AM1 (Figure 7). In agreement with experiment, C-6 was most favored followed by C-5. The former produced a charge delocalization pattern which was ethanoanthracenium ion like, whereas the latter had ethanonaphthalenium ion character.

(27) For previous examples and limitations of AM1, see refs 17, 18, 22, and 23 and related references therein.

(b) Carbocations and Carboxonium Ions. Carbocation $\mathbf{5}^+$ was generated to model bay-region epoxide ring opening and charge delocalization from C-1. Thus carbinol **5** was reacted with FSO_3H/SO_2ClF at dry ice−acetone temperature resulting in a dark-green solution. The NMR spectra showed clean generation of the carbocation with C^+ at 207.3 ppm with the charge delocalized primarily into three conjugated carbons (C-4a/C-6/C-7). The ring protons are all deshielded relative to **5-OH** except for H-12 which is shielded; a NOE effect was observed between this proton and H-11/1-Me and between H-7 and H-6/H-8. Low-temperature reaction of **5-OH** with $FSO_3H{\cdot}SbF_5$ (4:1)/SO_2ClF did not result in a dication by ring protonation; only $\mathbf{5}^+$ was cleanly reproduced.

Carboxonium ion $\mathbf{6H}^+$ is readily formed by protonation with TFAH whereas with FSO_3H/SO_2ClF ring protonation occurs in equilibrium leading to broadening of the aromatic resonances. By an increase of the acidity (4:1 $FSO_3H{\cdot}SbF_5/SO_2ClF$), the oxonium−arenium dication $\mathbf{6H_2}^{2+}$ can be cleanly generated with ring protonation occurring exclusively at C-12 ($\mathbf{6H}^+$ and $\mathbf{6H_2}^{2+}$ are both dark-red). Shielding of H-12 upon protonation and its *peri*-NOE effect with H-11 are noteworthy. The $\mathbf{C}{=}OH^+$ resonance is deshielded only by 8.5 ppm relative to **6** with C-4a and C-6 becoming most deshielded.

Protonation/ionization of **7-OH** with FSO_3H/SO_2ClF at dry ice−acetone temperature produced $\mathbf{7}^+$ as a purple solution. The NMR spectral data are consistent with the existence of two geometrical isomers for $\mathbf{7}^+$ (ca. 60:40 ratio), with coinciding methyl protons but slightly different methyl carbons. On the basis of NOED spectra, it was established that the major cation has its $\mathbf{Me}C^+H$ pointing toward C-8 and the minor toward C-6. The charge delocalization pattern and the presence of distinct geometrical isomers emphasize strong arenium ion character and the alkene-like nature of the $Ar{-}C^+$ bond in the α-benzylic carbocation. The "cation centers" were at 170.8 and 169.8 ppm, with the H-12 resonances appearing at 10.21/10.24 ppm, respectively. Although the complexity and the large number of resonances precluded the detection/assignment of some of the quaternary carbons, the overall charge delocalization mode is consistent with an anthracenium ion. Protonation of **7** with $FSO_3H{\cdot}SbF_5$ (4:1)/SO_2ClF similarly led to $\mathbf{7}^+$; further ring protonation to form a dication could not be achieved. AM1 predicted that the geometrical isomers had almost the same energy in the gas phase. Quenching of $\mathbf{7}^+$ with cold methanol gave the methyl ether in better than 90% yield (assayed by ^1H NMR).

Protonation of **8** with FSO_3H/SO_2ClF generated $\mathbf{8H}^+$ as a dark-red solution whose $Me\mathbf{C}{=}OH^+$ appears at 218.3 ppm deshielded by 10.50 ppm from the precursor. As expected, the arenium ion character in $\mathbf{8H}^+$ is much less than $\mathbf{7}^+$; nevertheless, it is seen that C-12, C-5, and C-9 gain substantial positive charge. To gain some insight into the preferred geometry of the carboxonium group, relative energies of the *E-syn/Z-anti* pairs (methyl group pointing toward H-6 or H-8 for each pair) were calculated. Out of these four possible configurations only the *E-syn* form with the methyl pointing toward H-6 could possibly be excluded since it was 8 kcal/mol higher in energy, whereas the other configurational isomers had similar energies (within 0.5 kcal/mol).

