重力モデル計算メモ（3）

＜物理探査ハンドブックより＞

重力異常の計算式として広く知られた方法に Talwani et al.(1959)がある。

断面 OPQ の Zi（単位密度重力値／２G）は

$$Z_i = \frac{(x_{i+1}-x_i)(x_i z_{i+1} - x_{i+1} z_i)}{(x_{i+1}-x_i)^2 + (z_{i+1}-z_i)^2} \left\{ \tan^{-1}\frac{z_i}{x_i} - \tan^{-1}\frac{z_{i+1}}{x_{i+1}} + \frac{1}{2}\frac{z_{i+1}-z_i}{x_{i+1}-x_i} \ln\left(\frac{x^2{}_{i+1} + z^2{}_{i+1}}{x^2{}_i + z^2{}_i} \right) \right\}$$

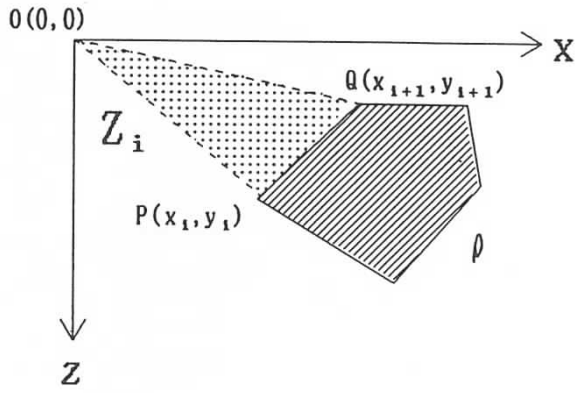


図8.20　2 次元の多角形（密度 ρ）モデル

図 8.20 に示す多角形（密度 ρ）の重力値（Δg）は

$$\Delta g = 2G\rho \sum_{i=1}^{n} Z_i$$

(n+1 は 1 に一致させて閉塞させる)

解析断面に直交する範囲が有限な場合の r- θ 座標による表現を示す（Komazawa,1995）。

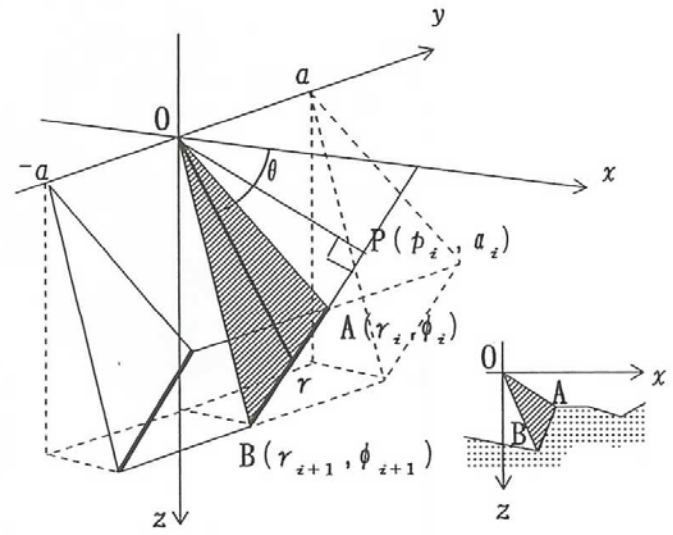


図8.21　2.5次元解析の計算断面モデル

図 8.21 より幾何学関係は

$$p_i = r_i \cos(\phi_i - \alpha_i) = r_{i+1} \cos(\phi_{i+1} - \alpha_{i+1}) = r \cos(\theta - \alpha_i)$$

$$r = r_i \cos(\phi_i - \alpha_i) / \cos(\theta - \alpha_i)$$

断面線から端の長さが a である有限 2 次元モデルの計算式について考慮する。

$$\int_0^a \frac{dy}{\left(x^2 + y^2 + z^2\right)^{3/2}} = \frac{1}{x^2 + z^2} \frac{a}{\sqrt{x^2 + z^2 + a^2}}$$

