(*8*) is also represented in Fig. 2, and demonstrates the response of sea level to both the accumulation of warm water and the wind stress. During the 2 months when the west winds blow, a slope of the sea surface of about 20 cm over a distance of 5000 km from west to east is generated; this is shown in the maps of dynamic topography in the Indian Ocean atlas (*6*). The rise of sea level along the coast of Sumatra is also documented by the observed sea level in Fig. 2. By the end of the 2-month period this slope essentially balances the wind stress. The wind stress τ and surface slope along the equator are related by the expression

$$\tau = \frac{\rho g D \Delta h}{L}$$

where $\Delta h = 20$ cm is the difference in sea level over the distance $L = 5000$ km, $D = 120$ m is the thickness of the upper layer below which the horizontal pressure gradient is assumed compensated, ρ is the water density, and g is the gravitational constant. With these values a wind stress of 0.5 dyne cm^{-2} results, which agrees with the observed strength of the west winds. Consequently, at the end of 2 months sufficient water has piled up off Sumatra to cause a surface slope which balances the wind stress and leads to a decrease in the strength of the current and to geostrophic flow away from the equator.

The following conclusions can be drawn from this investigation:

1) West winds over the equator during the transition periods between the two monsoon seasons cause the rapid development of a narrow jet at the equator.

2) This jet is the only ocean surface current that flows eastward at the equator.

3) The current develops within a very short time.

4) Uplifting of the thermocline at its western origin and sinking at its eastern terminus accompany the jet.

5) Thermocline upwelling can supply the water transport of a time-dependent current.

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Cadmium: Mode of Occurrence in Illinois Coals

Abstract. The cadmium content of 23 Illinois coals ranges from less than 0.3 to 28 parts per million. The higher cadmium contents are found in coals that also have a relatively high zinc content. Cadmium occurs in these coals in solid solution, replacing zinc in the mineral sphalerite (ZnS). The ratios of zinc to cadmium in sphalerites are similar to the ratios of zinc to cadmium in the whole coals from which the sphalerites were separated.

The investigation of Cd in coal has not kept pace with the studies of many other trace elements in coal. We are aware of only three references to Cd in coal and coal ash published prior to 1969 (*1*). During the past 4 years additional analyses have been reported (*2–6*). In the only study designed to investigate coals systematically, Swanson (*4*) analyzed 71 coal samples and found that 61 had a Cd content below detectable limits, which for the analytical method used was approximately 0.5 part per million (ppm) in a 1.0-g sample of coal ash.

Five of the seven recent publications that mentioned Cd in coal listed the results of individual analyses of coal samples (*4–6*), and the highest amount of Cd in coal reported was 0.7 ppm (*5*). The other two publications did not list the results of individual analyses of coal samples but gave Cd ranges of 2 to 100 ppm in the coal ash (*2*) and 1 to 2 ppm in the coal (*3*).

In a current investigation of the potentially volatile trace elements in coals being conducted at the Illinois State Geological Survey (*7*), relatively high Cd and Zn concentrations have been

Table 1. The Cd and Zn analyses of Illinois coals.

Analysis number	Zn (ppm)		Cd (ppm)		Zn : Cd ratio	
	HTA	LTA	HTA	LTA	HTA	LTA
			Herrin (No. 6)			
C-16030	1760	1610	3.6	3.2	490 : 1	500 : 1
C-14970	15	24	≤ 0.3	≤ 0.4		
C-16317	1670	2660	17.0*	28.0†	98 : 1	95 : 1
C-12062		3100		19.0‡		160 : 1
C-15117	41	121	0.5	1.2	82 : 1	100 : 1
C-15456	59	178	≤ 0.3	≤ 0.4		
C-13895	68	30	< 0.3	< 0.5		
C-15231		297		1.1		270 : 1
C-14684	39	31	< 0.2	< 0.3		
C-13464	41	31	0.5	0.5	82 : 1	62 : 1
C-14721	221	294	1.4	1.8	160 : 1	160 : 1
C-16139		86		0.9		96 : 1
C-12831		24		≤ 0.4		
C-15038		102		0.8		130 : 1
			Springfield-Harrisburg (No. 5)			
C-16264	182	166	3.1§	2.7‖	58 : 1	61 : 1
C-14796	97	64	0.5	≤ 0.3	190 : 1	
C-15384	34	34	≤ 0.3	≤ 0.4		
C-12495		18		≤0.6		
C-14774		885		7.1		120 : 1
C-17001	171	184	1.8	1.2	95 : 1	150 : 1
			Summum (No. 4)			
C-15331	54	54	0.7	0.7	77 : 1	77 : 1
			Colchester (No. 2)			
C-15566		213		0.9		240 : 1
			DeKoven			
C-15944		189		≤ 0.4		

