missing area below T_c, in contrast with the data. The impurity model seems to us to be unphysical, but (*32*) is important because it draws attention to the interplane *FF* correlator and shows explicitly that the *c* axis sum rule is less robust than the in-plane one.

The general arguments we present are confirmed by calculations of $\sigma_c(\omega,T)$. The crucial ingredient in these calculations is the in-plane electron self energy which represents the nontrivial in-plane physics. We have investigated a variety of model self energies; the results will be published elsewhere.

To conclude, we review several qualitative features of the data in light of our results. In underdoped cuprates, the formation of the pseudogap does not lead to an increase in $\sigma_c(\omega)$ at any observed frequency. If the pseudogap were due to an incipient density wave instability, spectral weight lost below the gap would reappear as a peak in $\sigma_c(\omega)$ just above the gap, in contradiction with the data. On the other hand, we show that superconducting pairing without long-ranged order leads to the observed behavior. Our results therefore provide additional strong evidence that the pseudogap is caused by superconducting pairing and not by an incipient density wave. Second, the fact that the spectral weight restored at $T \rightarrow 0$ does not compensate all of the weight lost by gap formation in underdoped $YBa_2Cu_3O_{6.6}$, but yet compensates it in $YBa_2Cu_4O_8$, directly implies that in $YBa_2Cu_3O_{6.6}$, fluctuations reduce the value of the $T = 0$ interplane F_iF_{i+1} correlator below the value of the same-plane correlator F_iF_i, while in $YBa_2Cu_4O_8$ they do not. There is other evidence (*30*) that $YBa_2Cu_3O_{6.6}$ has exceptionally large $T = 0$ fluctuations. A systematic comparison in a range of compounds of fluctuation strengths deduced from *c* axis conductivity and from other measurements would be interesting.

References and Notes

1. D. Basov, T. Timusk, B. Dabrowski, J. D. Jorgenson, *Phys. Rev. B* **50**, 3511 (1994).
2. S. L. Cooper and K. E. Gray in *Physical Properties of High-Temperature Superconductors IV*, D. M. Ginsberg, Ed. (World Scientific, Singapore, 1994), pp. 61–188.
3. C. C. Homes, T. Timusk, D. A. Bonn, R. Liang, W. N. Hardy, *Physica C* **254**, 265 (1995).
4. S. Uchida, K. Tamasaku, S. Tajima, *Phys. Rev. B* **53**, 14558 (1996).
5. S. Tajima *et al.*, *ibid.* **55**, 6051 (1997).
6. D. N. Basov *et al.*, *Science* **283**, 49 (1999).
7. P. W. Anderson, *ibid.* **268**, 1154 (1995).
8. A. V. Puchkov, D. N. Basov, T. Timusk, *J. Phys. Condens. Matter* **8**, 10049 (1996).
9. P. W. Anderson, *Science* **279**, 1196 (1998).
10. S. Chakravarty, *Eur. J. Phys. B* **5**, 337 (1998); S. Chakravarty, H.-Y. Kee, E. Abrahams, *Phys. Rev. Lett.* **82**, 2366 (1999).
11. R. J. Radtke and K. Levin, *Physica C* **250**, 282 (1995).
12. A. A. Abrikosov, *Phys. Rev. B* **54**, 12003 (1996).
13. N. Kumar, T. P. Pareek, A. M. Jayannavar, *ibid.* **57**, 13399 (1998).
14. S. Das Sarma and E. H. Hwang, *Phys. Rev. Lett.* **80**, 4752 (1998).
15. D. Pines and P. Nozieres, *Theory of Quantum Liquids* (Addison-Wesley, Reading, MA, 1966).
16. M. Tinkham, *Introduction to Superconductivity* (McGraw-Hill, New York, 1996).
17. J. Orenstein *et al.*, *Phys. Rev. B* **42**, 6342 (1990).
18. M. Takigawa *et al.*, *ibid.* **43**, 243 (1991).
19. W. W. Warren Jr. *et al.*, *Phys. Rev. Lett.* **62**, 1193 (1989).
20. Ch. Renner, B. Revaz, J.-Y. Genoud, K. Kadowaki, O. Fischer, *ibid.* **80**, 149 (1998).
21. N. Miyakawa, P. Guptasarma, J. F. Zasadzinski, D. G. Hinks, K. E. Grey, *ibid.*, p. 157.
22. H. Ding *et al.*, *Nature* **382**, 51 (1996).
23. A. G. Loeser *et al.*, *Science* **273**, 325 (1996).
24. O. K. Andersen *et al.*, *J. Phys. Chem. Solids* **56**, 1573 (1995); O. K. Andersen *et al.*, *Phys. Rev. B* **50**, 4145 (1994).
25. L. B. Ioffe and A. J. Millis, *Phys. Rev. B* **58**, 11631 (1998).
26. J. R. Schreiffer, *Theory of Superconductivity* (Benjamin/Cummings, Reading, MA, 1983).
27. W. Kohn, *Phys. Rev.* **133**, A171 (1964).
28. A. J. Millis and S. N. Coppersmith, *Phys Rev. B* **42**, 10807 (1990).
29. V. J. Emery and S. A. Kivelson, *Nature* **374**, 434 (1995).
30. V. B. Geshkenbein, L. B. Ioffe, A. I. Larkin, *Phys. Rev. B* **55**, 3173 (1997).
31. M. Franz and A. J. Millis, *ibid.* **58**, 14572 (1998).
32. E. H. Kim, *ibid.*, p. 2452.