Carbocations $\mathbf{7}^+$ and carboxonium ion $\mathbf{8H}^+$ may be viewed as "simplified" models for cholanthrylene (benz[*j*]aceanthrylene) epoxide ring opening[24] (cholanthrylene epoxide is highly potent[28]). For comparison, the α-anthracene-substituted cation $\mathbf{9}^+$ and carboxonium ion $\mathbf{10H}^+$ were studied; low-temperature reaction of **9-OH** with FSO_3H/SO_2ClF gave $\mathbf{9}^+$ as a dark-red solution, with $\mathbf{C}H(Me)^+$ appearing at 167.4 ppm, $C\mathbf{H}(Me)^+$ at 9.01, and H-10 at 9.73 ppm for which the NOE effect was observed with H-4/H-5. Extensive charge delocalization/alternation occurs, and the anthracenium ion character is revealed on the basis of the magnitude of $\Delta\delta$s.

Carboxonium ion $\mathbf{10H}^+$ was generated by low-temperature protonation of 9-acetylanthracene (**10**) with FSO_3H/SO_2ClF as a dark-red solution. Charge delocalization mapping suggests that the enol form with positive charge residing extensively at C-10 is a major contributor. Competing ring protonation as a minor process was evident judging from a small methyl signal at δ 20.6 and a CH_2 [δ 39.2(C), δ 5.13 (H)] signal plus minor low field doublets between 8.6 and 8.0 ppm. These resonances disappeared at higher temperatures. Independent protonation of **10** with $FSO_3H{\cdot}SbF_5$ (4:1)/SO_2ClF gave the carboxonium ion (where $MeC{=}O\mathbf{H}^+$ appears as a separate signal at δ 12.03) with minor competing ring protonation (a solid byproduct was also formed).

Comparative Discussion. Protonations at C-12 and C-7 both confer anthracenium ion character, but the sites are complimentary. For the parent BA (a borderline carcinogen[5]) a 3:1 mixture was obtained favoring C-7 protonation. Whereas C-12 protonation is thermodynamically favored for **3** and is the sole site of attack in **4**, both of which are potent carcinogens. The same pattern of charge delocalization would be produced via bay-region (1,2 positions) and K-region (5,6 positions) epoxide ring opening; these types of compounds are highly active.

The stable-ion based prediction that alkyl (and fluoro) substitution at the 6,7,8,10 positions should stabilize this charge alternation pattern and may hence increase potency seems to hold well, judging from most of the available structure/activity data for the BA derivatives.[1] Indeed, methyl introduction at these positions does lead to increased activity, whereas methyl introduction into the benz[*a*]ring (3,4 positions) was ineffective. Activity retardation has been observed by methyl substitution at the 1,2 positions due to steric hindrance.[1] Protonation of **2** (not a carcinogen) in this study is a relevant model, showing electrophilic attack moves more strongly to C-7, a pattern we may associate with reduced carcinogenicity. Lack of activity in 1,12-Me_2BA may be rationalized by blocking metabolic activation to form diol epoxides.[2] Lack of activity for the 12-Et derivatives (see also further) was suggested to indicate PAH intercalation between the base pairs of DNA.[1] It was also attributed to the radical cation mechanism, where nucleophilic attack at the benzylic center is prevented stereoelectronically.[5]

Both **4** and 3,6-DMC are potent; dimethylation in any combination at the 6,7,8,12 positions increases carcinogenicity. Thus the 6,7-, 6,8-, 6,12-, 7,12-, and 7,8-dimethyl derivatives are all potent, as are combinations of Et/Me and Et/Et except for those with Et at C-12 so that 7,12-Et_2 is inactive and 7-Me/12-Et is a weaker carcinogen; thus the presence of 12-Me is critical for the activity of **3**.[1]

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In summary, we have provided the first direct study of a series of arenium ions and carbocations/carboxonium ions in the BA series. Detailed NMR studies and charge delocalization mapping point to distinct anthracenium ion character. For carbocations derived from potent carcinogens and those that could be considered *simple* models for the potent bay-region and K-region epoxides as well as cholanthrylene epoxide, the unifying pattern is one where positive charge resides at the C-4a/C-6/C-7/C-8/C-10/C-11a/C-12a positions.