より

$$Z_i = \iint_S \frac{a}{\sqrt{x^2 + z^2 + a^2}} \frac{z dx dy}{x^2 + z^2}$$

$$= \iint_S \frac{a}{\sqrt{r^2 + a^2}} \sin\theta dr d\theta$$

$$= \int_{\phi i}^{\phi i+1} a \ln\left(\frac{r}{a} + \sqrt{1 + \frac{r^2}{a^2}} \right) \sin\theta d\theta$$

ここで a→∞とすれば

$$Z_i = \int_{\phi i}^{\phi i+1} r(\theta) \sin\theta d\theta = r_i \cos(\phi_i - \alpha_i) \left\{ \left(\phi_{i+1} - \phi_i\right) \sin\alpha_i - \cos\alpha_i \ln \left| \frac{\cos(\phi_{i+1} - \alpha_i)}{\cos(\phi_i - \alpha_i)} \right| \right\}$$

ただし

$$\alpha_i = \tan^{-1}\left(\frac{y_{i+1} - y_i}{x_{i+1} - x_i} \right) - \frac{\pi}{2}$$

Komazawa(1995)より 2 次元多層モデルの計算プログラム angmdl2.f

入力ファイル

重力データ gravdata.txt

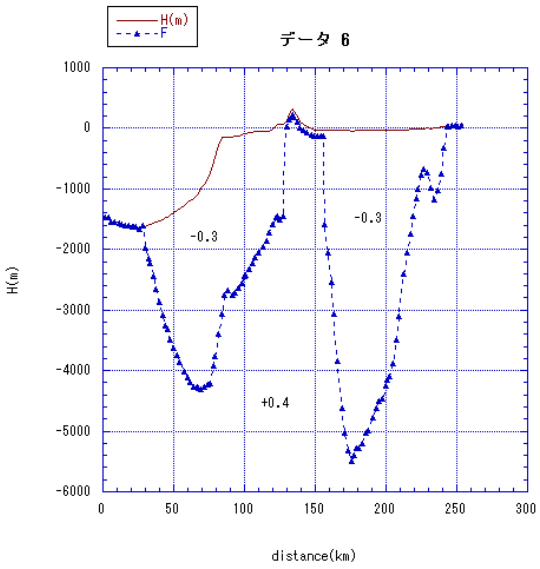
119　←　データ数

1　1.73774　-1473.8　12.426　←　NN, XD(km),H(m),G-obs(mgal)

2　3.96276　-1468.3　10.861

3　6.19107　-1537.8　7.485

入力モデルは下図。



モデルパラメーターmodel.txt

3 2 1 ← lay（層の数）、ipol（トレンドの次数）、it（１＝トレンドを計算する、０＝計算しない）

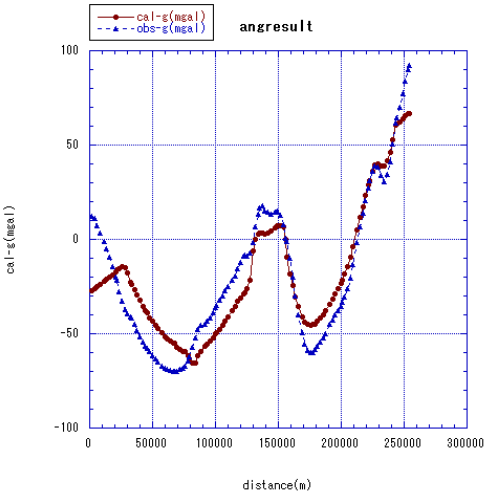
118 0.4 1 5000 ← lpnt（エッジの数）、dnl（密度差 mgal）、lex（１＝オープン層、０＝クローズ層；p(1)=p(end)であるような層をクローズ層という）、aa（層の幅m）

1 1.73774 -1473.8 ← NN, XD(km),H(m)