* 18 ppm by ASV. † 29 ppm by ASV; 21 ppm by NAA. ‡ 17 ppm by NAA; 28 ppm by ASV. § 3.0 ppm by ASV. ‖ 2.4 ppm by ASV.

found in several Illinois coals (Table 1). All of the coal samples analyzed were either face channel or drill core samples and were representative of the entire coal seam, with the exception of mineral bands over 0.95 cm thick. The coals were ashed and then analyzed by atomic absorption spectrophotometry. Both low-temperature ash (LTA), obtained at temperatures below 150°C by a radio-frequency, oxygen-plasma ashing technique (*8*), and high-temperature ash (HTA), prepared in a muffle furnace at 450°C, were analyzed. During the ashing of aliquots of two of the coals (samples C-16030 and C-16264), the effluents from the radio-frequency asher were collected in a cold trap at − 76°C and analyzed for Cd and Zn by atomic absorption spectrophotometry. Neither Cd nor Zn proved to have been volatilized in sufficient quantities during low-temperature ashing to be detected in the material collected in the cold trap.

The procedures developed by Bernas (*9*) and Buckley and Cranston (*10*) for the decomposition of silicates and aluminosilicates prior to analyses by atomic absorption spectrophotometry were modified for the decomposition of coal ash. Samples were heated with aqua regia and hydrofluoric acid in a Teflon-lined, acid digestion bomb. Samples were then treated with boric acid and diluted with deionized water.

Atomic absorption measurements for Cd and Zn were made on the solutions with a single-beam atomic absorption spectrophotometer that had single-element hollow cathode lamps. The background absorption was measured either at the analytical line by a hydrogen continuum source or at a nonabsorbing line adjacent to the analytical line in the spectrum of the hollow cathode lamp of the element being determined. In samples containing small amounts of Cd and Zn, correction for background absorption was found to be critical. Thirty-seven coal ash samples (23 LTA and 14 HTA) from 23 samples of Illinois coals were analyzed (Table 1). The relative standard deviation of the method is about 11 percent for Cd and about 6 percent for Zn; the lower limit of detection in the coal ash is 2.5 ppm for Cd and 20 ppm for Zn for a 0.1-g sample.

Five ash samples were also analyzed for Cd by anodic stripping voltammetry (ASV) and two by neutron activation analysis (NAA) to provide a comparison with the atomic absorption analyses. The results of all determinations, calculated to the whole coal basis from the percentage of ash in the coals, of Cd and Zn are given in Table 1.

The Cd content of the coals ranged from less than 0.3 to 28 ppm, and the Zn content ranged from 18 to 3100 ppm. Values determined on the HTA and LTA of the same sample were generally in good agreement for both elements. The larger discrepancies, for example, sample C-16317 which has a high Zn content, are thought to be related to problems associated with representative sampling of coal for HTA and LTA and not to the chemical analyses. Samples used for low-temperature ashing are reduced in size to only − 20 mesh (740 μm) because of the difficulty in handling finer samples, and individual sphalerite (ZnS) particles of that size may affect analytical results.