Experimental Section

Compounds **1**, **3**, **4**, **6**, and **10** were purchased from Aldrich and used without further purification after determining (by NMR) that their purities were no less than 98%.

FSO_3H (Allied) and SbF_5 (Aldrich or Fluorochem) were doubly distilled in an all-glass distillation unit under argon and stored in Nalgen bottles with Teflon cap-seals under argon.

SO_2ClF was prepared from SO_2Cl_2 with NH_4F and TFAH using a modified procedure of Prakash et al.[29] The Hyperchem package (hypercube 1994) was used for energy minimization and AM1 calculations.

Synthesis of 8.[6] $AlCl_3$ (200 mg, 1.5 mmol) was added to a solution of BA (228 mg, 1 mmol) and CH_3COCl (100 mg, 1.3 mmol) in dry 1,2-dichloroethane (30 mL) at room temperature, and the reaction mixture was stirred for 5 h; it was then poured into ice−water and extracted with $CHCl_3$. After removal of the $CHCl_3$ and 1,2-dichloroethane, the product was isolated and purified by column chromatography using hexane−chloroform (yield 95%): ^{13}C NMR δ 208.3 (*C*O),137.2 (*C*COMe),129.0 (CH),128.7 (CH),128.6 (CH),127.4 (2CH), 127.0 (CH),125.9 (CH),124.1 (CH),122.9 (2CH),122.8 (CH),131.3 (C),-130.2 (C),128.3 (C), 128.0 (C),126.9 (C),125.3 (C); ^{1}H NMR δ 9.16 (s), 8.78, 8.11, 7.84, 7.81, 7.67, 7.63, 7.62, 7.59, 7.56 (2H), 2.80 (Me).

Synthesis of 7-OH. $LiAlH_4$ (76 mg, 2 mmol) was added to a dry ether solution (20 mL) of **8** (220 mg, 1 mmol) at room temperature. After the mixture was stirred for 5 h at room temperature, methanol (5 mL) was added to destroy excess LAH, after which the reaction mixture was poured into 1 N aqueous HCl (200 mL) and extracted with ether. After removal of ether, the product was purified by column chromatography using chloroform as solvent (yield 77%; MS *m*/*z* 272, M^+): ^{13}C NMR δ 136.1 (C), 131.8 (C), 131.1 (C), 130.8 (C), 129.5 (CH), 129.1 (C), 128.2 (CH), 127.6 (C), 127.0 (CH), 126.9 (CH), 126.8 (CH), 125.7 (CH), 125.0 (CH), 124.5 (CH), 123.4 (CH), 122.9 (CH), 122.5 (CH), 67.2 (*C*HOHMe), 23.5 (Me); ^{1}H NMR δ 9.01 (s), 8.71, 8.59, 8.37, 8.0, 7.76, 7.61, 7.58, 7.52, 7.47, 6.29, 2.31 (OH), 1.83 (Me).