33. We thank E. Abrahams for helpful discussions. A.J.M. thanks the NSF (grant DMR-9707701) for support.

12 April 1999; accepted 13 July 1999

Decreased Rates of Alluvial Sediment Storage in the Coon Creek Basin, Wisconsin, 1975–93

Stanley W. Trimble

The total measured rate of alluvial sediment accretion in the agricultural Coon Creek Basin for the period 1975–93 was only about 6 percent of the rate that occurred in the 1930s, but the distributed changes within the basin were highly variable and systematic. Sediment yield (efflux), however, remained relatively constant despite large stream and valley changes within the basin. These observations demonstrate (i) that sediment sources, sinks, and fluxes vary widely over time and space and (ii) that, although improved soil conservation measures have decreased soil erosion, the downstream effects are complex.

Erosion and sediment yield in any stream basin are rarely in a steady state. For monitoring environmental change, it is thus necessary to construct a sediment budget that accounts for storage fluxes within the basin during any time period (*1*). Here, I present results from a long-term study, attempting to account for the sediment budget over the 140-year period of European agriculture in Coon Creek, a typical agricultural basin of 360 km^2 in the Driftless Area of Wisconsin (Fig. 1). Measurements are largely based on surveyed and monumented stream and valley cross sections that have also received extensive stratigraphic studies for the agricultural period (*2, 3*). Over 150 such cross sections have been installed since 1938, of which 92 were recovered and resurveyed (see supplemental data, available at www.sciencemag.org/feature/data/1041853.shl). These resurveys were done from 1991 to 1995, but most were done in 1993; therefore, 1993 is used as the median date. Sediment yields were calculated by standard extrapolation techniques from measurements on the Grant River at Burton, Wisconsin, a similar basin ~90 km south of Coon Creek (U.S. Geological Survey District Office, Madison, WI).

Department of Geography and Institute of the Environment, University of California, 1255 Bunche Hall, Los Angeles, CA 90095–1524, USA.

The major change in the sediment budget from earlier periods (Fig. 1) is the overall decrease in rates of storage, a trend that started in the 1940s and is directly attributed to improvements in agricultural land management (*3, 4*). From 1853 to 1938, an average of 405×10^3 Mg year^{-1} of sediment went into storage (*2, 3*). This was reduced to 209×10^3 Mg year^{-1} from 1938 to 1975 and then reduced to 80×10^3 Mg year^{-1} from 1975 to 1993. These averages, however, disguise some striking shorter term rates. In the 1920s and 1930s (the period of maximum erosion and sediment storage), alluvial sediment accumulation in the basin was $\sim 1260 \times 10^3$ Mg year^{-1} (*3, 4*). The recent (1975–93) rate of 80×10^3 Mg year^{-1} is only ~6% of that highest rate. This decrease was due to improvements in land use and not due to a change in climate. Indeed, most of the period 1975–93 was wetter than average, with many large storms (*5*). A basin-wide 100-year flood occurred in 1978, and 1993 was also extremely wet.