Heavy-mineral concentrates, obtained by separating the low-temperature mineral matter residue in bromo-

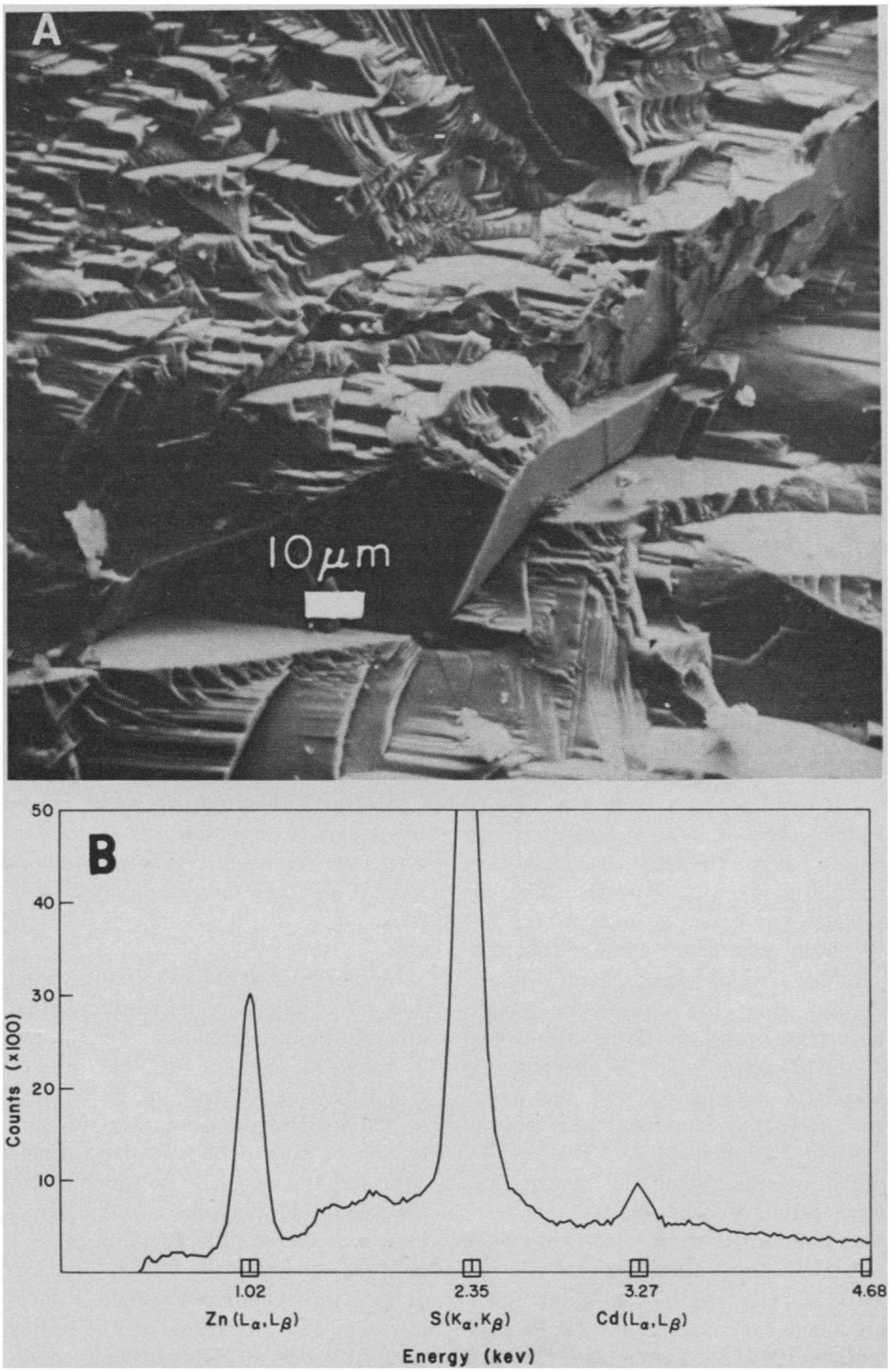

Fig. 1. (A) Scanning electron photomicrograph of sphalerite (ZnS) from the LTA of coal sample C-16264. (B) A portion of the energy-dispersive x-ray spectrum of sphalerite in (A). An accelerating voltage of 8 kv was used to excite the sample.