Synthesis of 5-OH. MeLi (1.4 M, 7.6 mL, 3.64 mmol) was added to a dry ether (100 mL) solution of **6** (186 mg, 0.76 mmol) at 0 °C under Ar atmosphere. The reaction mixture was then warmed to room temperature and stirred for 12 h after which MeOH (5 mL) was added to quench excess MeLi; the reaction mixture was poured into water and extracted with ether. After removal of ether, the product was purified by column chromatography with chloroform (yield 76%): ^{13}C NMR δ 135.7 (C), 134.0 (C), 131.9 (C), 131.1 (C), 130.2 (C), 129.3 (C), 129.0 (CH), 128.1 (CH), 127.5 (CH), 127.3 (CH), 126.5 (CH), 126.4 (CH), 125.1 (CH), 124.9 (CH), 73.0 (*C*OHMe), 43.3 (CH_2), 31.7 (CH_2), 28.8 (CH_2), 20.2 (Me); ^{1}H NMR δ 9.40 (s), 8.14 (s), 7.94, 7.81, 7.60, 7.36, 6.92, 2.74 (CH_2), 2.17 (CH_2), 2.01 (CH_2), 1.81 (Me).

Synthesis of 9-OH. $LiAlH_4$ (38 mg, 1 mmol) was added to a dry ether (50 mL) solution of **10** (70 mg, 0.26 mmol) at room temperature, and the reaction mixture was stirred for 18 h. After addition of methanol (5 mL) to quench excess LAH, the reaction mixture was poured into 1 N aqueous HCl (100 mL) and extracted with ether. After removal of solvent, the product was purified by column chromatography using chloroform (yield 67%; MS *m*/*z* 222, M^+): ^{13}C NMR δ 135.6 (C), 131.4 (C), 129.1 (CH), 128.5 (C), 127.5 (CH), 125.2 (CH), 124.6 (CH), 124.5 (CH), 66.7 (*C*HOHMe), 23.1 (Me); ^{1}H NMR δ 8.38 (2H), 8.08 (s,1H), 7.75 (2H), 7.28 (4H), 6.02 (q), 2.94 (OH),1.59 (d, Me).

Synthesis of 2 (Lit. Ref 30). DDQ (227 mg, 1 mmol) was added to a dry benzene (50 mL) solution of **5-OH**, and the mixture was refluxed for 6 h under Ar atmosphere. It was then cooled to room temperature, the resulting precipitate was filtered off, and the benzene layer was washed twice with water. After removal of the benzene, the product was separated by column chromatography using hexane (yield 40%).

Cation Generation from Hydrocarbons and Ketones. Using a HV-line, SO_2ClF (0.3 mL) was condensed into a 5 mm NMR tube containing the substrate (30 mg). After addition of 0.1 mL of CD_2Cl_2 (NMR lock and reference), FSO_3H (5 drops) was added to the resulting slurry at dry ice temperature under an argon atmosphere with vigorous (vortex) mixing. For generation of $\mathbf{6H_2}^{2+}$, 5 drops of FSO_3H-SbF_5 (4:1) was used (at dry ice acetone temperature). The monocation $\mathbf{6H}^+$ was generated at room temperature by addition of either TFAH (0.3 mL) or TFAH (0.3 mL)−H_2SO_4 (5 drops) mixture together with CD_2Cl_2 (0.1 mL).

Preparation of Carbocations from Carbinols. Using a HV-line, SO_2ClF (0.3 mL) was first condensed into a 5 mm NMR sample, and then five drops of FSO_3H was added to this NMR tube at atmospheric pressure at dry ice/acetone temperature under an argon atmosphere. Finally, a CD_2Cl_2 (0.1 mL) solution of the alcohol (30 mg) was directly added to this cold tube with efficient mixing (vortex) to generate the carbocations.

Quenching of 7^+ with MeOH. The SO_2ClF solution of 7^+ was poured into dry CH_3OH at 0 °C; the product was extracted with $CHCl_3$, and the crude reaction mixture was analyzed directly by NMR: ^{1}H NMR δ 9.20 (s), 8.85 (d), 8.39 (m), 7.84 (d), 7.69−7.55 (7H), 5.93 (q, *C*HOMe), 3.22 (s,OMe), 1.89 (d, Me).

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Supporting Information Available: Representative ^{1}H,^{13}C, and 2D NMR spectra of the carbocations and carboxonium ions (29 pages). This material is contained in libraries on microfiche, immediately follows the article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering.

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