・・・・・

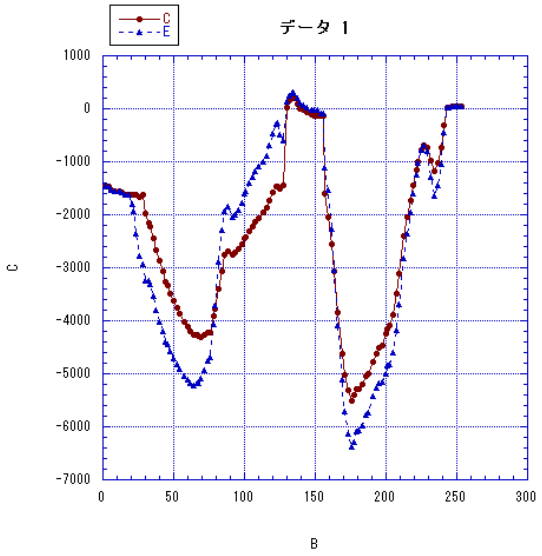
2222 ← ik（2222＝層の終わり、3333＝ファイルの終わり）

計算結果

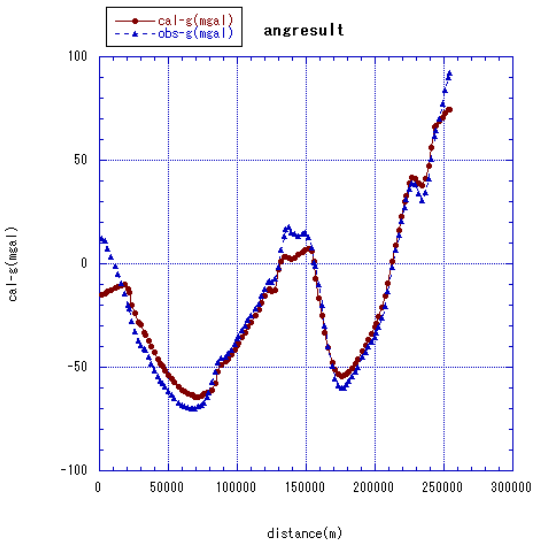


ここから同様にモデルを微修正する。
ΔH(m)=(calcg-obsg) (mgal)/(2*3.14*6.67*0.001*Δ ρ (mgal))
を計算し、修正したい箇所に加える。ここで修正値が地形データより大きくなったら、その部分は地形データで置き換える。