Whereas sediment fluxes (sources and amounts) have changed drastically over the past 140 years, efflux, or sediment yield, has held relatively steady. This result demonstrates how poorly sediment yield can relate to sediment fluxes within a basin and thus how reliance on sediment yield monitoring can lead to erroneous conclusions about erosional processes within a basin (*1–4, 6*).

There are also substantial distributed changes of storage within the basin. The average storage rate in the lower main valley from 1975 to 1993 was only 37% of that from 1938 to 1975, but again, averages disguise remarkable changes. In the 1920s and 1930s, floodplains of the lower main valley were receiving, on average, ~15 cm of vertical accretion per year (*3, 4*) (Fig. 2). The average rate of vertical accretion for the period 1975–93 was 0.53 cm year^{-1} or ~3 to 4% of the maximum rate in the 1930s (Fig. 2). However, this reach has been affected by bank erosion as a result of riparian reforestation, which reduces the net accretion rates (*7*).

The major surprise for the period 1975–93 was that the upper main valley and tributaries were only minor sediment sources in comparison to those of previous years, and indeed, the tributaries became a net sediment sink. Earlier work by Trimble and by Trimble and Lund (*3, 4*) had predicted that the upstream portions of the basin would be substantial net sediment sources for perhaps decades to come and might actually cause sediment yield per unit area to increase downstream rather than decrease from storage losses, as is usually the case (*1*). This prediction was wrong—one reason being that many tributaries were stabilized by stream-bank structures (*8*). Even without the structures, there was a morphological feedback: As headward stream channels widened from lateral erosion, new floodplains developed that were lower, fine textured, and vegetated (Fig. 3), a condition noted in 1975 (*2*). As these floodplains widened and became more vegetated, they became more efficient sediment traps, thus providing a negative feedback by reducing sediment yield (*9*). Although many reaches still have extremely active cut banks, they are now often net sediment sinks (Fig. 3). These observations show the role of a wider floodplain as a trap for limiting the downstream movement of sediment (*1, 4*).

The decrease of sources and increase of sinks in upstream areas were greatly aided by a decrease of flood peaks as the result of improved land management. This change in stream response was first noted on the basis of the fact that newly forming floodplains were lower than the historical floodplain, suggesting lower flood peaks (*2, 10*). During the past decade, this amelioration has also been demonstrated from analyses of hydrologic data (*5, 11*).

The greatly decreased rate of alluvial sediment storage during the past two decades contrasts with the ostensible increase of soil erosion described for the United States for the past two decades (*12*), which has been described as "severe as it was in the 1930s" (*13*, p. 129). These studies, however, are not based on physical measurements at the basin scale but rather are based on plot studies or models. Because Coon Creek is a typical agricultural watershed of the upper midwestern United States, it would have been affected by any such general increase of soil erosion, but the measured mass budget demonstrates