form, were investigated by means of a scanning electron microscope (SEM) (Cambridge Stereoscan) equipped with an energy-dispersive x-ray spectrometer. The following coal samples were studied by SEM: C-16030, C-16317, C-12062, C-16264, and C-15566; of these samples, the first three were from Herrin (No. 6) coal, the fourth was from Springfield (No. 5) coal, and the last was from Colchester (No. 2) coal, all members of the Carbondale formation (Pennsylvanian). Sphalerite was identified in each sample studied, and the identification was confirmed by x-ray diffraction. The presence of sphalerite in a sample of Herrin (No. 6) coal from northern Illinois had previously been identified by Zubovic (*11*). Cadmium was qualitatively determined by energy-dispersive x-ray spectrometry in the three samples on which analysis was attempted (C-16317, C-12062, and C-16264). An accelerating voltage of 8 kv was used and the $L\alpha_1$ (3.133-kev) x-ray emission peak of Cd was used to identify the element. A scanning electron photomicrograph of a sphalerite particle from sample C-16264 is shown in Fig. 1A; a portion of the x-ray spectrum of sphalerite is shown in Fig. 1B. Although this sample had less than one-tenth the Zn content of the three coals with the highest Zn contents, it had the lowest Zn : Cd ratio and therefore gave a clearer indication of the Cd content on the x-ray spectrogram.

Sphalerite samples were obtained from a fraction of high specific gravity from a LTA (sample C-16317) and from a fraction of similar specific gravity of an unashed coal (sample C-16264). The particles were individually picked from the high-specific-gravity fraction with a fine brush while the sample was under a microscope. The sphalerite was dissolved in nitric acid, and the solution was diluted with deionized water for analysis by atomic absorption. The sphalerite from coal C-16317 contained 0.55 percent Cd and 61.2 percent Zn, and that from coal C-16264 contained 0.88 percent Cd and 54.5 percent Zn. The Zn : Cd ratios of the sphalerite concentrates were similar to the Zn : Cd ratios of the whole coals from which they were obtained. For sample C-16317, the Zn : Cd ratio was 93 : 1 in the sphalerite and 97 : 1 in the whole coal. Sample C-16264 had a Zn : Cd ratio of 62 : 1 for the sphalerite and 60 : 1 for the whole coal.

The similarity of the Zn : Cd ratios of sphalerite and the Zn : Cd ratios of the whole coal from which the sphalerite was obtained suggests that most, if not all, of the Cd in the coal is within the sphalerite. Because no separate Cd-containing phase was observed, the Cd is thought to substitute for Zn in the sphalerite. The Cd contents we have reported (Table 1) for the sphalerites obtained from coals are not unusually large. As much as 4 to 5 percent Cd has been reported in other sphalerites (*12*).

The presence of sphalerite in discrete particles in the LTA and in the coal fractions with high specific gravity suggests that it occurs as an epigenetic mineral. We have observed sphalerite, associated with authigenic calcite, kaolinite, and pyrite, filling vertical fractures (cleats) in coals. Many coals are prepared by "washing" (various specific-gravity separation methods are normally used) prior to their utilization. A significant reduction in the Cd and Zn contents could likely be effected in some coals by such separation methods inasmuch as the high specific gravity of sphalerite (4.1) favors its removal during washing.

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Information Processing in the Retina: Importance of Chloride Ions

Abstract. *Electrophysiological recording methods were applied to the isolated, retina-eyecup preparation of the rabbit. Perfusion with a chloride-free solution has a selective, reversible effect on the retinal network. This study establishes chloride ions as an important requirement for certain "information channels" within the retina.*

Many recent advances in retinal function have relied on preparations that are artificially maintained after the eye is removed. Studies of the isolated retina have established the importance of sodium and potassium for the generation of both light- and dark-dependent responses (*1*, *2*). In comparison, the role of chloride ions in retinal function has received little attention (*3*). We used the isolated retina-eyecup preparation of the rabbit to examine electrophysiological properties of the retina under a variety of different ionic conditions. In the present study we report the selective, reversible effects that follow the introduction of perfusing medium in which chloride has been replaced by a large anion, usually sulfate. The effects of chloride-free solutions are apparent at many levels of retinal function, as revealed by recordings of mass ganglion cell discharge, the proximal negative response (PNR), the transretinal electroretinogram (ERG), and through intracellular recordings from cells presumed to be horizontal cells. Our results demonstrate the importance of chloride as a major ionic requirement for certain "information channels" within the retina.

The eye of a New Zealand White