Blakely の計算式を使ったモデルと少々違うのは当然のこと。
C→E へモデルを修正。



計算結果



両端の値はモデルの打切り誤差の影響なので、ここでは無視する。
更に修正を加える場合もあるし、この辺で良しとする場合もある。

プログラム

```
c       2-D Gravity Model program
c                               ver.1       with observed data
c                               original Komazawa-san
c                               modified RIE Morijiri
c
c           - ang -
         common /ag/ag(500)
        common /xa/xa(500)/ya/ya(500)
        common /xb/xb(500)/yb/yb(500)
c           - iteration -
         common /gc/gc(500)/go/go(500)
         common /to/to(500)/rg/rg(500)
        common /xo/xo(500)/yo/h(500)
        common /xp/xp(500)/yp/d(500)
        common /xc/xc(500)/yc/dc(500)
        common /ite/iobs,den,ipol,it
c           - layers data -
         common /gl/gl(500,20)
        common /xl/xl(500,20)/yl/yl(500,20)
        common /lay/lay,lpnt(20),dnl(20),lex(20),ldpl(20),aa(20)
c       - - - - - - - - - - - - - - - - -
           data i2,i3/2222,3333/
c
           open(10,file='I:¥grav-DB¥model.txt',status='old')
           open(15,file='I:¥grav-DB¥gravdata.txt',status='old')
           open(30,file='I:¥grav-DB¥angresult.txt')
c       -----   obs.pnt. input   -----
        read(15,*) iobs
        m = 0
        do 2 k=1, iobs
           read(15,*) nn,xd,hei,gobs
           m = m + 1
```

```
              xo(m) = xd*1000
              h(m)   = hei
              go(m)   = gobs
       2 continue
         mw=m
         close(15)
c
c        write(6,616)
c 616 format(1h ,'--- distance from origin ---')
c        write(6,603) (xo(i),i=1,mw)
c        write(6,617)
c 617 format(1h ,'--- height data ---')
c        write(6,603) (h(i),i=1,mw)
c        write(6,618)
c 618 format(1h ,'--- observed gravity data ---')
c        write(6,603) (go(i),i=1,mw)
c          if( mw .ne. iobs )   go   to   3
c        - - - - - - - - - - - - -
         read(10,*) lay,ipol,it
c        - - - - - - - - - - - - -
         write(6,601) iobs,lay,ipol,it
   601 format(1h ,'iobs =',i5,5x,'lay no. =',i5/
        &           1h ,'ipol=',i2,5x,'it =',i2)
c
c        ++++++++++++++++++++++++++++++++++++++++
c        +++ calculation of layers structure +++
c        ++++++++++++++++++++++++++++++++++++++++
c            ****************************
c            *      l     : layer's no.         *
c            *      lpnt: layer's points     *
c            *      dnl : layer's density    *
c            ****************************
c          if( lay .le. 0 )   go   to   4
           l = 0
    11     l = l + 1
c         <---< l-th layer data input <---<
```

```
      read(10,*) lpnt(l),dnl(l),lex(l),aa(l)
        k = 0
c       >------------------------->
      do 12 i=1,lpnt(l)
       read(10,*) ii,xd,yd
       k = k + 1
       xl(k,l) = xd*1000
       yl(k,l) = yd
   12 continue
c       <--------------------------<
      read(10,*) inum
      write(6,*) '83-inum     ; ',inum
        if( k .ne. lpnt(l) )   go   to   5
        if( inum .eq. i2 )   go   to   11
        if( l .ne. lay )   go   to   4
        if( inum .eq. i3 )   go   to   13
c      >---> l-th layer data input >--->
c    ---   calculation of layers structure   --->
   13 continue
        do   21   l=1,lay
        lw = 10*( lpnt(l)/10 + 1 )
      write(6,619) l,dnl(l),lpnt(l),lex(l),aa(l)
  619 format(1h0,10x,'***',i2,'-th layer ***',5x,'den =',f6.2,5x,
     & 'lpnt =',i3,5x,'lex =',i2,5x,'width =',f8.1/)
      write(6,606)
  606 format(1h ,10x,'--- x(layer boundary) ---')
      write(6,603) (xl(i,l),i=1,lw)
      write(6,607)