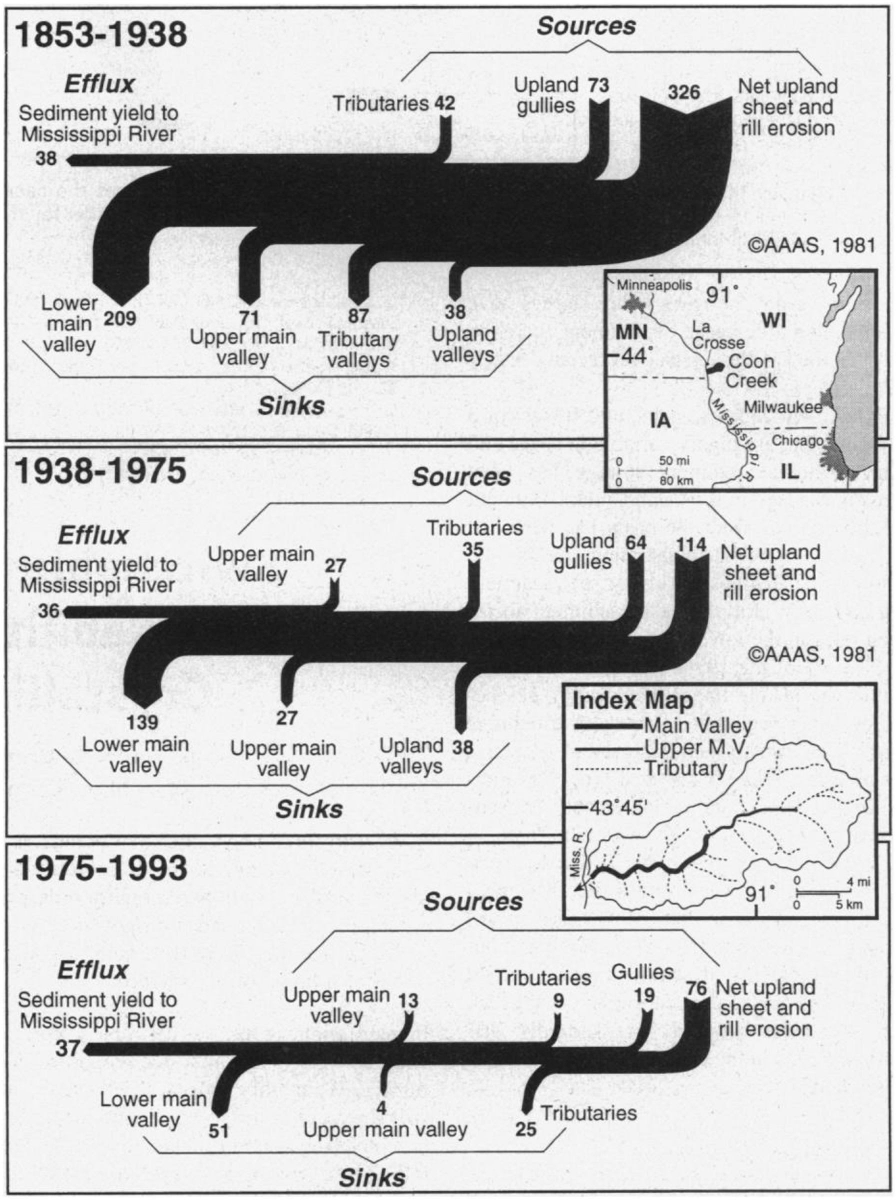
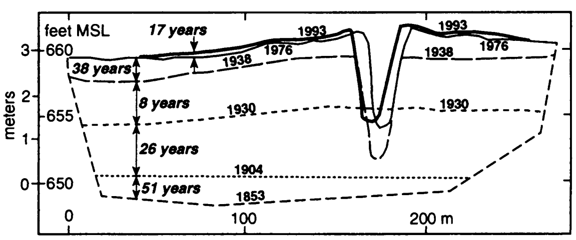


Fig. 1. Sediment budgets for Coon Creek, Wisconsin, 1853–1993. This agricultural basin is ~25 km southeast of La Crosse, Wisconsin, and has an area of 360 km^2. Numbers are annual averages for the periods in 10^3 Mg year^{-1}. All values are direct measurements except "Net upland sheet and rill erosion," which is the sum of all sinks and the efflux minus the measured sources. The lower main valley and tributaries are sediment sinks, whereas the upper main valley is a sediment source. [Modified from (3)]

Fig. 2. A sediment sink. This is a cross-sectional profile in the lower main valley of Coon Creek showing succeeding, higher floodplain levels dated from 1853 to 1993. MSL, mean sea level. Such accretion accounts for most storage in the Coon Creek Basin. [Modified from (3)]



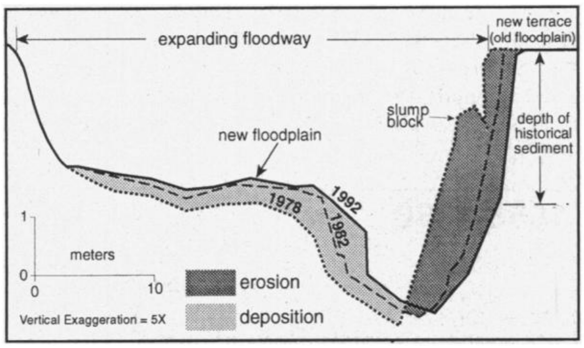


Fig. 3. A sediment source. This is a cross-sectional profile in the upper main valley of Coon Creek showing the removal of mostly historical sediment in a cut bank and the lateral expansion and accretion of a new, lower floodplain ~2 m below the level of the historical floodplain, now a terrace. As the channel has migrated laterally to the right over the past 60 years, the void between the levels of the new and old floodplains is indicative of the volume of sediment supplied downstream by this reach. A typical tributary cross section would be similar except the banks would be lower (1 to 2 m high) and deposition generally would be greater than erosion for the period 1975–93. [Modified from (9)]

that this is not the case. Other studies have also shown a decrease of sediment accretion rates in the Driftless Area over recent decades (*2, 3, 10, 14*).

Sediment sources, sinks, and fluxes for a stream basin are highly variable in space and time. Alluvial sediment storage has been greatly reduced in the Coon Creek Basin, but sediment yield from the basin has remained constant, further demonstrating the limited short-term diagnostic utility of sediment yields (*6*). Within the basin, sediment accretion rates in the lower main valley were only ~3 to 4% of the 1930s rates, but during the same period, the upper main valley has become a net sediment source and tributaries have been transformed from sediment sources to sinks. These distributed processes indicate the complex and variable quality of sediment sources and sinks within a basin, a principle first proposed by Brune in 1950 (*15*), which is exceedingly difficult to measure. General and substantial increases of soil erosion in the United States are not borne out by measurements of sedimentation in Coon Creek. The processes occurring in Coon Creek are indicative of many agriculturally disturbed basins in the eastern United States and elsewhere.

References and Notes

1. W. Dietrich and T. Dunne, *Z. Geomorphol. Suppl.* **29**, 191 (1978); H. Kelsey, *Geol. Soc. Am. Bull.* **91**, 190 (1980); F. Swanson, F. Janda, T. Dunne, D. Swanston, Eds., *Sediment Budgets and Routing in Forested Drainage Basins* (U.S. Department of Agriculture, Forest Service General Technical Report PNW141, 1982); R. Meade, *J. Geol.* **90**, 235 (1982); D. Walling, *J. Hydrol.* **65**, 209 (1983); P. Patton and P. Boison, *Geol. Soc. Am. Bull.* **97**, 369 (1986); J. Phillips, *Am. J. Sci.* **287**, 780 (1987); M. Church and O. Slaymaker, *Nature* **337**, 352 (1989); P. Ashmore, *Prog. Phys. Geogr.* **17**, 190 (1993); A. Schick and J. LeKach, *Phys. Geogr.* **14**, 225 (1993); O. Slaymaker, *ibid.*, p. 305; S. Trimble, in *Changing River Channels*, A. Gurnell and G. Petts, Eds. (Wiley, Chichester, UK, 1995), pp. 201–215; *Science* **278**, 1442 (1997).
2. S. Trimble, in *Landscapes of Wisconsin*, B. Zakrzewska-Borowiecki, Ed. (Association of American Geographers, Washington, DC, 1975), pp. 24–29; in *Proceedings of the Third Federal Interagency Sedimentation Conference* (Water Resources Council, Washington, DC, 1976), section 5, pp. 100–112.
3. ______, *Science* **214**, 181 (1981); S. Trimble and S. Lund, *U.S. Geol. Surv. Prof. Pap. 1234* (1982).
4. S. Trimble, *Am J. Sci.* **283**, 454 (1983).
5. W. Gebert and W. Krug, *J. Am. Water Resour. Assoc.* **32**, 733 (1996).
6. S. Trimble, *Science* **188**, 1207 (1975); *ibid.* **191**, 871 (1976); *Am. J. Sci.* **277**, 876 (1977).
7. ______, *Geology* **25**, 467 (1997).
8. ______, *Environ. Geol.* **32**, 230 (1997).
9. ______, *Phys. Geogr.* **14**, 285 (1993).
10. J. Knox, *Ann. Assoc. Am. Geogr.* **67**, 323 (1977); F. Magilligan, *ibid.* **75**, 583 (1985).
11. K. Potter, *Water Resour. Res.* **27**, 845 (1991); W. Krug, *J. Am. Water Resour. Assoc.* **32**, 745 (1996).
12. F. Steiner, *Soil Conservation in the United States: Policy and Planning* (Johns Hopkins Univ. Press, Baltimore, 1990); D. Pimentel *et al.*, *Science* **267**, 1117 (1995).
13. O. Owen, D. Chrias, J. Reganold, *Natural Resource Conservation* (Prentice Hall, Upper Saddle River, NJ, 1998).
14. J. Knox, *Ann. Assoc. Am. Geogr.* **77**, 224 (1987); T. Beach, *ibid.* **84**, 5 (1994).
15. G. Brune, *Trans. Am. Geophys. Union* **31**, 587 (1950).
16. This study was established in 1938 by the late S. C. Happ and the late V. E. McKelvey, and I am grateful for their gracious assistance. The study was supported by the U.S. Geological Survey, the Wisconsin Department of Natural Resources, the Natural Resources Conservation Service, the National Geographic Society, the NSF, the Wisconsin Department of Transportation, the University of California at Los Angeles Faculty Senate, and New Badger Enterprises. R. H. Meade designed Fig. 1. The report was greatly improved through critical reviews by M. Church, W. W. Emmett, A. Mendel, R. Shreve, L. Smith, and M. G. Wolman, but any errors remain mine. I also thank E. Brick and the many others who assisted me in the field.