  607 format(1h ,10x,'--- y(layer boundary) ---')
      write(6,603) (yl(i,l),i=1,lw)
c               - - - - - - - - - - -
                jpnt = lpnt(l)
                dnj   = dnl(l)
                jex   = lex(l)
c               jdpl = ldpl(l)
                aaj = aa(l)
```

```
c                - - - - - - - - - - -
                call    chg1(xo,xa)
                call    chg1(h,ya)
                call    chg2(xl,l,xb)
                call    chg2(yl,l,yb)
c                --- l-th layer's values --->
          call    angleg(iobs,jpnt,dnj,jex,aaj)
c               <-------------------------
                call    chg3(ag,gl,l)
c         - - - - - - - - - - - - - - - -
          write(6,608)
  608 format(1h ,10x,'--- g(calculated values) ---')
          write(6,603) (gl(i,l),i=1,mw)
   21 continue
c   <---    calculation of layers structure    ---
            do    15    i=1,iobs
              gc(i) = 0.
            do    14    l=1,lay
          gc(i) = gc(i) + gl(i,l)
   14 continue
   15 continue
          write(6,615)
          write(6,603) (gc(i),i=1,mw)
                      go       to       8
c         >------------------------------------->
    3 write(6,620)
  620 format(1h ,'***** observed point(iobs) is error. *****')
          go    to    310
    4 write(6,621)
  621 format(1h ,'***** layers number is error. *****')
          go    to    310
    5 write(6,622) l
  622 format(1h ,'*****',i2,'-th layer points is error. *****')
          go    to    310
c     <-----------------------------------------------<
    8 continue
```

```
c       - - - - - - - - - - - - - - - - - - -
        call    trend(ipol,it)
        call    stadev(iobs,gc,go)
        write(6,615)
  615 format(1h0,5x,'-----    calculated gravity    -----')
        write(6,603) (gc(i),i=1,mw)
c       - - - - - - - - - - - - - - -
        do 88 i=1,mw
        write(30,*) xo(i),gc(i),go(i)
   88 continue
        close(30)
c       ++++++++++++++++++++++++++++++++++++++++++++++
  310 continue
  600 format(1h0,5x,'------------------------'/
     /            1h ,5x,'line name = ',3a4/
     /            1h ,5x,'------------------------')
  603 format(1h ,10f10.2)
  605 format(1h ,11x,' mean depth = ',f10.2)
  609 format(1h ,10(5x,5h-----))
        stop
        end
c               ******************************
c     angleg    *    two dimensional analysis    *
c               *       by angle integration       *
c               ******************************
          subroutine angleg(iobs,ipnt,den,iex,aa)
        common /ag/ag(500)
        common /xa/xo(500)/ya/yo(500)
        common /xb/xp(500)/yb/yp(500)
c       -------     exterpolation of structure     ----
          call    kyoku(xo,iobs,omin,omax)
          call    kyoku(xp,ipnt,pmin,pmax)
          call    kyoku(yo,iobs,ymin,ymax)
          xs = amin1(omin,pmin)
          xe = amax1(omax,pmax)
          rng = xe - xs
```

```
            m = iobs
            n = ipnt + 6
            if( iex .eq. 0 )    n = ipnt
            dm = 0.
              do    1    i=1,ipnt
            dm = dm + yp(i)
      1     continue
            dmean = dm/float(ipnt)
            dpl=amin1(dmean,ymin)
c           if( idpl .eq. 0 )    dpl = 0.
c           if( idpl .ne. 0 )    dpl = dmean
        write(6,601) iobs,ipnt,den,xs,xe,rng,dmean
  601 format(1h0,15x,'angtal : iobs =',i4,3x,
     &                    'ipnt =',i4,5x,'den =',f6.2/
     &      1h ,15x,'          : xs =',e12.4,3x,'xe =',e12.4,5x,
     &                'rng =',e12.4/
     &      1h ,15x,'          : mean depth = ',e12.4/)