18 May 1999; accepted 15 July 1999

Switchable Tackiness and Wettability of a Liquid Crystalline Polymer

Guillaume de Crevoisier,[1] Pascale Fabre,[1] Jean-Marc Corpart,[2] Ludwik Leibler[1]

The spreading velocity of liquids on the surface of a liquid crystalline polymer can be tremendously affected by a slight temperature change. Indeed, a bulk transition between a highly ordered smectic and an isotropic phase induces a sharp change from a rigid to a soft behavior, with consequent effects on the tack properties of the liquid crystalline polymer and on the dewetting dynamics of a liquid on its surface.

In many applications, it is desirable to control both the wetting and adhesive properties of a surface. Wettability reflects whether a liquid will spread on a surface as a continuous film or, conversely, retract as one or several droplets. There are many ways to control the wettability of a material by surface modification, and a number of elegant and efficient surface treatments have been proposed (*1–5*). Another key property of a surface is its stickiness, or tackiness. A typical example of tackiness is the feeling one has when touching fresh pine resin. This property can be deliberately sought after, such as in adhesive labels, or carefully avoided, as in varnish or paint. In general, a polymer surface has fixed properties—either tacky or nontacky, and hydrophilic or hydrophobic—that vary only slightly with the surrounding conditions such as humidity or temperature. For example, to make a glassy polymer sticky, one has typically to raise the temperature 50° to 60°C above its glass transition temperature. In this context, the design of a system with wetting and adhesive properties that are switchable with temperature over a narrow range of a few degrees presents a formidable challenge. To achieve this goal, we propose here the use of structured polymer films organized at a mesoscopic scale on the order of 10 nanometers.

A material is sticky when the energy required to break its bond with a surface is a thousand times as large as the simple interfacial energy; this extra work comes from the dissipation during the separation process, which involves deformation and friction in the polymer film. Moreover, to achieve a strong bond, a good contact needs to be established between the two surfaces, which requires some degree of softness of the ma-

[1]Unité Mixte de Recherche 167 CNRS/Elf Atochem, [2]Service Agents d'Interfaces, Elf Atochem, 95 rue Danton, 92303 Levallois-Perret, France.