            xs = xp(1)
            ys = yp(1)
            xe = xp(ipnt)
            ye = yp(ipnt)
            xp(ipnt+1) = xe + 0.5*rng
            xp(ipnt+6) = xs - 0.5*rng
            xp(ipnt+2) = xe + rng
            xp(ipnt+5) = xs - rng
            xp(ipnt+3) = xe + 4.*rng
            xp(ipnt+4) = xs - 4.*rng
            yp(ipnt+1) = ye
            yp(ipnt+6) = ys
            yp(ipnt+2) = 0.6*ye + 0.4*dpl
            yp(ipnt+5) = 0.6*ys + 0.4*dpl
            yp(ipnt+3) = dpl
            yp(ipnt+4) = dpl
c       ----------------------------------------
c       -----     calculation of obs.pnt     -------
          do    10    i=1,m
```

```
      atl = 0.
      x0 = xo(i)
      y0 = yo(i)
         do   20   j=1,n
      x1 = xp(j)
      y1 = yp(j)
      k = j + 1
      if( j .eq. n )   k = 1
      x2 = xp(k)
      y2 = yp(k)
      if( aa. eq. 0. .or. aa. eq. 99999. )   go   to   11
      atl = atl + den*sal(x0,y0,x1,y1,x2,y2,aa)
         go   to   20
   11 atl = atl + den*tal(x0,y0,x1,y1,x2,y2)
   20 continue
      ag(i) = atl
   10 continue
c     ---------------------------------------
      return
      end
c           *-*-*-*-*-*-*-*-*-*-*-*-*-*-*
        function   tal(x0,y0,x1,y1,x2,y2)
       pai = 3.141593
       yen = 2.*pai
      gg = 6.670e-3
      rr1 = (x1-x0)**2 + (y1-y0)**2
      rr2 = (x2-x0)**2 + (y2-y0)**2
      if( rr1 .eq. 0. .or. rr2 .eq. 0. )   go   to   100
      r1 = sqrt(rr1)
      r2 = sqrt(rr2)
        pl = (x1-x0)*(y2-y0) - (x2-x0)*(y1-y0)
            sg = 1.0
        if( pl .lt. 0. )   sg = -1.
      qh = phase(x2-x1,y2-y1) - 0.5*pai
      ph1 = phase(x1-x0,y1-y0)
      ph2 = phase(x2-x0,y2-y0)
```

```
      phm = abs(ph2-ph1)
      if( phm .eq. 0. )  go  to  100
      if( phm .gt. pai .and. phm .le. yen )  phm = yen - phm
        c1 = cos(ph1-qh)
        c2 = cos(ph2-qh)
        if( c1 .eq. 0. )  go  to  100
        ab = abs(c2/c1)
        alg = alog(ab)
      tt = r1*c1*( sg*phm*sin(qh) - alg*cos(qh) )
      go  to  200
  100 tt = 0.
  200 continue
      tal = 2.0 * tt * gg
      return
      end
c          *-*-*-*-*-*-*-*-*-*-*-*-*-*-*
        function  sal(x0,y0,x1,y1,x2,y2,aa)
       pai = 3.141593
       yen = 2.*pai
      gg = 6.670e-3
           tt = 0.
      rr1 = (x1-x0)**2 + (y1-y0)**2
      rr2 = (x2-x0)**2 + (y2-y0)**2
      if( rr1.eq.0. .or. rr2.eq.0. )  go  to  100
        r1 = sqrt(rr1)
      ph1 = phase(x1-x0,y1-y0)
      ph2 = phase(x2-x0,y2-y0)
      qh = phase(x2-x1,y2-y1) - 0.5*pai
         pp1 = ph1 - pai
         pp2 = ph1 + pai
            if( ph2 .lt. pp1 )  ph2 = ph2 + yen
            if( ph2 .gt. pp2 )  ph2 = ph2 - yen
      if( abs(sin(ph2-ph1)) .lt. 0.0001 )  go  to  100
c           ------ nn : division number ------
                    nn = 16
      if( abs( ph2-ph1 ) .gt. 0.25*pai )  nn = 31
```

```
      if( abs( ph2-ph1 ) .gt. 0.50*pai )    nn = 51
c               ---------------------------------
           dh = ( ph2 - ph1 ) / float(nn-1)
      do    1    m = 1,nn
        phm = ph1 + float(m-1)*dh
        r = r1 * cos(ph1-qh) / cos(phm-qh)
        ra = abs( r / aa )
        ab = abs( ra + sqrt( ra*ra + 1.0 ) )
        alg = alog( ab )
          sg = 1.0
        if( m .eq. 1 .or. m .eq. nn )    sg = 0.5
c       tt = tt     +    sg * dh * r * sin(phm)
      tt = tt     +    sg * dh * aa * alg * sin(phm)
    1 continue
      go    to    200
  100 tt = 0.
  200 continue
      sal = 2.0 * tt * gg
      return
      end
c     *-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
        function    phase(px,py)
        pai = 3.141593
      if( px .ne. 0. .and. py .ne. 0. )    go    to    1
      if( py .eq. 0. .and. px .ge. 0. )    ph = 0.
      if( py .eq. 0. .and. px .lt. 0. )    ph = pai
      if( px .eq. 0. .and. py .gt. 0. )    ph = 0.5 * pai
      if( px .eq. 0. .and. py .lt. 0. )    ph = 1.5 * pai
              go    to    6
    1 ph = atan(py/px)
      if( px .lt. 0. )    ph = ph + pai
      if( px .gt. 0. .and. py .lt. 0. )    ph = ph + 2.0*pai
    6 phase    =    ph
      return
      end
c      ****************************
```

```
      subroutine    trend(ipol,it)
      common    /equ/p(6,7),pn(6),q(6)
      common    /gc/gc(500)
      common    /go/go(500)
      common    /to/to(500)
      common    /rg/rg(500)
      common /ite/iobs
      common /xo/xo(500)/xc/xc(500)
      if( ipol.ge.0 .and. ipol.le.5 ) go    to    100
      write(6,600)
  600 format(1h0,' the value of ipol is exceptional. ')
      go    to    110
  100 continue
        call kyoku(xo,iobs,omin,omax)
        rng = 3.*(omax-omin)/float(iobs)
c       - - - - - - - - - -
      jpol = ipol + 1
        do    1    i=1,6
      pn(i) = 0.
        do    1    j=1,6
    1 p(i,j) = 0.
c      >- - - - - - - - - -
        do    2    i=1,iobs
      x = xo(i)
      sa = go(i) - ( gc(i) + rg(i) )
      q(1) = 1.
      if( ipol .eq. 0 )    go    to    4
        do    3    k=1,ipol
    3 q(k+1) = x*q(k)
    4 continue
c      -    -    -    -    -    -    -
        do    5    l=1,jpol
      pn(l) = pn(l) + sa*q(l)
        do    5    j=1,jpol
    5 p(l,j) = p(l,j) + q(l)*q(j)
    2 continue
```

```
c      <- - - - - - - - - -
         call    matrix(jpol)
         write(6,603) (pn(i),i=1,6)
   603 format(1h0,'trend : a(0)=',e12.3,3x,'a(1)=',e12.3,3x,
        /                        'a(2)=',e12.3,3x/
        /           1h ,'        a(3)=',e12.3,3x,'a(4)=',e12.3,3x,
        /                        'a(5)=',e12.3)
            do    6    i=1,iobs
         x = xo(i)
         q(1) = 1.
         if( ipol .eq. 0 )    go    to    8
            do    7    k=1,ipol
       7 q(k+1) = x*q(k)
       8 continue
         gx = 0.
            do    9    j=1,jpol
       9 gx = gx + pn(j)*q(j)
         to(i) = gx + rg(i)
         if(it .eq. 1)    gc(i) = gc(i) + to(i)
       6 continue
     110 return
         end
c         ******************************
            subroutine       matrix(iv)
         common /equ/p(6,7),pp(6),q(6)
         dimension    m(6)
         ih = iv + 1
            do    41    i=1,iv
         m(i)=i
      41 continue
         do    15    i=1,iv
         p(i,ih) = pp(i)
      15 continue
            do    1    i=1,iv
         if( p(i,i).ne.0. )    go    to    5
         do    6    j=i,iv
```

```
      if( p(j,i).ne.0. )    go    to    8
    6 continue
      go    to    12
    8     do    7    k=1,ih
      b = p(j,k)
      p(j,k) = p(i,k)
      p(i,k) = b
    7 continue
      go    to    5
   12     do 9 j=i,iv
      if( p(i,j).ne.0. )    go    to    10
    9 continue
      go    to    13
   10 ic = m(i)
      m(i) = m(j)
      m(j) = ic
      do    11    k=1,iv
      b = p(k,j)
      p(k,j) = p(k,i)
      p(k,i) = b
   11 continue
    5 w = p(i,i)
      do    2    j=1,ih
      p(i,j) = p(i,j)/w
    2 continue
      do    3    k=1,iv
      if( k.eq.i )    go    to    3
      s = p(k,i)
         do    4    l=1,ih
      p(k,l) = p(k,l) - s*p(i,l)
    4 continue
    3 continue
    1 continue
         do    51    i=1,iv
      ip = m(i)
      pp(ip) = p(i,ih)
```

```
   51 continue
      go    to    14
   13 continue
      write(6,600)
  600 format(1h ,'matrix : calculation is impossible.')
   14 continue
      return
      end
c      ********************************
         subroutine        stadev(m,gc,go)
         dimension    gc(1)
         dimension    go(1)
         dimension    gs(500)
      su = 0.
      do    1    i=1,m
      s = gc(i) - go(i)
    1 su = su + s
      sa = su/float(m)
      do    2    i=1,m
    2 gs(i) = gc(i) - sa
      su = 0.
      do    3    i=1,m
      s = gs(i) - go(i)
    3 su = su + s*s
      su = su/float(m-1)
      sd =sqrt(su)
      write(6,600) sa,sd
      write(30,600) sa,sd
  600 format(1h ,'stadev : mean difference       =',f12.5/
     /           1h ,'           : standard deviation =',f12.5)
      return
      end
c      ********************************
         subroutine    kyoku(a,m,rmin,rmax)
        dimension a(1)
      rmin = a(1)
```

```
      rmax = a(1)
      do   1   i=1,m
        ad = a(i)
        if( ad .lt. rmax )   go   to   2
        rmax = ad
        go   to   1
    2   if( ad .gt. rmin )   go   to   1
        rmin = ad
    1 continue
      return
      end
c      ****************************************
      subroutine gxysa(xor,xen,gmin,gmax,smin,smax)
      common /ite/m
      common /gc/gc(500)/go/go(500)/to/to(500)
      common /xo/xo(500)/yo/h(500)
        call   kyoku(xo,m,omin,omax)
      xor = omin
      xen = omax
        call   kyoku(h,m,hmin,hmax)
      smin = hmin
      smax = hmax
        call   kyoku(go,m,omin,omax)
        call   kyoku(gc,m,cmin,cmax)
        call   kyoku(to,m,tmin,tmax)
      gmin = amin1(omin,cmin,tmin)
      gmax = amax1(omax,cmax,tmax)
      return
      end
c      ****************************************
      subroutine glxymm(xlor,xlen,glmin,glmax,slmin,slmax)
        common /ite/m
        common /lay/lay,lpnt(20),dnl(20),lex(20)
      common /gl/gl(500,2)
      common /xl/xl(500,2)
      common /yl/yl(500,2)
```

```
      dimension a(500)
              if( lay .eq. 0 )   go   to   10
        do   1   l=1,lay
      call   chg2(gl,l,a)
      call   kyoku(a,m,amin,amax)
      if( lay .eq. 1 )   glmin = amin
      if( lay .eq. 1 )   glmax = amax
      if( amin .lt. glmin )   glmin = amin
      if( amax .gt. glmax )   glmax = amax
    1 continue
   10          continue
        call   tpbtl(xl,xlor,xlen)
        call   tpbtl(yl,slmin,slmax)
      return
      end
c      ****************************************
          subroutine   tpbtl(gl,glmin,glmax)
        common /lay/lay,lpnt(20),dnl(20),lex(20)
        dimension gl(500,20),a(500)
      if( lay .eq. 0 )   go   to   10
        do   1   l=1,lay
      call   chg2(gl,l,a)
      jpnt = lpnt(l)
      call   kyoku(a,jpnt,amin,amax)
      if( lay .eq. 1 )   glmin = amin
      if( lay .eq. 1 )   glmax = amax
      if( amin .lt. glmin )   glmin = amin
      if( amax .gt. glmax )   glmax = amax
    1 continue
   10 continue
      return
      end
c     **********************
        subroutine   chg1(a,b)
      dimension   a(500),b(500)
        do   1   i=1,500
```

```
      1 b(i) = a(i)
        return
        end
c       *************************
          subroutine  chg2(a,m,b)
        dimension  a(500,20),b(500)
          do  1  i=1,500
      1 b(i) = a(i,m)
        return
        end
c       *************************
          subroutine  chg3(a,b,n)
        dimension  a(500),b(500,20)
          do  1  i=1,500
      1 b(i,n) = a(i)
        return
        end
```